CHAPTER THREE
COMPUTER CIRCUITS

3.1 Meaning of Electronic Circuit

An electronic circuit is composed of individual electronic components, such as resistors, transisors, capacitors, inductors and diodes, connected by conductive wires or traces through which electric current can flow. The electronic circuit symbols mainly involve wires, power supplies, resistors, capacitors, diodes, transistors, meters, switches, sensors, logic gates, audio devices, and other components

Computer circuitry- Complete path or combination of interconnected paths for electron flow in a computer. Computer circuits are binary in concept, having only two possible states. They use on-off switches (transistors) that are electrically opened and closed in nanoseconds and picoseconds (billionths and trillionths of a second). A computer's speed of operation depends on the design of its circuitry. Faster rates are achieved by shortening the time it takes to open and close the switches and by developing circuit paths that can handle the increased speeds.

3.2 What types of circuits are used in homes?

There are two types of circuits used for wiring up houses and electrical appliances. **Series circuits** have all the **components** in a line, with current flowing through all the appliances one after the other. In parallel circuits, the current splits up and flows through separate paths through each component.

What are the Electronic Circuits and Their Symbols?

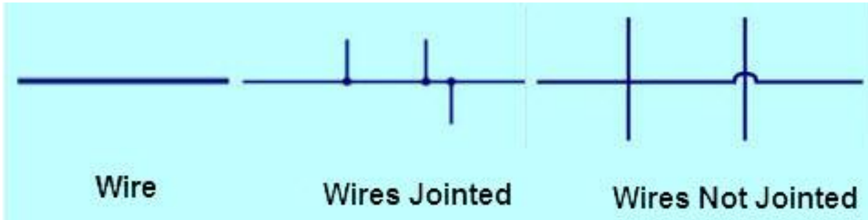
Electronics is a branch of an engineering, which deals with electronic and electrical circuits like Integrated circuits, Transmitters, and Receiver etc. The electronic circuit is defined as it is a combination of various electronic components that allow the flow of electric current. The electronic components consist of two or more terminals that are used to connect one component to another component to design a circuit diagram. The electronic components are soldered on circuit boards to make a system. If you want to focus on core side projects like electronics/ electrical, you should know the basic concepts of electronic circuit symbols and their usage. This article gives an overview of electronic circuit symbols with their functionality.

Electronic Circuit Symbols

The electronic circuit symbols mainly involve wires, power supplies, resistors, capacitors, diodes, transistors, meters, switches, sensors, logic gates, audio devices, and other components.

1. Wires

A wire is a two terminal, single and flexible material that allows the flow of power through it. These are mainly used to connect the power supplies to the PCB (Printed Circuit Board) and in between the components. The different types of wires will be as

