CHAPTER THREE

PERIPHERAL DEVICES

3.0 INTRODUCTION

A peripheral device is generally defined as any ***auxiliary device*** such as a computer mouse or keyboard that connects to and works with the computer in some way. Other examples of peripherals are expansion cards, graphics cards, image scanners, tape drives, microphones, loudspeakers, webcams, and digital cameras. **Peripheral devices** (or **peripherals** or **devices**) are information handlers. Therefore, a **computer peripheral** is a device that is connected to a computer but is not part of the core computer architecture. The core elements of a computer are the central processing unit, power supply, motherboard and the computer case that contains those three components. Technically speaking, everything else is considered a peripheral device. However, this is a somewhat narrow view, since various other elements are required for a computer to actually function, such as a hard drive and random-access memory (or RAM).

Most people use the term peripheral more loosely to refer to a device external to the computer case. You connect the device to the computer to expand the functionality of the system. For example, consider a printer; once the printer is connected to a computer, you can print out documents. Another way to look at peripheral devices is that they are dependent on the computer system. For example, most printers cannot do much on their own, and they only become functional when connected to a computer system.

3.1 Types of Peripheral Devices

There are many different peripheral devices, but they fall into three general categories:

1. **Input devices**, such as a mouse and a keyboard
2. **Output devices**, such as a monitor and a printer
3. **Storage devices**, such as a hard drive or flash drive

Some devices fall into more than one category. Consider a CD-ROM drive; you can use it to read data or music (input), and you can use it to write data to a CD (output).

Peripheral devices can be **external** or **internal**. For example, a printer is an external device that you connect using a cable, while an optical disc drive is typically located inside the computer case. Internal peripheral devices are also referred to as integrated peripherals.

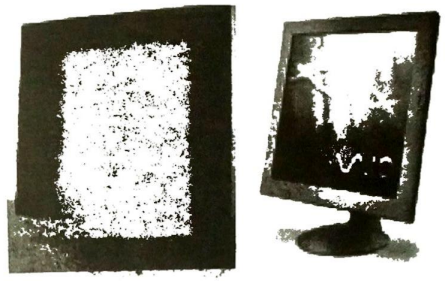
The concept of what exactly is 'peripheral' is therefore somewhat fluid. For a desktop computer, a keyboard and a monitor are considered peripherals - you can easily connect and disconnect them and replace them if needed. For a laptop computer, these components are built into the computer system and cannot be easily removed. The term 'peripheral' also does not mean it is not essential for the function of the computer. Some devices, such as a printer, can be disconnected and the computer will keep on working just fine. However, remove the monitor of a desktop computer and it becomes pretty much useless.

3.2 OUTPUT DEVICES

3.2.1 MONITORS

A computer display is also called a display screen or video display terminal (VDT) or monitor. A monitor or screen can display graphics, text and video output. To display video in the monitor, the computer needs a video card (or graphics card) for converting the digital signal (i.e data in form of 0s and 1s) to analog signal (i.e data in form of a continuous electrical wave). Therefore, a monitor is a screen used to display the output. Images are represented on monitors by individual dots called pixels. A pixel is the smallest unit on the screen that can be turned on and off or made different shades. The density of the dots determines the clarity of the images (the resolution).

Screen resolution: This is the degree of sharpness of a displayed character or image. The screen resolution is usually expressed as the number of columns by the number of times. A 1024 x 768 resolution means that it has 1024 dots in a line and 768 lines. A smaller screen looks sharper on the same resolution. Another measure of display resolution is a dot pitch.



3.2.2 Types of Monitor based on the colour display

There are two types of computer monitor based on the colour display. They are

(a) Monochrome monitor: A monochrome monitor has two colours, one for foreground and the other for background. The colours can be white, amber or green.

(b) Colour Monitor: A colour monitor is a display peripheral that displays more than two colours. Colour monitors have been developed through the following paths:

(i) Colour Graphic Adapter (CGA): With a CGA monitor, it is harder to read than with a monochrome monitor, because the CGA (320 x 200) has much fewer pixels than the monochrome monitor (640 x 350). It supports four colours.

(ii) Enhanced Graphic Adapter (EGA): It is a video display standard that has a resolution of 640 by 350 pixels and supports 16 colours.

(iii) Video Graphic Adapter: This is a video display standard that provides medium to high resolution. In a text mode, the resolution of this board is 720 by 400 pixels. It supports sixteen colours with a higher resolution of 640 by 480 pixels and two hundred and fifty-six colours with 320 x 200 pixels.

(iv) Super VGA: This is a very high resolution standard that displays up to 65,536 colours. Super VGA can support a16.8 million colours at 800 by 600 pixels and 256 colours at 1024 by 768 pixels. A high-priced super VGA allows 1280 by 1024 pixels.

3.2.3 Types of Monitors Based on Technology

Monitors come in two main varieties based on the technology, namely:
(a) Cathode-ray tubes (CRT): CRT computer monitors were the most common computer monitors until flat panel screens became affordable. Similar to older TVs, CRT monitors still typically have much better contrast ratios and viewing angles than other computer monitor alternatives.

(b) Flat panel display: Portable computers such as laptops use flat panel displays, because they are more compact and consume less power than CRTs. Portable computers use several kinds of flat panel screens such as

(i) Liquid crystal displays (LCD): Flat-screen LCDs are generally used in notebooks and laptops. LCD (Liquid Crystal Display) computer monitors save a lot of space and can even be mounted on walls. LCDs are difficult to read in a strong light, because they do not emit their own light. Portable computers have brighter and easier to read displays. They provide a wide viewing angle and come in sizes typically ranging from 17-inches to 60-inches.

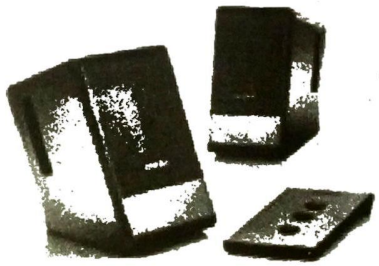
(ii) Backlit LCDs: This is a type of LCD having its own light source provided from the back of the screen. The backlit makes the background brighter and clear, as a result the texts and images appear sharper. However, this is still less clearer than CRTs.

(iii) Active Matrix LCDs: This is an LCD display technique in which every dot on the screen has a transistor to control it more accurately. This uses a transistor for each monochrome or each red, green and blue dot. It provides better contrast, speeds up screen refresh and reduces motion smearing.

(iv) Gas-plasma displays: Gas-plasma displays are capable of larger displays with good resolution and can be in excess of 42 inches. Plasma computer monitors are less commonly used with computers due to their high operating temperatures, high power consumption, and fixed resolution. This is also called a gas panel or a plasma panel and is another flat screen technology. A plasma panel contains a grid of electrodes in a flat, gas filled panel. The image can persist for a long time without refreshing in this panel. The disadvantages of the gas plasma displays are that they must use AC power and cannot show sharp contrast.
(v) OLED (Organic Light Emitting Display): Computer monitors are much thinner and brighter than LCD or plasma screens. OLED monitors can also be placed on transparent surfaces, such as glass, allowing the user to see through them when not active.

3.2.3 Speaker

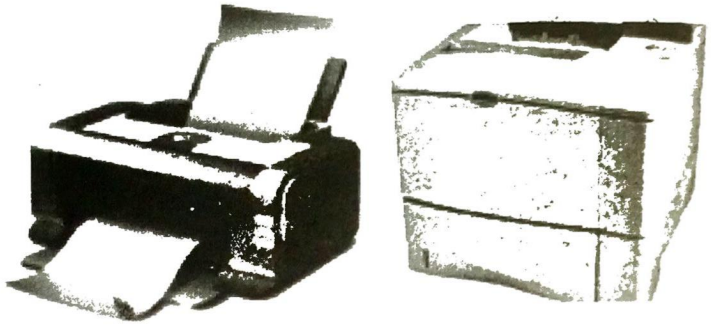
Speakers are an output device which are used to produce data such as sound mostly when connected to a computer. Speakers output sound that is generated by the computer. Speakers can also be used to listen to music which plays on your computer. The sound quality of speakers will depend on the watts for the speakers as computer speakers range widely in quality and price.



3.3 PRINTERS

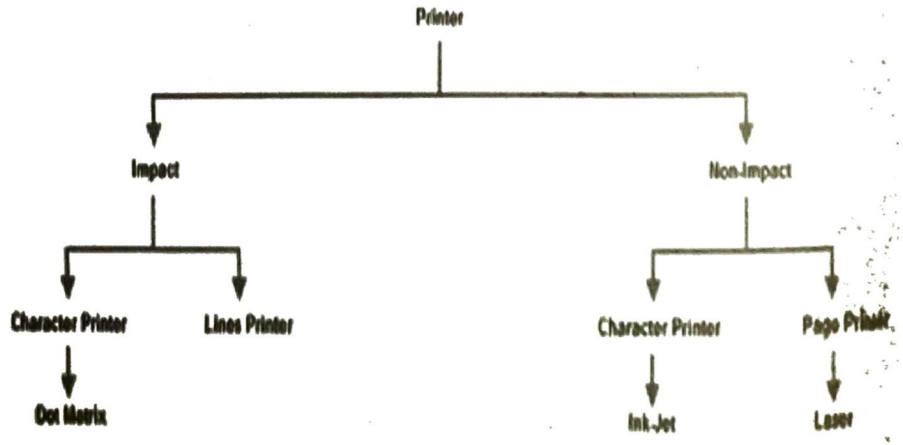
A computer printer is a device or an instrument that must be connected to a computer which allows users to print text and graphics on the plain papers. In some case they can be directly connected to digital camera for printing pictures without connecting to any computer.