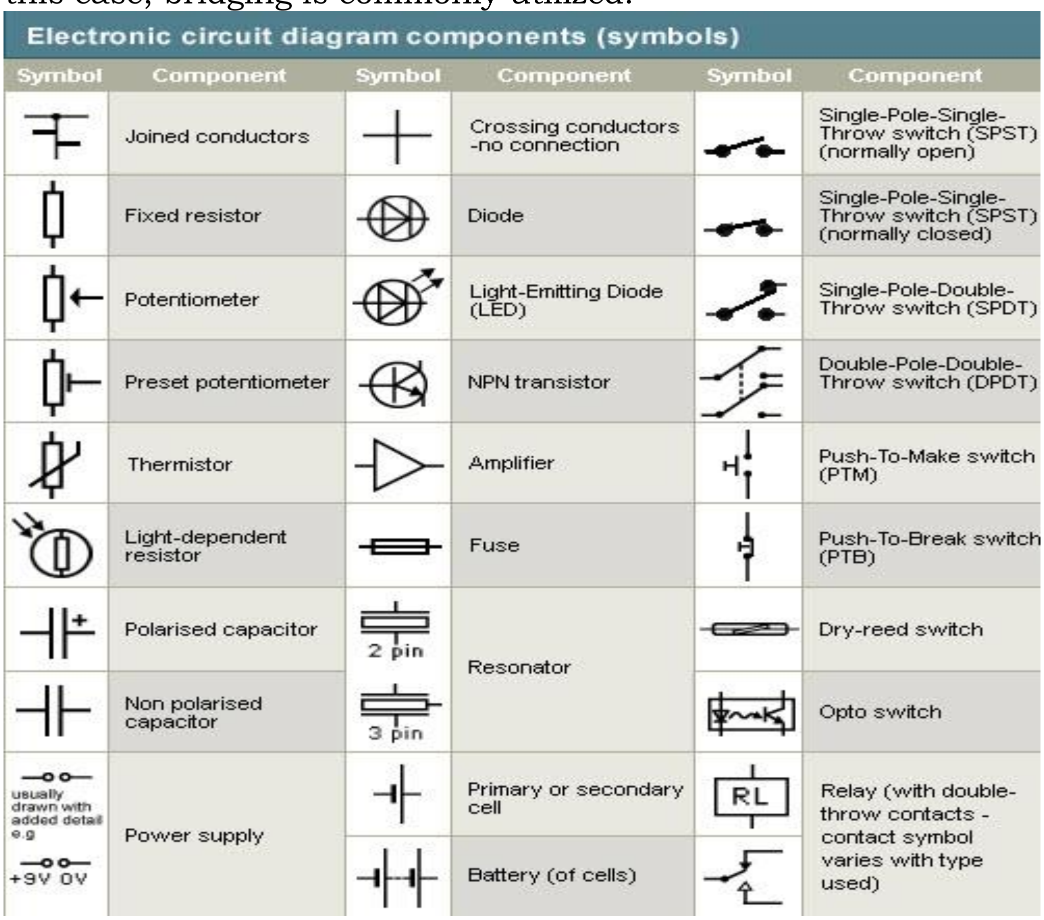


Wires

Wires: A single wire with two terminals will pass the current from one component to another.

Wires Jointed: When two or more wires are connected with each other that is called as wires jointed. The joining or shorted of wires at one point is indicates the "blob".

Wires not Jointed: In complex circuit diagrams, some wires may not connect with others, in this case, bridging is commonly utilized.

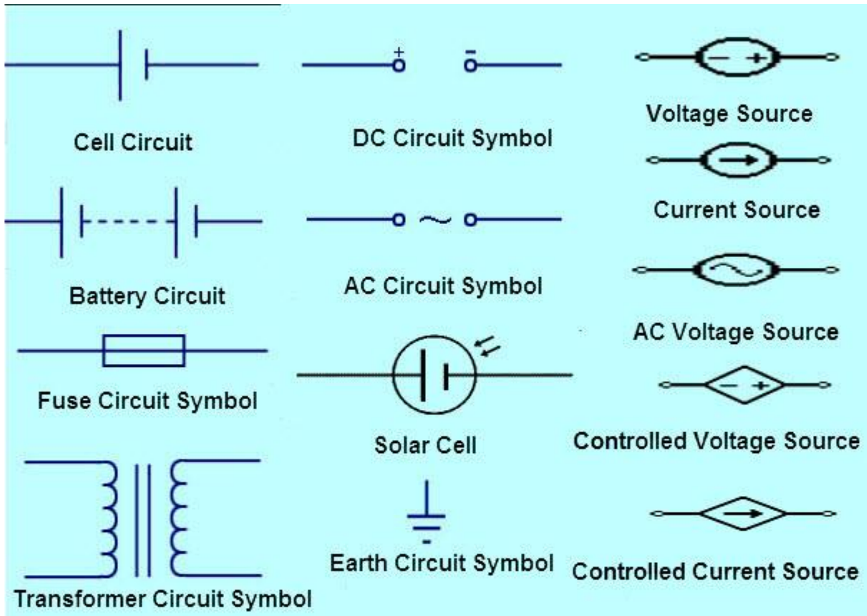


Electronic circuit diagram components (symbols)