Computer printer is one of the essential hardware, whether it is for a large company or for personal use. The usage of printer is depend upon the requirement of the company or individual person. For a big company they might print lots of paper or documents where as an individual need seldom. **Printers** are output devices used to prepare permanent output on paper. Printers can be divided into two main categories:



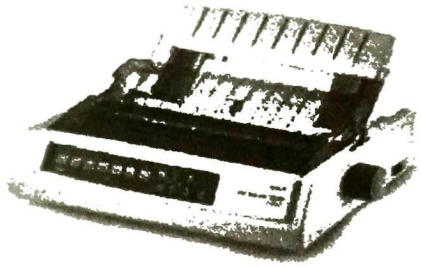
3.3.1 Impact Printers

In this, hammers or pins strike against a ribbon and paper to print the text. This mechanism is known as electro-mechanical mechanism. They are of two types.



3.3.1.1 Character Printer

It prints only one character at a time. It has relatively slower speed. E.g., Dot Matrix Printers. **Dot Matrix Printer** prints characters as combination of dots. Dot matrix printers are the most popular among serial printers. It has a matrix of pins on the print head of the printer which form the character. The computer memory sends one character at a time to be printed by the printer. There is a carbon between the pins and the paper. The words get printed on the paper when the pin strikes the carbon. There are generally 24 pins.



Advantages of Dot-matrix printer:

(i) Can print on multi-part forms or carbon copies.
(ii) Low printing cost per page.
(iii) Can be used on continuous form paper, useful for data logging.
(iv) Reliable and durable.

Disadvantages of Dot-matrix printer:

(i) Noisy.
(ii) Limited print quality.
(iii) Low printing speed.
(iv) Limited colour printing.

3.3.1.2 Line printer

A line printer uses a long drum imprinted with raised characters. As the drum rotates, words are formed on the page. The drum moves in a

horizontal direction, printing one line at a time. Line printers have limited font availability and no graphic capability. Due to their design, they require special paper with pre-punched holes on the sides that attach to the printer by raised grooves. The line printer is still found in some businesses due to its durability and ease of use.

***Advantages of Line printer*:**

(i) It is a High Speed impact printer.
(ii) Less expensive.
(iii) Print entire line at a time.

***Disadvantage is that it is* Noisy.**

3.3.1.3. Daisy-Wheel printer

It uses a wheel as a print head. When the wheel rotates, hammers strikes the backside of the spoke and press it against the paper to print a character.

Advantages of Daisy-Wheel printer:

(i) It can print letter quality characters.

Disadvantages of Daisy-Wheel printer:

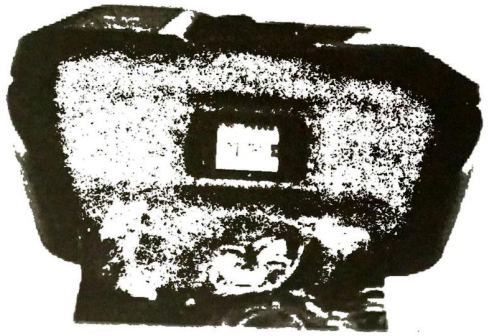
(i) Printing speed is slow.
(ii) It cannot print graphics.

3.3.2 Non-Impact Printers

These printers use non-impact technology such as ink-jet or laser technology. There printers provide better quality at higher speed. These printers are of two types:

1 Ink-Jet Printer

It prints characters by spraying patterns of ink on the paper from a nozzle or jet. It has nozzles having very fine holes from which a specially made ink is pumped out to create various letters and shapes. The ink comes out of the nozzle in a form of vapours. After passing through a reflecting plate, it forms the desired letter/shape at the desired place.



Advantages of Inkjet printers:

(i) Low cost.
(ii) High quality of output, capable of printing fine and smooth details.
(iii) Capable of printing in vivid colour, good for printing pictures.
(iv) Easy to use.
(v) Reasonably fast.
(vi) Quieter than dot matrix printer.
(vii) No warm up time.

Disadvantages of Inkjet printers:

(i) Print head is less durable, prone to clogging and damage.
(ii) Expensive replacement ink cartridges.
(iii) Not good for high volume printing.
(iv) Printing speed is not as fast as laser printers.
(v) Ink bleeding, ink carried sideways causing blurred effects on some papers.
(vi) Aqueous ink is sensitive to water, even a small drop of water can cause blurring.
(vii) Cannot use highlighter marker on inkjet printouts.

2. Laser Printer

It is a type of printer that utilizes a laser beam to produce an image on a drum. The light of the laser alters the electrical charge on the drum

wherever it hits. The drum is then rolled through a reservoir of toner, which is picked up by the charged portions of the drum. Finally, the toner is transferred to the paper through a combination of heat and pressure. The available resolutions range from 300 dpi (dots per inch) at the low end to 1,200 dpi at the high end. In addition to text, laser printers are very adept at printing graphics, so you need significant amounts of memory in the printer to print high-resolution graphics. To print a full-page graphic at 300 dpi, for example you need at least 1 MB (megabyte) of printer RAM. For a 600 dpi graphic, you need at least 4 MB RAM.

Because laser printers are non-impact printers, they are much quieter than dot matrix or daisy-wheel printers. They are also relatively fast, although not as fast as some dot-matrix or daisy-wheel printers.

Advantages of Laser printers:

(i) High resolution.
(ii) High print speed.
(iii) No smearing.
(iv) Low cost per page (compared to inkjet printers).
(v) Printout is not sensitive to water.
(vi) Good for high volume printing.

Disadvantages of Laser printers:

(i) More expensive than inkjet printers.
(ii) Except for high end machines, laser printers are less capable of printing vivid colours

and high quality images such as photos.
(iii) The cost of toner replacement and drum replacement is high.
(iv) Bulkier than inkjet printers.
(v) Warm up time needed.

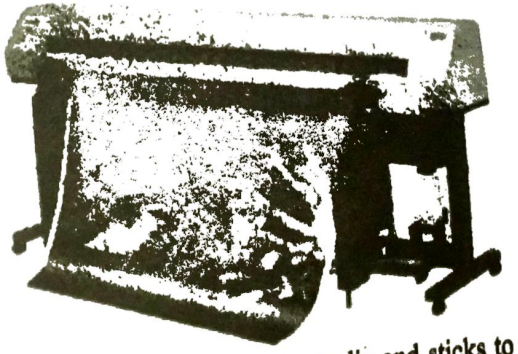
3. Thermal printers

Thermal inkjet printers use heating element to heat liquid ink to form vapour bubble, which forces the ink droplets onto the paper through the nozzle.

Thermal printers use two types of printing technologies: direct thermal and thermal transfer printing. Traditional thermal printers use direct thermal method by pushing electrically heated pins against heat-sensitive paper (thermal paper). The coating on the thermal paper turns black in the areas where it is heated, producing characters or images. Direct thermal printers have no ink, toner or ribbon. These printers are durable, easy to use and cost less to print than other printers. However, the thermal paper is sensitive to heat, light, water, and abrasion and the text and images may fade over time. In thermal transfer printing, a thermal print head applies heat to heat-sensitive ribbon, which melts ink onto paper and a wide range of materials to form text and images. The printouts can be extremely durable and can be stored over long period of time. Thermal printers are often used in cash registers, ATM, and point-of-sales terminals. Thermal printer is not the same as thermal inkjet printer. The latter uses inkjet print technology by heating liquid ink to form vapour bubble, which forces the ink droplet onto the paper from the nozzle.

4. Electrostatic Printer:

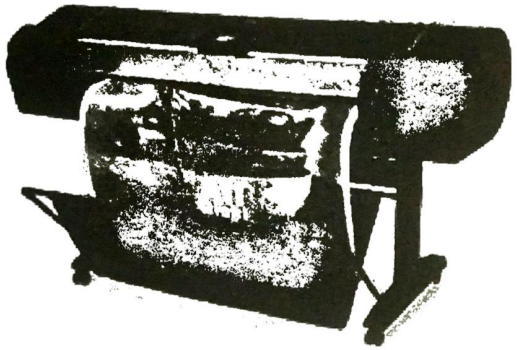
An **Electrostatic Printer** has many print head, actually covering the entire 36 media width. So, instead of a single print head moving across the width of the media. The electrostatic printer prints an entire width of the page at one time.



The toner solution circulates past the media and sticks to the energized portion of the media. Thus it producing a very fast high-quality image. The printer creates colour prints by breaking three basic colours (cyan, magenta, and yellow) plus black. It printing one colour at a time.

2. Plotter

A **plotter** is a vector device that can directly reach specific positions on printer paper without raster scan device. In colour plotters, the carriage accommodates a number of pens with varying colours and widths. In 5-pass print mode, the combinations of cyan, magenta, yellow and black colour provides a wide range of different colours.



3.3.3. Audio Output Devices

Some functionality are required for audio and video convert into hear able voice that our ears can hear these voice. This functionality may be special hardware and processing system, and this task can be fulfill by "**Audio output devices**".

Here few examples for **Audio output devices** are:

1. Sound Cards This is external card which is attached with motherboard for yielding the audio output information.

2. Speakers This is **output hardware component** that is used for the producing the sound.

3. Headphone This device is wear on the head so its name is **headphone,** this device allow to user listen music without anyone.

4. Onboard Audio This circuit embedded internal y in the motherboard **that** produce the output in the form of sound, after processed data.

Factors for selecting the appropriate Printer

Multiple factors should be taken into consideration when selecting a printer. Some of them are as follows –

Cost That's always a major factor. As well as the printer's purchase price, consideration must be taken of the expense of printers, toners, cartridges, paper, maintenance, etc. Some printers, like laser printers, have a short life span. A good printer's price will cost quite a lot. Inkjet printers are cheap nowadays while laser printers are more costly.

Speed For a typist who needs to print a document on a word processor, a wait of one minute could be acceptable, but that would be unreasonable if several hundred documents (e.g. invoices and bills) needed to be printed. Generally, the best printers are more costly and this needs to be taken into account along with the amount of work they have to do.

Print Quality Good print quality is required for customer-friendly letters and other documents. These documents are typically printed using laser nowadays. A programmer may, however, want a fast hard copy of a program's listing.

Graphics printing ability Using a laser printer, high-quality graphics like logos, diagrams, charts, and even photographs can be generated easily. Dot-matrix printers can generate graphics that are of lesser quality. Daisy wheel printers can print text only.

Ability to generate text and color graphics Inkjet printers are the widely used printers that are capable of color printing unless you are rich in having and maintaining a laser printer.

3.4 Input Devices

3.4.1 Computer Keyboard

A **computer keyboard** is an input device used to enter characters and functions into the computer system by pressing buttons, or **keys**. It is the primary device used to enter text. A keyboard typically contains keys

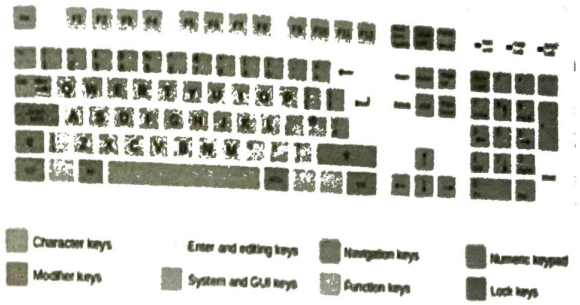
for individual letters, numbers and special characters, as well as keys for specific functions. A keyboard is connected to a computer system using a cable or a wireless connection.

Typical keyboard for a desktop computer

Most keyboards have a very similar layout. The individual keys for letters, numbers and special characters are collectively called the **character keys**. The layout of these keys is derived from the original layout of keys on a typewriter. The most widely used layout in the English language is called **QWERTY**, named after the sequence of the first six letters from the top left. Other sets of keys common to almost all keyboards are entering and editing keys (e.g., Enter, Delete, Insert), modifier keys (e.g., Control, Shift), navigation keys (e.g., arrows for up, down, left, right) and lock keys (e.g., Caps Lock). Additional keys are operating system specific (such as the Windows and Apple keys). Most keyboards also include a set of function keys at the top (F1, F2, etc.). The function keys typically perform specific task within a particular software application. So, what they do may depend on what you are doing on your computer at the time.

Most keyboards for desktop computers also contain a separate numeric keypad to the right. Even though there are numeric keys already in a row near the top, having them all close together makes it faster to enter numeric data. On smaller keyboards, like those on most laptops, these numeric keypads are typically no longer present due to space constraints.

Below, you can see a typical keyboard layout. Keep in mind that there are many different variations on this layout, although most manufacturers follow this general pattern:



Standard layout of keys

However, this general layout has remained remarkably unchanging over the years. This has made it easy for users to move from one computer system to the next and to use their typing skills on multiple devices.

For many tasks, you need to press more than one key at the same time. For example, to get a capital letter 'A,' you need to press the Shift key and the A key at the same time. This is described as 'Shift + A.' Another example, in most software applications, Ctrl + S means to save the current document. There are a number of such combinations. The most famous combination of all is Ctrl + Alt + Del, also referred to as Control-Alt-Delete. This actually rebooted your computer. In Windows operating system, the combination brings up options to log off or shut down, as well as options to force a particular software application to quit. This is useful if you are not able to exit an application in a regular fashion.

What else can a keyboard do?

A computer keyboard has many more functions than typing. Below is a list of additional tasks you can perform using a keyboard.

- Enter *commands* in a command line or another CLI (command-line interface).
- Use *keyboard shortcuts* to perform tasks more quickly. For example, using Ctrl+C to copy text and Ctrl+V to paste it elsewhere.

- Use the *function keys* to perform tasks. For example, pressing F5 in a browser to refresh a web page.
- Control computer hardware. For example, many keyboards can change your speakers' volume.
- Use the *arrow keys* to move the text cursor on the screen.
- Use the *WASD keys* or arrow keys to move a character in a game.
- Use the *numeric keypad* to make calculations in a calculator.

Multimedia keys

Multimedia keys are those keys that allow the user to control music on their computer keyboard. These keys add functionality, such as play, pause, stop, rewind, fast forward, skip track, eject, shuffle, and for music.

Keys that appear twice on a keyboard

On a typical PC keyboard, three keys appear twice. They are the Alt keys, Ctrl keys, and Shift keys. Almost all the keys on the numeric keypad are duplicated. These keys include the divide (/), times (*), subtract (-), plus (+), period (.), numbers 0 through 9, and the Enter key. The only key on the numeric keypad that does not appear twice is the Num lock key.

The three keys that appear twice on Apple keyboards are the Command keys, Control keys, and the Shift keys. For Apple keyboards with a numeric keypad, there are seventeen duplicate keys. These keys include the equal (=), divide (/), times (*), subtract (-), plus (+), period (.), numbers 0 through 9, and the Enter key.

3.4.2 Character Recognition Devices

An optical character recognition device, often abbreviated as OCR, **is able to recognize text that is printed in a specific type font**. Scanners are a form of OCR family that can read almost any type font and their accuracy depends in large part on the text or recognition software used. The device converts light—an analog continuous wave form—into digital binary bits of zero and one [0,1] which is a discrete wave form. To accomplish this, scanners use electronic components such as charge-coupled devices (CCD), a diode that is light sensitive when electrically charged, or photomultiplier tubes (PMT), a light sensitive tube that detects light at any

intensity by amplifying it. PMTs are usually associated with drum scanners. To recognize text on the surfaces of real three dimensional objects, one has to be able to cope with several disturbing factors. These include camera lens aberrations and deformations arising from perspective projection. There are also sudden changes of lighting as the recognition environment is not closed.

Optical character recognition (OCR) refers to a computer's ability to recognize printed letters, numerals, or symbols (optical characters) as discrete entities rather than as simply an image containing lines, curves, and shading. Useful for document management, form processing, and a host of other commercial applications, this powerful tool allows businesses to convert paper documents into electronic files that can then be manipulated and retrieved at will.

Companies often use OCR to reduce human data entry, as in bill processing, and for a wide number of other applications that save time and improve accuracy. Newer uses under development have included noncontact scanning from a distance (for instance, scanning license plate numbers) and recognition of handwriting as opposed to printed text.

An effective OCR system depends heavily on both the physical scanner and the software used to interpret the scanner's input. The most common type of scanner is flatbed. Flatbed scanners look and act much like photocopy machines, with pages being scanned placed flat on the scanner's glass. They generally copy single pages at a time. **Advanced scanners** have feeding systems for scanning large batches of documents without requiring a human operator to switch pages. These scanners may digitize dozens of pages per minute. **Drum scanners** are high end devices

for capturing fine details, and therefore are often used more for graphic images than for OCR. Instead of bringing the page to the scanner, a handheld scanner allows the scanner to go to the page. Software allows wide images to be "stitched" together from two passes of a handheld over a large image. Generally, however, handheld devices are not as effective at full-page scanning as flatbeds. Finally, one of the newest types of scanners looks like a pen. It allows the user to select certain lines of type in a book for scanning. This type of scanner connects to a computer printer port without the addition of any other computer boards, which may be necessary with other types of scanners.

3.4.3 Pointing Device

Pointing devices create the input interface, with the help of this interface user help to control and feed the instructions to the PC using physical moving hand held devices like as mouse and more. Control the all positions of pointer on the screen of monitor with using pointing devices. There are many **examples of input devices of computer** such as:

A. Computer Mouse

Douglas Engelbart **is computer mouse inventor**. When computer mouse was created in 1960 then Douglas Engelbart was working in Stanford Research Institute in Menlo Park, California.

Mouse is a pointing input **device of computer**. Mouse help to control cursor that is visible on the computer screen while moving the mouse on flat surface place. Its name was originated by its shape that look as mouse, because it has elliptical shaped with mouse tail. Mouse reduces usability of a keyboard.

Traditional mouse was connected with computer through cable or cord, but now these days in the market have to various mouse are available such as wireless mouse, those mice do not need any physical wire to make connection with **computer**. In technology time, some mouse has some extra buttons for performing other special tasks.

Different types of computer mouse are available as stated below;

1. Mechanical Mouse:

Another name of **mechanical mouse** is ball mouse. Mechanical mouse is a **computer input terminal** that contains the metal or rubber ball in the back surface side. When we move the mouse then mouse's ball roll and sensors that are embedded inside identify the motion and move on screen's surface portion at the same directions. Today, **mechanical mouse** has been replaced in the Optical mouse. **These types of mouse** have to need cable (wire) to making connection **in computer.**

2. Optical Mouse:

In the **optical mouse** use advance technology such as LED (light-emitting diode), optical sensor, and other DSP (digital signal processing) instead of the rubber ball mechanical mouse. In the **optical mouse**, detect the movement by the sensors when reflected light. No need the cleaning to optical mouse because it has not contained any moving components.

3. Infrared Frequency Cordless Mouse:

Cordless mouse is also known as wireless mouse, and these types of mouse are connected with computers with the help of different unique technologies such as Bluetooth, RF, or infrared radio waves. In the computer, has to contain USB device that receives the spreaded signals from the wireless mice.

4. Traceball Mouse:

Trace ball mouse is an input pointing device. It contains ball upside of the socket, and detecting the movement of ball with the help of sensors while rolling the ball with fingers, palm or thumbs of human hand for moving cursor on the computer screen.

5. Stylus Mouse:

Stylus mouse is another type of input device. This stylus mouse use for the high volume graphic and drawing purpose, and it looks like as pen. The graphic and drawing tasks are performed on the special pad by artistic.