Symbol	Component	Symbol	Component	Symbol	Component
	Joined conductors		Crossing conductors -no connection		Single-Pole-Single-Throw switch (SPST) (normally open)
	Fixed resistor		Diode		Single-Pole-Single-Throw switch (SPST) (normally closed)
	Potentiometer		Light-Emitting Diode (LED)		Single-Pole-Double-Throw switch (SPDT)
	Preset potentiometer		NPN transistor		Double-Pole-Double-Throw switch (DPDT)
	Thermistor		Amplifier		Push-To-Make switch (PTM)
	Light-dependent resistor		Fuse		Push-To-Break switch (PTB)
	Polarised capacitor	2 pin	Resonator		Dry-reed switch
	Non polarised capacitor	3 pin			Opto switch
usually drawn with added detail e.g +9V 0V	Power supply		Primary or secondary cell	RL	Relay (with double-throw contacts - contact symbol varies with type used)
			Battery (of cells)		

1. **Power Supplies**

A Power supply/ power supply unit is an electronic device, that supplies electric energy to an electrical load. The flow of an electric current will be measured in terms of Watts. The function of the power supply is, it converts energy from one form to another according to our requirement. The various types of power supplies are



Power Supplies

Cell Circuit: Supplies electrical energy from larger terminal (+) positive sign.

Battery Circuit: A Battery is two or more cells, the function of battery circuit is the same as cell circuit.

DC Circuit Symbol: Direct current (DC) always flows in one direction.

AC Circuit Symbol: AC (Alternating Current) flows periodically reverses direction.

Fuse Circuit: The fuse will flow sufficient current and it is used to provide overcurrent protection.

3. Transformer:
It is used to produce AC power supply, energy is transferred in between primary and secondary coils in the form of mutual inductance.

Solar cell: It will convert light energy into electrical energy.

Earth: It supplies the 0V to the circuit that will connect to the earth.

Voltage Source: It will supply voltage to the circuit elements.

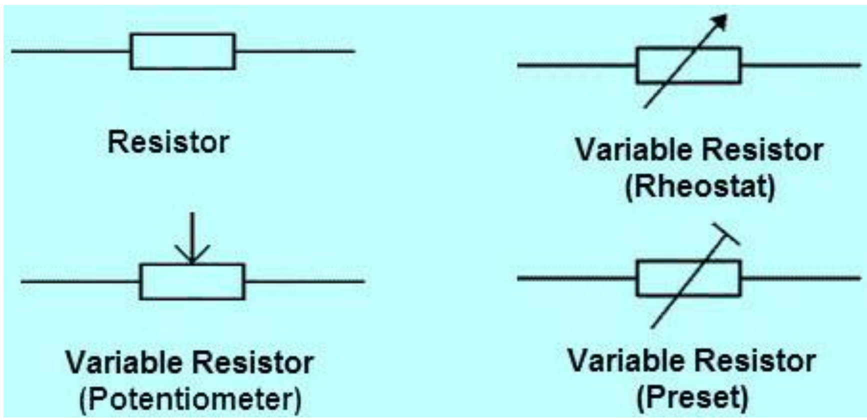
Current Source: It will supply current to the circuit elements.

AC Voltage Source: It will supply the AC voltage to the circuit elements.
Controlled Voltage Source: It generates controlled voltage to the circuit elements.

Controlled Current Source: It generates controlled current to the circuit elements.

4. Resistors

A Resistor is a passive element that opposes current flow in a circuit. It is a two-terminal element, dissipates its energy in the form of heat. The resistor will damage due to the overflow of electric current through it. Resistance is measured in units of ohms and resistance, resistor color code calculator is used to calculate the value of the resistor according to its colors.



Resistors

Resistor: It is a two terminal component that restricts the flow of current.

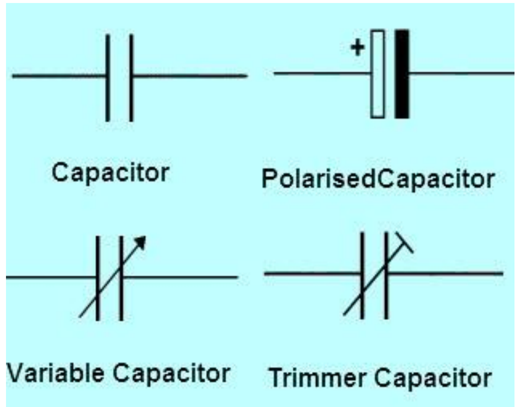
Rheostat: It is a two terminal component that is used to adjust the flow of current.