6. 3-D Mouse:

A **3D mouse** is special input pointing device for creating movement in virtual 3D and 2D environment. This 3D mouse is not use for normal task, mainly designed for the gaming controller to create the game console. Other application areas are where to use the 3D mouse like as CAD, architecture design, and 3D modeling is the 3DConnexion SpaceNavigator.

7. Specialty Mouse and Mice-like Devices:

These **types of mouse** mostly use for showing the presentation on the screen, but if, you are not able to use proper smooth surface for rolling the mouse then that situation using accelerometer for converting the motion your hand with the using air into movements of on screen pointer.

8. Laser Mouse:

In **laser mouse**, implements the laser light for detecting mouse directions. Laser mouse do not contain any moving components inside mouse, its accuracy is good compare to other optical mouse because these types of mouse provide 20X greater sensitivity and precision, due to this feature those mouse use for gaming, graphic, and engineering designs, where to require pinpoint accuracy.

9. Foot Mouse:

A **foot mouse** is used by those people who are unable to use mouse with their hands or arms. For using foot mouse, install the software programs in the system then work it properly for selecting any spot of screen. In that mouse are needed two parts, one for controlling the cursor, and other for clicking the mouse.

10. Intelli Mouse:

Intelli Mouse is also knows as wheel mouse or scroll mouse and this mouse was designed by Microsoft in 1996. Its wheel set in the center between left and right button. Users use wheel of mouse for scroll up and down any document page. If user wants to open any link on the new tab, then mouse cursor hover on the link and press down to mouse wheel.

11. J-Mouse:

Today, **J Mouse's trend** has been stop because this technology used in the traditional portable computer such as Laptop. 'J' key was placed on the traditional keyboard for performing various tasks, and other two buttons (left, right) were embedded below the Spacebar key.

12. Joystick Mouse:

Mostly this typed of mouse uses for playing video game and graphic applications. Joystick is like as plastic stick for reporting its directions to component it's controlling.

13. Touchpad Mouse:

Touchpad is also known as **Glide pad or track pad**, use for giving the input to computer. These types of touch pad are place on the laptop or other special keyboards. Users can move the cursor on the screen with their fingers, and other two external buttons are embedded below track pad.

14. Trackball Mouse:

Trackball is special type of mouse because one ball is placed on the surface of socket, and that sockets contain the sensors. With using sensor to detect the rotation of ball about different two axes like as upside-downside.

15. Track Point Mouse:

Trace Point mouse was designed by IBM in 1992. This component used in the traditional computer, and Trace Point is also known as **Pointing stick, style pointer, or nub** also. It has placed in between the *G*,H, and B keys on the keyboard. For moving the cursor of Track Point's pointer, users push the stick in desire direction where want to move cursor of pointer.

16. Inertial and Gyroscopic mice:

Inertial and gyroscopic mouse is also called "**air mouse**", because this mouse does not need the surface area for operating mouse. In Inertial and gyroscopic mouse, to be used accelerometer for detecting movement at every x-axis and y-axis. Benefits are less power consumption, enhance sensitivity, decrease weight, and more comfortable to other mouse.

17. Tactile mice:

Tactile mouse was designed by Logitech in 2000. It contains a small size actuator for making mouse vibrate. Main motive of designing tactile mouse is for providing education to blind persons in graphical nature. In tactile mouse is used pins and with the movement of these pins user can be able to distinguish various pictures such as triangles, squares, pentagons, hexagons, and circles.

18. Pucks Mouse:

Puck mouse is also known as also "Hockey Puck", and it has round shape as well as USB connection format. First, Puck mouse was introduced by Apple Inc with Bondi Blue iMac G3 in 1988. Its main application areas are graphic designing and Auto CAD.

19. Ergonomic Mice:

Ergonomic mouse is vertical mice, and main objective of introducing this mouse to minimize the wrist and forearm pain because these types of problems are associated with traditional mouse while using them.

20. Gaming Mice:

These types of mice are developed specially for computer games. **Gaming mouse** allow providing the flexibility to users, for using real-time strategy game like as StarCraft or multiplayer battle arena. Other advantages, manage the weight by adding or subtracting weight for easier control, and more comfortable for user's palm and thumb.

3.5. Trackball

Trackball Definition – Users can use a trackball with alternative to mouse. If you have not little bit space for placing the mouse then you has trackball is best option to mouse. The trackball use for taking full control over the cursor (pointer) that is flow on the screen of desktop and laptop. Mostly, Trackball placed on the keyboard and down to space bar key. For moving the cursor of pointer, user traces the finger on the surface of trackball's socket. Two buttons are also embedded with trackball socket, for selecting any object or text as well. Now these days, mostly some computer like as Macintosh PowerBook and Laptop are come with inbuilt trackball system. PowerBook and Laptop are come with inbuilt.

Trackball Definition – Users can be used a trackball with alternative to mouse. If you have not little bit space for placing the mouse then you has trackball is best option to mouse. The trackball use for taking full control over the cursor (pointer) that is flow on the screen of desktop and laptop. Mostly, Trackball placed on the keyboard and down to space bar key. For moving the cursor of pointer, user traces the finger on the surface of trackball's socket. Two buttons are also embedded with trackball socket, for selecting any object or text as well. Now these days, mostly some computer like as Macintosh

Types of Trackball

Trackballs are developed for various **types of computer** interfaces. There are two **types of trackball** such as **serial and parallel interface trackball.**

In serial interface, use the serial data flow model because in this model transmit all data in serial format like as one by one, when one data is

processed then permission allows to other data for entry in processing room. Some serial interface examples are RS232, RS422, RS485, and other universal serial bus (USB).

Parallel interface trackball opposite to serial interface, because in this model use parallel transmission model such have permission to execution multiple bit data at once without any waiting pool of pending bit. These types of trackballs have more speed compare to serial interface trackballs model. In parallel interface use general-purpose interface bus (GPIB). Two technology companies have proprietary support – Sun® Microsystems® workstations and the IBM® Personal System 2 (PS/2).

Here, some other types of trackballs are –

- Kensington Orbit Wireless Trackball Mouse (K72352US)
- Logitech M570 Wireless Trackball-(Certified Refurbished)
- YUMQUA Y-10W 2.4 GHz Portable Finger Handheld Mouse Wireless USB
- Kensington Expert Trackball Mouse (K64325)
- Dconnexion 3DX-700040 Space mouse Pro 3D Mouse
- Logitech Optical Trackball Marble Mouse
- Logitech Trackman Wheel Optical
- Tonor Portable Finger Handheld 4D UBS Mini Trackball Mouse Wired
- Kensington SlimBlade Trackball Mouse

Use of Trackball

Every user, one question will be created in their minds that **what a trackball is used for**? So here we will discuss about all areas where to **use trackball.**

Scrolling Enlarge Document: If you have enlarge document, and want to navigate it then trackball is best option for you because this device can spins very rapidly while simple flick your finger, and can be produced scroll much longer while giving your hands.

Games: Trackball plays very eminent role in game area because trackball more useful for some specific games like as golf, baseball and bowling, in these game user moves their pointing terminals to strength of throw otherwise hit. **While muscular dystrophy**, user cannot use their hands on the table but can use fingers then trackball is best solution here.

Graphic Areas: With the help of **trackball**, user can draw 2d or 3D images in quickly without more movement of trackball device. There are some graphics software, where to use of trackball such as Corel draw and Photoshop etc. Trackball also play vital role for air-traffic controlling system and other drafting equipments etc.

No Physical Limitation: The trackball can be used indoor and outdoor areas because no need any surface place for operating trackball device as well as more flexible.

Trackball Advantages and Disadvantages

Each users must be known about numerous **advantages and disadvantages** over **trackball.**

Advantage:

1. Trackball provides to users for accessing 4K-5K high resolution screen compare to other traditional devices.
2. More comfortable for user's wrist and palm.
3. Trackball has more speed.
4. No need more services.
5. Most suitable for playing game.
6. Having ergonomic merit because for performing task only move ball instead of entire socket.
7. No required more space for positioning of trackball.
8. Trackball' buttons are well designed that provide rest while performing task by this device.
9. No need for any track pad like mouse need **mouse pad**.
10. Trackball is more suitable if users are ambidextrous because trackball can be used very easily with any hand either this is right hand or left hand.
11. Have good disability.

Disadvantage:

1. More expensive because trackball cost may be vary up to 20 $ to 100$.
2. Not easy to use because trackball's cursor performs more activities while spinning ball with lightly because it has more accessibility.

3. Need accurate control over the ball with one finger or thumb because can be got more difficulties to cut, paste, click and drag.
4. Physical Limitation – if your hands have small than user can face more difficulties to operating this devices.
5. Not comfortable to fast pace games.

Trackball vs Mouse

1. User get mouse while buying **computer** but buy trackball externally as need of user.
2. Every user can operate mouse without massive training but before using trackball user must be known about some instruction about **trackball**.
3. Mouse has cost effective but trackball may be costly to mouse.
4. Need flat surface area for operating mouse but no require for trackball because its ball fit in his socket, and this socket can be used any areas.
5. Trackball have more accuracy compare to **mouse accuracy**.
6. Trackball has good speed to mouse.
7. Trackball can be operate any indoor and outdoor space without hindrance because this **input device** no bound to flat surface area but mouse need smooth place for using.
8. Professional designer give first preference to trackball for designing task and second priority on mouse.
9. Trackball device more comfortable to mouse because users get pain on their palm while operating mouse but not in trackball.
10. Mouse needs service on regular basis but trackball do not more service compare to mouse.

3.6 Touchpad

First touchpad was designed by George E. Gerpheide in 1988 along with Psion's MC 200/400/600/WORD Series. Touchpad had been started to be **used in laptops** in 1990.

Touchpad is a controlling **input positioning device of computer.** Touchpad is also known as **glide pad and glide point**. Touchpad is best alternative option to **computer mouse**. Mostly, **Computer touchpad**

device is attached **on the laptop**, but some time it found on keyboard as well. **Computer touchpad** is totally controlled by user's finger, when they slide his fingers on the surface area of touchpad. Touchpad allows to fast movement cursor on the monitor screen while slow finger movement on the touchpad's surface zone.

Computer touchpad has two buttons that are called left-click and right-click same as mouse buttons. In latest touchpad is acquired large **surface area** for fingertips, and their buttons are embedded below the surface area due to users convenience.

Advantages of Touchpad

Below, we will spread the light on the **touchpad features** as well as **benefits** such as:

- No required more space for using it because touchpad is embedded in to laptop or keyboard.
- Touchpad has better as well as fast selection control any objects to mouse.
- No need any smooth surface area under it like as using for mouse.
- Easy to operate.
- It is more sensitive device.
- If you are using laptop then it more comfortable while laying on your bed.
- No tension for wireless and wire device because it is built in your laptop.
- No need to pay extra money for buying it because touchpad is linked
- On your keyboard or laptop.
- When you are travelling then it can be easily carry without any hindrance.
- It has good portability.
- It has better finger control.
- It has fast navigation via various application areas and internet as well.
- Need little bit finger movement for moving the cursor on the **screen**.

- No more wait for using mode while booting your system.
- Touchpad provides the rest to wrist while using it compare to **mouse** because it can be used by one or two finger, not use your fully palm.
- Touchpad is attached with your system, so it does not need special drivers for its installation in the computer system.

Disadvantages of Touchpad

- Need some skills for using touchpad to handle the cursor's position on your monitor screen.
- Touchpad cannot be used while wearing gloves in winter season.
- Probably, some problem can be arising while controlling the cursor on the monitor display, if you are using first time.
- Touchpad is costly to **mouse**.
- Mostly, touchpad is built-in on the laptop.
- If you are performing some activities such as drag and drop then some difficulties can be create.
- It can be created disturbance to sending signals through sensor, if you are using moist and sweaty fingers.
- It has more difficult to use in cramped condition as there space limitation for moving.
- Required limited area for using it.
- Not possible to scroll across the **monitor screen** in one go.
- Touchpad cannot perform massive movement.

Functions of Touchpad

There are numerous **touchpad functions** with solving the question that **how does Touchpad work?** Below describe every one

- **Enhance Sound** – Perform dragging with your finger to upside direction on the touchpad surface.
- **Decrease Sound** – Perform dragging along with finger to downside on the touchpad.
- **Pause/Resume** – Lightly tap two times to touch pad surface.
- **Play forward track** – When you drag your finger to forwards side on the touchpad.

- **Play backward track** – Execute dragging to reverse side on the touch pad.
- **Fast forward** – Drag finger upward direction on the surface of touch pad while holding it minimum 1 second duration.
- **Rewind function** – Drag finger downward side on the touch pad while holding it minimum 1 second duration.

3.7 Audio Input Device

With the help of **audio input devices**, user can send audio instructions to computer for different tasks such as processing, recording, and more. Many audio input devices work with speech recognition programs, because this software helps to translate spoken words into text document.

There are some **examples of audio input devices** such as

1. Microphone

This device is able to convert sound waves into electrical waves.

2. Midi keyboard

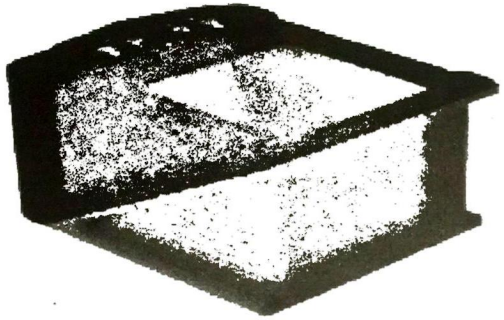
This device looks like as piano that is connect to computer via USB cable.

3.8 Remote control

This is a very commonly used input device. It sends data signals each time a button is pressed using infrared light or radio signals. The signals can control the system from some distance. It is also used to control a presentation slide show.

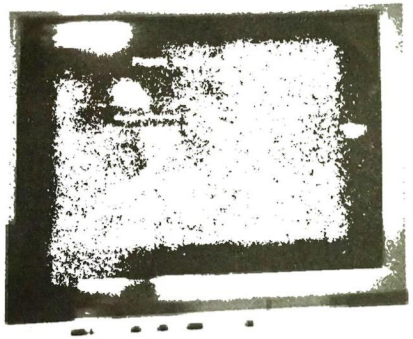
3.9 Biometric sensor

It is a device that identifies unique human physical features with high accuracy. It is an essential component of a biometric system which uses physical features like fingerprints, retina, iris patterns, etc., to identify, verify, and authenticate the identity of the user. The three major types of biometric sensors are semiconductor sensor, optical sensor, and ultrasound sensor. Figure 3.21 shows a biometric sensor.



3.10 Touch screen

It is an input device that allows the user to operate by simply touching on the display screen. Some computers, tablets, smartphones, etc., have touch-sensitive display screens. It can also be operated using a stylus which gives more precision. Information kiosks at railway stations and bank ATMs also use touch screens as input device. Nowadays, touch screens is the most common hardware interface for electronic gadgets.



CHAPTER FOUR
OPERATIONAL AMPLIFIER

4.1 INTRODUCTION

An operational amplifier, or op-amp, is a ***very high gain*** ($A \approx \infty$) differential amplifier with ***high input impedance*** ($Zi \approx \infty$) and ***low output impedance*** ($Zo \approx 0$). it is basically a complete high-gain voltage amplifier in a small package. Op-amps were originally developed to perform mathematical operations in analog computers, hence the odd name. They are now made using integrated circuit technology, so they come in the typical multi-pin IC packages. With the proper external components, the operational amplifier can perform a wide variety of "operations" on the input voltage. It can multiply the input voltage by nearly any constant factor, positive or

negative, it can add the input voltage to other input voltages, and it can integrate or differentiate the input voltage. The respective circuits are called *amplifiers*, *summers*, *integrators*, and *differentiators*. Op-amps are also used to make active frequency filters, current-to-voltage converters, voltage-to-current converters, current amplifiers, voltage comparators, etc.

4.2 OPAMP Operation

The op amp is one of the basic building blocks of linear design. In its classic form it consists of two input terminals, one of which inverts the phase of the signal, the other preserves the phase, and an output terminal. The standard symbol for the op amp is given in Figure 4.1. This ignores the power supply terminals, which are obviously required for operation.

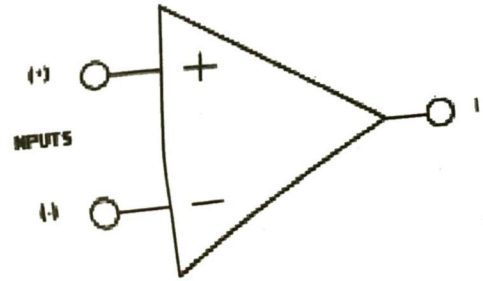


Figure 4.1: *Standard op amp symbol*

The name "op amp" is the standard abbreviation for operational amplifier. This name comes from the early days of amplifier design, when the op amp was used in analog computers. When the basic amplifier was used with a few external components, various mathematical "operations" could be performed.

4.2.1 Op-amp characteristics

Operational amplifiers have several very important characteristics that make them so
useful:

1. An op-amp has *two* inputs and it amplifies the *voltage difference* between those two inputs.

   These two inputs are known as the non-inverting input, labeled (+), and the inverting input,
   labeled (-).
2. The op-amp must be connected to external sources of power. The output voltage (v_o) cannot be more positive than the positive power source or more negative than the negative power source. The gain (G) is very high, typically more than 100,000. Together that means that if the output (v_o) is in the *active* range (somewhere between its physical limits, often called "rails"), then $v_a - v_b = 0$, and $v_a = v_b$.
3. In fact, v_a - v_b must be so small that it's very difficult to make v_a and v_b close enough
4. Op-amps amplify DC as well as AC.
5. The input currents are almost zero. In more technical terms, the op-amp has very high input
   impedance.

4.3 The Ideal Operational Amplifier

In order to introduce operational amplifier circuitry, we will use an ideal model of the operational amplifier to simplify the mathematics involved in deriving gain expressions, etc., for the circuits presented. With this understanding as a basis, it will be convenient to describe the properties of the real devices themselves in later sections, and finally to investigate

circuits utilizing practical operational amplifiers. To begin the presentation of operational amplifier circuitry, then, it is necessary first of all to define the properties of a mythical "perfect" operational amplifier. The model of an ideal operational amplifier is shown in figure 4.3..