Potentiometer: Potentiometer is a three-terminal component that will adjust the voltage flow in the circuit.

Preset: Preset is a low-cost adjustable resistor that operates by using small tools like Screwdrivers.

5. Capacitors

A Capacitor generally referred to as a condenser, it is a two-terminal passive component that will capable of storing energy in the form of electricity. These are the rechargeable batteries mainly used in power supply. In the capacitors, electrical plates differ by a dielectric medium and these are acts like a filter that allows only AC signals and blocks DC Signals. The capacitors are classified into various types that are discussed below



Capacitors

Capacitor: A capacitor is used to store the energy in electrical form.

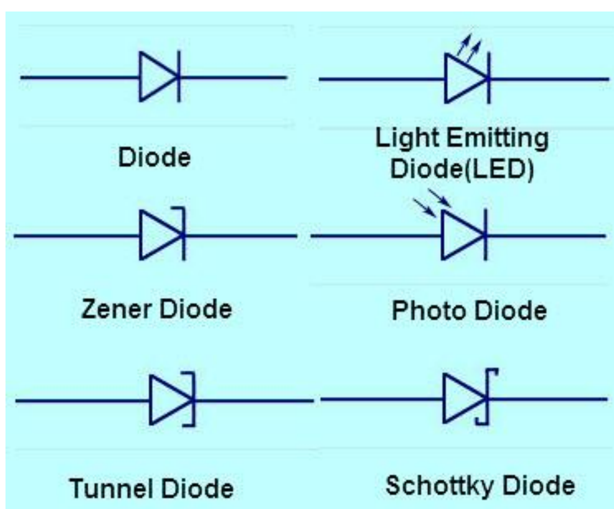
Polarized Capacitor: Stores electrical energy these must be a one way round.

Variable Capacitor: These capacitors are used to control the capacitance by adjusting the Knob.

Trimmer Capacitor: These capacitors are used to control the capacitance by using Screwdriver or similar tools.

6. Diodes

A Diode is an electronic component with two terminals that are anode and cathode. It allows electron current flow from cathode to anode but it blocks another direction. The diode will have low resistance in one direction and high resistance in another direction. The diodes are classified into various types that are discussed below



Diodes

Diode: A diode allows the current flow in one direction.

Light Emitting Diode: It will emit the light when the electric current flows through it.

Zener Diode: It will allow a constant electric current after the breakdown voltage.

Photo Diode: Photodiode will convert light into respective current or voltage.

Tunnel Diode: Tunnel diode is used for very high-speed operations.

Schottky Diode: Schottky diode is for forwarding low voltage drop.

7. Transistors
The transistors are invented in 1947 at Bell Laboratories to replace vacuum tubes, that it will control the flow of current and voltage in the circuits. It is a three terminal device and amplifies the current, transistors plays an important role in all modern electronics.