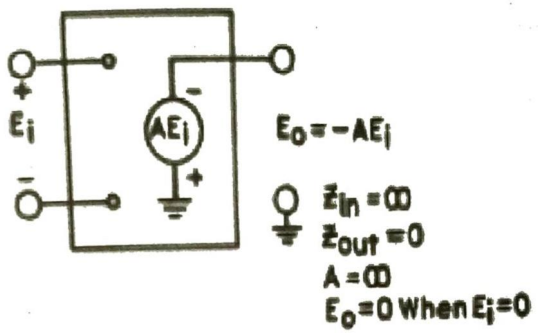


Figure 4.3. Equivalent Circuit of the Ideal Operational Amplifier

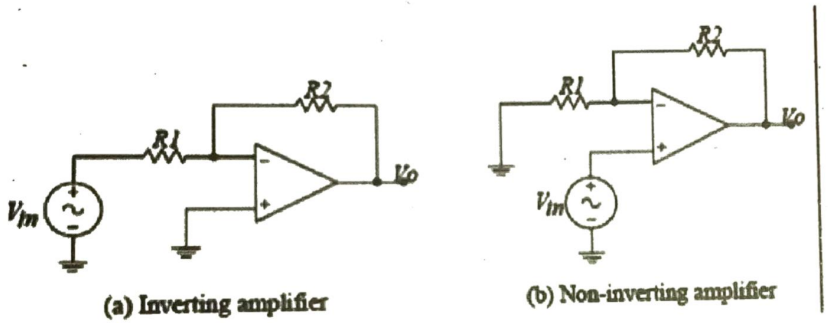
Defining the Ideal Operational Amplifier

- **Gain:** The primary function of an amplifier is to amplify, so the more gain the better. It can always be reduced with external circuitry, so we assume gain to be infinite.
- **Input Impedance:** Input impedance is assumed to be infinite. This is so the driving source won't be affected by power being drawn by the ideal operational amplifier.
- **Output Impedance:** The output impedance of the ideal operational amplifier is assumed to be zero. It then can supply as much current as necessary to the load being driven.
- **Response Time:** The output must occur at the same time as the inverting input so the response time is assumed to be zero. Phase shift will be 180^0. Frequency response will be flat and bandwidth infinite because AC will be simply a rapidly varying DC level to the ideal amplifier.
- **Offset:** The amplifier output will be zero when a zero signal appears between the inverting and non-inverting inputs.

4.4 FORMS OF OP-AMP

4.4.1 Negative Feedback Amplifiers

With two resistors we can construct the fundamental feedback network of a negative feedback amplifier. Depending on the terminal at which the signal is applied, the fundamental negative feedback configuration can be in the **inverting amplifier arrangement**, where the input signal, *Vin*, is applied to the inverting terminal, Figure 4.3(a), or in the **non-inverting amplifier arrangement**, where the input signal, *Vin*, is applied to the non-inverting terminal, Figure 4.3(b).



(a) Inverting amplifier (b) Non-inverting amplifier

Figure 4.3. Basic feedback amplifier configurations: (a) inverting, (b) non-inverting

4.4.2 Inverting Amplifier

The basic inverting amplifier configuration is shown on Figure 4.4. The input signal, V_{in}, is applied to the inverting terminal and the balance of the circuit consists of resistors *R1* and *R2*.

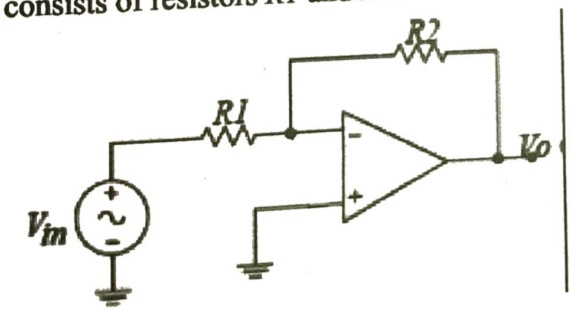


Figure 4.4. Inverting amplifier circuit

4.4.2 Summer

The inverting amplifier can also be used as a summing amplifier; that is, it can be made to add the effects of several input voltages together. The summer can be expanded to any number of inputs. Look at the circuit in Fig. 4.5.

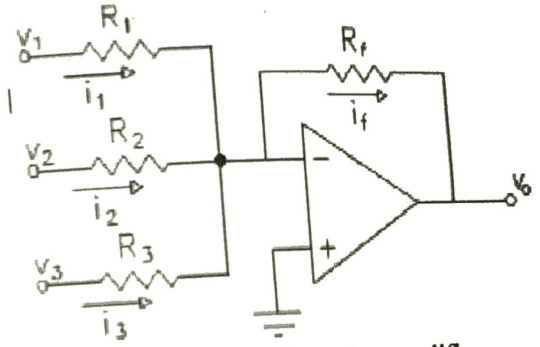


Figure 4.5. Summing amplifier

4.4.3 Differentiator

The differentiator looks an awful lot like the inverting amplifier, and is analyzed in a very similar way.

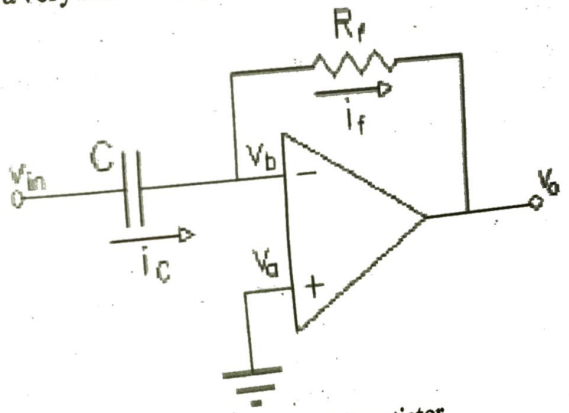


Figure 4.6 Differentiator

4.4.5 Integrator

Another useful op-amp circuit is the integrator, shown in Fig.4.7. Unfortunately, The simple integrator does have one little practical problem. Notice that if the input voltage has any dc component, the output voltage will soon try to run off to infinity. A resistor is usually placed in parallel with the capacitor to eliminate this rather annoying effect. The circuit in Fig. 4.8 has such a resistor. This is a *running average* or *Miller* integrator.

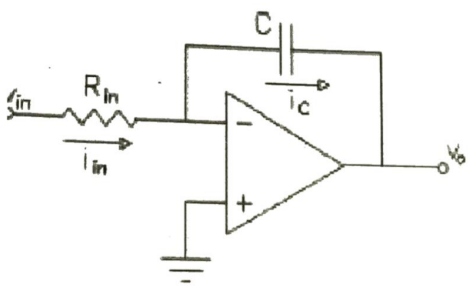
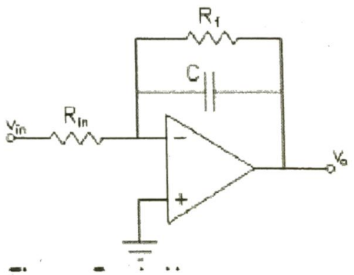


Figure 4.7 Integrator**Figure**



4.8 Practical integrator

4.4.6 Active Filters

If you replace the resistors in the inverting and non-inverting amplifiers with frequency dependant impedances (capacitors and/or inductors), you can make all sorts of frequency dependant circuits, including filters. In fact, the differentiator and integrator circuits can be thought of as filters. One of the main advantages of active filters is that you don't need to use inductors.

4.4.7 Comparator

Now look at Fig. 4.9. This circuit will **not** work as a linear circuit. If va > 0 the output will be as high as the op-amp can make it, usually a volt or two below the positive power supply. If va < 0 the output will be as low as the op-amp can make it, usually a volt or two above the negative power supply. The output is no longer linearly related to the input– it's more like a digital signal, high or low depending on how vin compares to ground (0 V). The comparator is a *nonlinear* circuit.

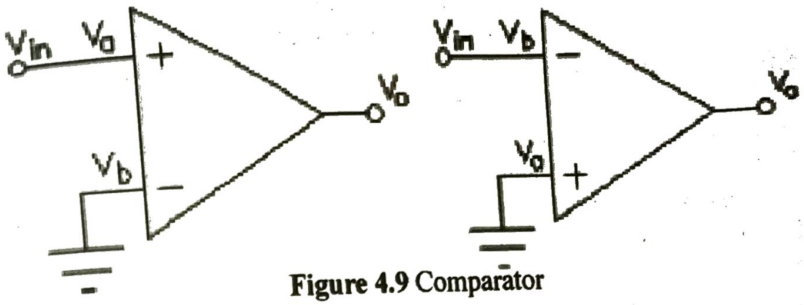


Figure 4.9 Comparator

CHAPTER FIVE
COMPUTER MEMORY

5.0 Introduction

A computer system can be basically divided into three basic blocks. They can be called the Central Processing Unit, commonly called the Processor, the Memory subsystem and the I/O subsystem. The Memory subsystem forms the backbone of the whole system storing vital and large amount of data that can be retrieved at any given time for processing. Memory is categorized into volatile and non-volatile memories, with the former requiring constant power ON of the system to maintain data storage. Furthermore, a typical computer system provides a hierarchy of different types of memories for data storage as shown in figure 5.1.

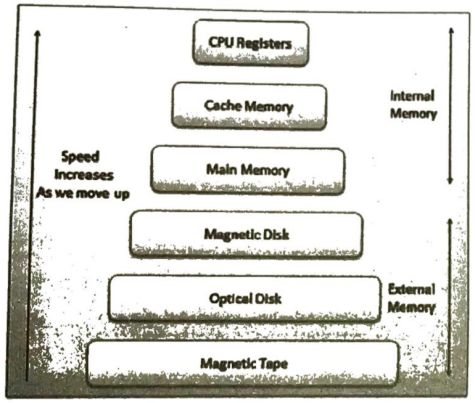


Figure 5.1: Memory hierarchy

There are four major storage levels

- ☐ **Internal** - Processor registers and cache.
- ☐ **Main** - the system RAM and controller cards.
- ☐ **On-line mass storage** - Secondary storage.
- ☐ **Off-line bulk storage** - Tertiary and Off-line storage.

1. Internal or cache:
   - ☐ Cache is the fastest accessible memory of a computer system.
   - ☐ Its access speed is in the order of a few nanoseconds.
   - ☐ It is volatile and expensive, so the typical cache size is in the order of megabytes.
2. Main memory (gb):
   - ☐ Main memory is arguably the most used memory.
   - ☐ The main memory is reasonably fast, with access speed around 100 nanoseconds.
   - ☐ It also offers larger capacity at a lower cost. Typical main memory is in the order of 10 GB. However, the main memory is volatile.
   - ☐ RAM: Random Access Memories are volatile in nature. As soon as the computer is switched off, the contents of memory are also lost.
   - ☐ ROM: Read only memories are non volatile in nature. The storage is permanent, but it is read only memory. We cannot store new information in ROM. Types of ROM includes Programmable Read Only Memory; Erasable Programmable Read Only Memory; Electrically Erasable Programmable Read Only Memory; etc.