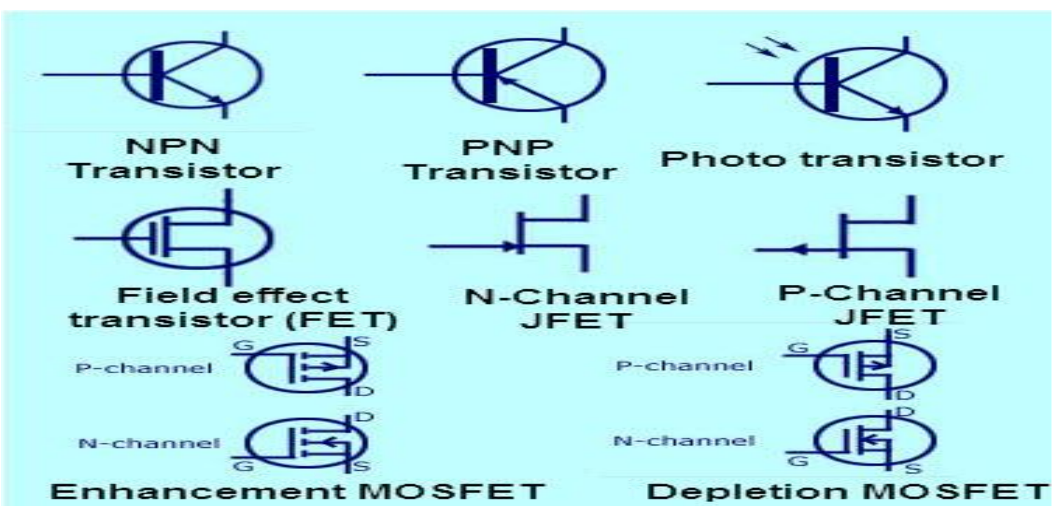
Transistors
NPN transistor: A P-type doped semiconductor material is placed in between two N-type semiconductor materials. The terminals are the emitter, base, and collector.
PNP transistor: A N-type doped semiconductor material is placed in between two P-type semiconductor materials. The terminals are an emitter, base, and collector.
Phototransistor: It is similar to bipolar transistors, but it converts light to current.
Field Effect Transistor: FET controls the conductivity with the help of an electric field.

N-channel JFET: The Junction Field Effect Transistors are simple of FET for switching.

P-channel JFET: P-type semiconductor is placed in between N-type junctions.

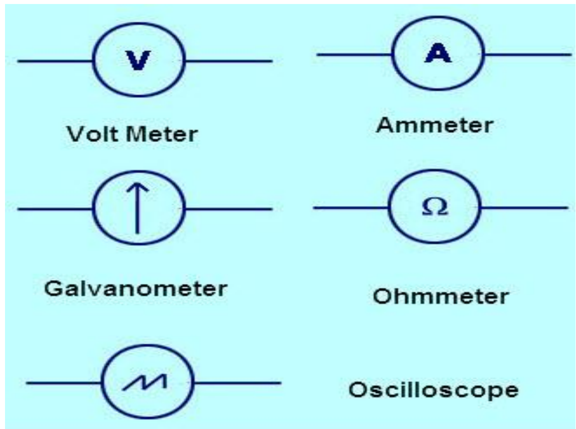
Enhancement MOSFET: Similar to DMOSFET but an absence of conducting channel.

Depletion MOSFET: The current flows from source to drain terminal.



8. Meters

A Meter is an instrument used for measuring voltage and current flow in electrical and electronic components. These are used to measure the resistance and capacitance of the electronic components.



Meters

Voltmeter: It is used to measure voltage.

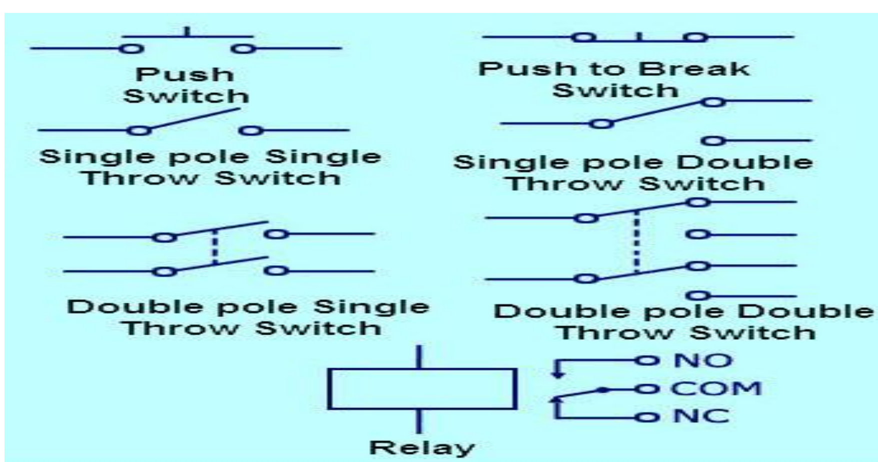
Ammeter: It is used to measure current.

Galvanometer: It is used to measure small currents.

Ohmmeter: It is used to measure the electrical resistance of a particular resistor.