3. Online mass storage (or) Secondary Storage (tb

Secondary storage refers to non-volatile data storage units that are external to the computer system. Hard drives and solid state drives are examples of secondary storage.

They offer very large storage capacity in the order of terabytes at very low cost. Therefore, database servers typically have an array of secondary storage devices with data stored distributedly and redundantly across these devices. Modern hard drives have access speed in the order of a few milliseconds.

4. Off-line bulk storage or tertiary storage (pb):

Tertiary storage refers storage designed for the purpose data backup. Examples of tertiary storage devices are tape drives and robotic driven disk arrays. They are capable of petabyte range storage, but have very slow access speed with data access latency in seconds or minutes.

5.1 Primary Memory Types

Primary memory includes ROM and RAM, and is located close to the CPU on the computer motherboard, enabling the CPU to read data from primary memory very quickly indeed. It is used to store data that the CPU needs imminently so that it does not have to wait for it to be delivered.

5.2 Random Access Memory

RAM is a form of computer data storage. A random-access memory device allows data items to be accessed (read or written) in almost the same amount of time irrespective of the physical location of data inside the memory.

Today, random-access memory takes the form of integrated circuits. RAM is normally associated with volatile types of memory (such as DRAM memory modules), where stored information is lost if power is removed, although many efforts have been made to develop non-volatile RAM chips. Integrated-circuit RAM chips came into the market in the late 1960s, with the first commercially available DRAM chip, the Intel 1103, introduced in October 1970.

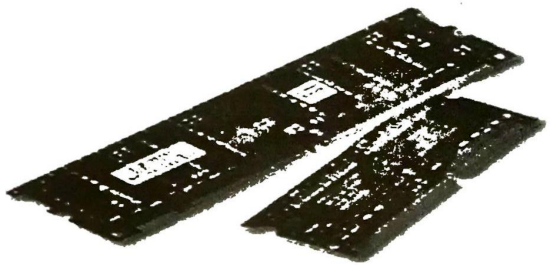
Magnetic-core memory was invented in 1947 and developed up until the mid-1970s. It became a widespread form of random-access memory, relying on an array of magnetized rings. By changing the sense of each ring's magnetization, data could be stored with one bit stored per ring. Since every ring had a combination of address wires to select and read or write it, access to any memory location in any sequence was possible.

Magnetic core memory was the standard form of memory system until displaced by solid-state memory in integrated circuits, starting in the early 1970s. Robert H. Dennard invented dynamic random-access memory (DRAM) in 1968; this allowed replacement of a 4 or 6-transistor latch circuit by a single transistor for each memory bit, greatly increasing memory density at the cost of volatility. Data was stored in the tiny capacitance of each transistor, and had to be periodically refreshed every few milliseconds before the charge could leak away.

5.2.1 Types of RAM

Random Access Memory is the internal memory of the CPU for storing

data, program, and program result. It is a read/write memory which stores data until the machine is working. As soon as the machine is switched off, data is erased.



Access time in RAM is independent of the address, that is, each storage location inside the memory is as easy to reach as other locations and takes the same amount of time. Data in the RAM can be accessed randomly but it is very expensive.

RAM is volatile, i.e. data stored in it is lost when we switch off the computer or if there is a power failure. Hence, a backup Uninterruptible Power System (UPS) is often used with computers. RAM is small, both in terms of its physical size and in the amount of data it can hold.

The two main forms of modern RAM are static RAM (SRAM) and dynamic RAM (DRAM).

A. Static RAM

In SRAM, a bit of data is stored using the state of a six transistor memory cell. This form of RAM is more expensive to produce, but is generally faster and requires less power than DRAM and, in modern computers, is often used as cache memory for the CPU. SRAM stands for Static RAM, and it is a particular type of RAM which is faster than DRAM, but more expensive and bulker, having six transistors in each cell. For those reasons SRAM is generally only used as a data cache within a CPU itself or as RAM in very high-end server systems. A small SRAM cache of the most imminently-needed data can result in significant speed improvements in a system

B. Dynamic RAM

DRAM stores a bit of data using a transistor and capacitor pair, which together comprise a DRAM memory cell. The capacitor holds a high or low charge (1 or 0, respectively), and the transistor acts as a switch that lets the control circuitry on the chip read the capacitor's state of charge or change it. As this form of memory is less expensive to produce than static RAM, it is the predominant form of computer memory used in modern computers. The oldest type is known as single data rate (SDR) DRAM, but newer computers use faster dual data rate (DDR) DRAM. DDR comes in several versions including DDR2 , DDR3, and DDR4, which offer better performance and are more energy efficient than DDR. However different versions are incompatible, so it is not possible to mix DDR2 with DDR3 DRAM in a computer system. DRAM consists of a transistor and a capacitor in each cell.

Similarities

Both static and dynamic RAM are considered *volatile*, as their state is lost or reset when power is removed from the system. In general, the term *RAM* refers solely to solid-state memory devices (either DRAM or SRAM), and more specifically the main memory in most computers.

key differences

SRAM is faster than DRAM – perhaps two to three times faster – but more expensive and bulkier. SRAM is usually available in megabytes, while DRAM is purchased in gigabytes.

DRAM uses more energy than SRAM because it constantly needs to be refreshed to maintain data integrity, while SRAM – though volatile – does not need constant refreshing when it is powered up.

Other uses of RAM

In addition to serving as temporary storage and working space for the operating system and applications, RAM is used in numerous other ways.

1. Virtual memory

Most modern operating systems employ a method of extending RAM capacity, known as "virtual memory". The main memory can act as a "cache" for the secondary storage, this technique is called virtual memory. Virtual memory role is to protect and ensuring that a program can only read and write the portions of main memory that have been assigned to it.

2. **RAM disk**

Software can "partition" a portion of a computer's RAM, allowing it to act as a much faster hard drive that is called a RAM disk. A RAM disk loses the stored data when the computer is shut down, unless memory is arranged to have a standby battery source.

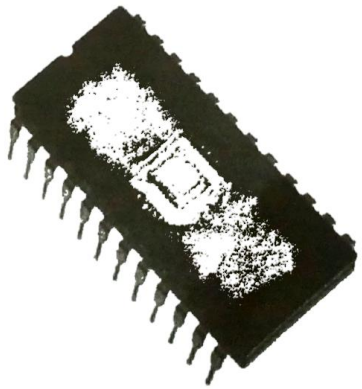
3. **Shadow RAM**

Sometimes, the contents of a relatively slow ROM chip are copied to read/write memory to allow for shorter access times. The ROM chip is then disabled while the initialized memory locations are switched in on the same block of addresses (often write-protected). This process, sometimes called *shadowing*, is fairly common in both computers and embedded systems.

5.3 Read-Only Memory

ROM stands for read-only memory, and the name stems from the fact that while data can be read from this type of computer memory, data cannot normally be written to it. It is a very fast type of computer memory which is usually installed close to the CPU on the motherboard.

ROM is a type of non-volatile memory, which means that the data stored in ROM persists in the memory even when it receives no power – for example when the computer is turned off. In that sense it is similar to secondary memory, which is used for long term storage.



When a computer is turned on, the CPU can begin reading information stored in ROM without the need for drivers or other complex software to help it communicate. The ROM usually contains "bootstrap code" which is the basic set of instructions a computer needs to carry out to become aware of the operating system stored in secondary memory, and to load parts of the operating system into primary memory so that it can start up and become ready to use.
ROM is also used in simpler electronic devices to store firmware which runs as soon as the device is switched on.

Types of ROM
ROM is available in several different types, including PROM, EPROM, and EEPROM.
- **PROM**

PROM stands for Programmable Read-Only Memory, and it is different from true ROM in that while a ROM is programmed (i.e. has data written to it) during the manufacturing process, a PROM is manufactured in an empty state and then programmed later using a PROM programmer or burner. Typically, this device uses high voltages to permanently destroy or create internal links (fuses or antifuses) within the chip. Consequently, a PROM can only be programmed once.
- **EPROM**

EPROM stands for Erasable Programmable Read-Only Memory, and as the name suggests, data stored in an EPROM can be erased and the EPROM reprogrammed. Erasing an EPROM involves removing it from the computer and exposing it to ultraviolet light before re-burning it.
- **EEPROM**

EEPROM stands for Electrically Erasable Programmable Read-Only Memory, and the distinction between EPROM and EEPROM is that the latter can be erased and written to by the computer system it is installed in. In that sense EEPROM is not strictly read-only. However in many cases the write process is slow, so it is normally only done to update program code such as firmware or BIOS code on an occasional basis. Writing or *flashing* an EEPROM is much slower (milliseconds per bit) than reading from a ROM or writing to a RAM (nanoseconds in both cases).

- **EAROM**

Electrically alterable read-only memory (EAROM) is a type of EEPROM that can be modified one bit at a time. Writing is a very slow process and again needs higher voltage (usually around 12 V) than is used for read access. EAROMs are intended for applications that require infrequent and only partial rewriting. EAROM may be used as non-volatile storage for critical system setup information; in many applications, EAROM has been supplanted by CMOS RAM supplied by mains power and backed-up with a lithium battery.
- ***Flash memory***

Flash memory (or simply *flash*) is a modern type of EEPROM invented in 1984. Flash memory can be erased and rewritten faster than ordinary EEPROM, and newer designs feature very high endurance (exceeding 1,000,000 cycles). Modern NAND flash makes efficient use of silicon chip area, resulting in individual ICs with a capacity as high as 32 GB as of 2007; this feature, along with its endurance and physical durability, has allowed NAND flash to replace magnetic in some applications (such as USB flash drives). Flash memory is sometimes called *flash ROM* or *flash EEPROM* when used as a replacement for older ROM types, but not in applications that take advantage of its ability to be modified quickly and frequently.

Differences between RAM and ROM
ROM:
- Non-volatile
- Fast to read
- Usually used in small quantities
- Cannot be written to quickly
- More reliable than RAMs
- Used to store boot instructions or firmware
- Relatively expensive per megabyte stored compared to RAM
- Contents are always known and can be verified

RAM:

- Volatile
- Fast to read and write
- Used as system memory to store data (including program code) that the CPU needs to process imminently
- Relatively cheap per megabyte stored compared to ROM, but relatively expensive compared to secondary memory

5.4 Secondary Memory

Secondary memory by contrast, is usually physically located within a separate storage device, such as a hard disk drive or solid state drive (SSD), which is connected to the computer system either directly or over a network. The cost per gigabyte of secondary memory is much lower, but the read and write speeds are significantly slower.

Secondary memory comprises many different storage media which can be directly attached to a computer system. These include:

- hard disk drives
- solid state drives (SSDs)
- Optical (CD or DVD) drives
- Tape drives

Secondary memory also includes:

- Storage arrays including 3D NAND flash arrays connected over a storage area network (SAN)
- Storage devices which may be connected over a conventional network (known as network attached storage, or NAS)

Arguably cloud storage can also be called secondary memory.

5.5 MAGNETIC DEVICES

Magnetic storage refers to magnetized media, such as hard disk drives, that are used by computer systems to store data. Computer systems need to store data in digital format. One of the most widely used types of digital data storage is **magnetic storage**. This refers to any type of data storage using a magnetized medium. Digital data consists of **binary information,** which is data in the form of zero and ones. There are two types of magnetic polarities, each one used to represent either zero or one.

Several types of magnetized media are used in computer systems, including **magnetic tape, floppy disks** and **hard disk drives**. The basic approach to magnetic data storage, however, is very similar for the different types of media. A read-write head moves very close to the magnetic surface - the distance is often no more than tens of nanometers. The head is able to detect and modify the magnetization of the material. The magnetic surface is divided into very small regions, each of which has a mostly uniform magnetization. As the head moves relative to the surface, the changes in magnetization from region to region are detected and recorded as zeros and ones. Different technologies vary in how the head moves relative to the surface of the media and how the regions on the media are organized, but the basic principle is the same.

Magnetic storage is a form of **non-volatile storage**. This means that the data is not lost when the storage device is not powered. This is in contrast to **volatile storage**, which is typically used for the main memory of a computer system. Volatile storage requires a constant power supply - when a computer system is turned off, the data is lost.

Magnetic storage is widely used because it is relatively cheap in comparison with other storage technologies. Magnetic storage is read-write, which makes it possible to re-use the storage capacity over and over again by deleting older data. The storage capacity is also very large, making it attractive for storing very large amounts of data. The major limitation of magnetic storage is that accessing the data can be quite slow. As a result, most computer systems use magnetic storage for non-volatile storage of large amounts of data (typically in a form of a hard-disk drive) but a different type of storage for system memory, such as read-only memory (ROM), which is much smaller but can be accessed much faster.

5.6 NEW EMERGING MEMORY (NEM) TECHNOLOGIES

in high resistance) or set (reformed, resulting in lower resistance) by applying an appropriate voltage

5.6.5 Polymer Memory

Throughout the last few years, polymers have found growing interest as a result of the rise of a new class of nonvolatile memories. In a polymer memory, a layer consists of molecules and/or nanoparticles in an organic polymer matrix is sandwiched between an array of top and bottom electrodes

Moreover, polymer memory has the advantage of a simple fabrication process and good controllability of materials [9]. Polymer memory could be called digital memory with the latest technology. It is not possible for a silicon-based memory to be established in less space, but it is possible for polymer memory. The non volatileness and other features are inbuilt at the molecular level and offers very high advantages in terms of cost. But turning polymer memory into a commercial product would not be easy.

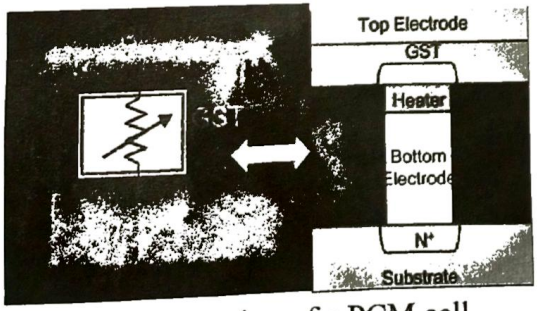
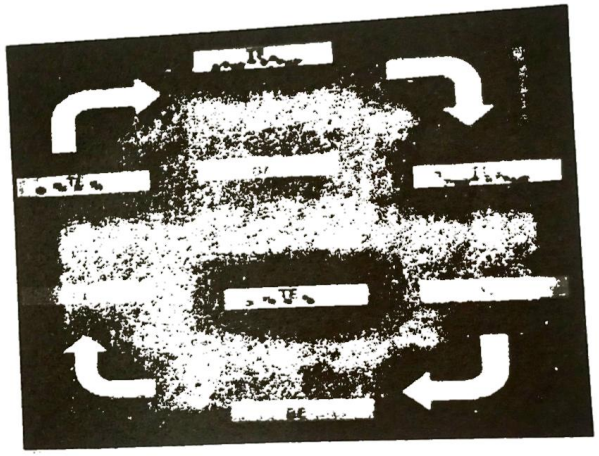
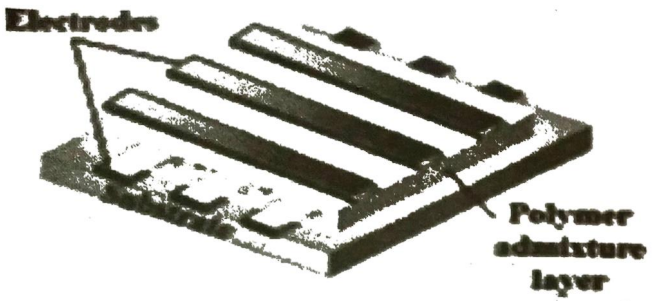


Illustration of a PCM cell



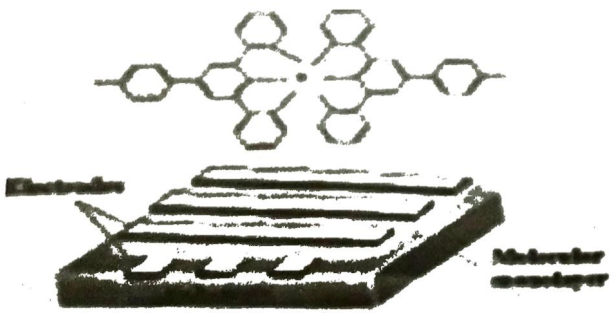
ReRAM structure



Structure of a polymer memory device

5.6.6 Molecular Memory

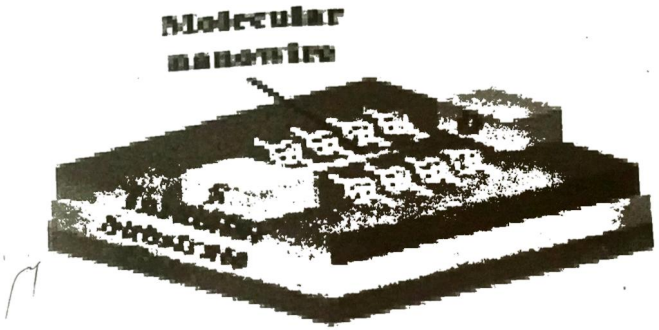
A molecular memory is a nonvolatile data storage memory technology that uses molecular species as the data storage element, rather than, e.g., circuits, magnetics, inorganic materials, or physical shapes. In a molecular memory, a monolayer of molecules is sandwiched between a cross-point array of top and bottom electrodes. The molecules are packed in a highly ordered way, with one end of the molecule electrically connected to the bottom electrode and the other end of the molecule connected to the top electrode, and this molecular component is described as a molecular switch. Then, regarding the molecular memory operation, by applying a voltage between the electrodes, the conductivity of the molecules is altered, enabling data to be stored in a nonvolatile way. This process can then be reversed, and the data can be erased by applying a voltage to the opposite polarity of the memory cell.



Cell structure of a molecular memory device

5.6.7 MNW

The molecular nanowire array (MNW) memory is fundamentally different from other semiconductor memories; information storage is achieved through the channel of a nanowire transistor that is functionalized with redox-active molecules rather than through manipulation of small amounts of charge. It is relatively slow and lacks the random access capability, wherein data that can be randomly read and written at every byte are being actively pursued.



A MNW memory cell structure

5.6.8 QD (QUANTUM DOTS) Memory

Memory made from tiny islands of semiconductors - known as quantum dots - could fill a gap left by today's computer memory, allowing storage that is fast as well as long lasting. Researchers have shown that they can write information into quantum dot memory in just nanoseconds. New research shows that memory based on quantum dots can provide the best of both: long-term storage with write speeds nearly as fast as DRAM. A tightly packed array of tiny islands, each around 15 nm across, could store 1 terabyte (1,000 GB) of data per square inch, the researchers say. Dieter Bimberg and colleagues at the Technical University of Berlin, Germany, with collaborators at Istanbul University, Turkey, demonstrated that it is possible to write information to the quantum dots in just 6 ns. The key advantages of quantum dot (QD) are the high read/write speed, small size, low operating voltage, and, most importantly, multibit storage per device.