Oscilloscope: It is used to measure voltage with respect to time for signals.

Switches: A Switch is an electrical/electronic component that will connect electrical circuits when the switch is closed, otherwise, it will break an electrical circuit when the switch is open.



Switches

Push switch: It will pass the current flow when the switch is pressed. **Push to break switch:** It will block the current flow when the switch is pressed.

Single pole single throw switch (SPST): Simply, it is an ON/OFF switch allows flow only when the switch is in ON.

Single pole double throw switch (SPDT): In this type of switch current flows in two directions.

Double pole single throw switch (DPST): It is a dual SPST switch, mainly used for electrical lines.

Double pole double throw switch (DPDT): It is a dual SPDT switch.

Relay: A relay is a simple electromechanical switch made up of an electromagnet & a set of contacts. These are found hidden in all sorts of devices.

9. Audio Devices

These devices convert an electric signal into sound signals and vice versa, which will be audible to humans. These are input/output electronic components in the circuit diagram.

Microphone: converts sound or noise signal to an electrical signal.

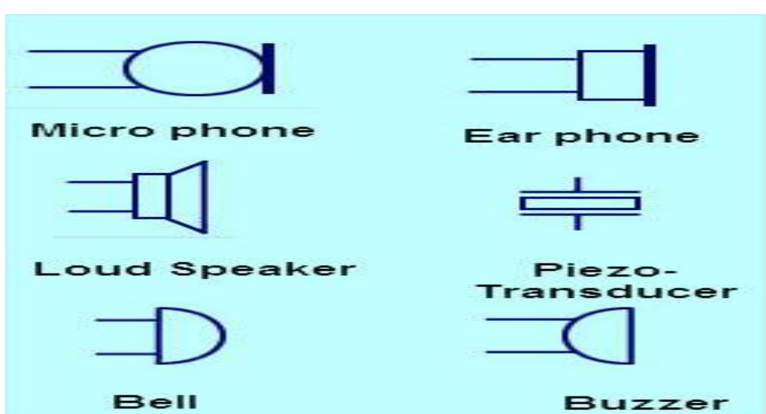
Earphone: converts an electrical signal to a sound signal.

Loudspeaker: converts the electrical signal to sound signal but it will amplify version.

Piezo-transducer: converts flow of electrical energy to sound signal.

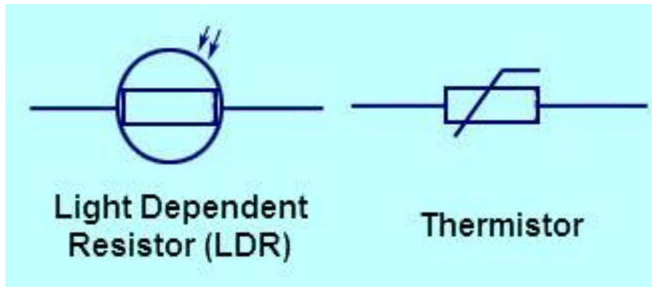
Bell- converts the electrical signal to sound signal.

Buzzer: converts an electrical signal to sound signal.



Audio Devices

Sensors
Sensors will sense or detect moving objects and devices, it will convert those signals into electrical or optical. For example, a temperature sensor is used sense temperature present in the room. The various types of sensors are



Sensors

Light-dependent resistor: These sensors will sense light.

Thermistor: These sensors will sense heat or temperature.

CHAPTER FOUR
INTEGRATED CIRCUIT

4.1 Introduction

An **integrated circuit** or **monolithic integrated circuit** (also referred to as an **IC**, a **chip**, or a **microchip**) is a set of electronic circuits on one small flat piece (or "chip") of semiconductor material that is normally silicon. The integration of large numbers of tiny transistors into a small chip result in circuits that are orders of magnitude smaller, faster, and less expensive than those constructed of discrete electronic components. The IC's mass production capability, reliability, and building-block approach to circuit design has ensured the rapid adoption of standardized ICs in place of designs using discrete transistors. ICs are now used in virtually all electronic equipment and have revolutionized the world of electronics. Computers, mobile phones, and other digital home appliances are now inextricable parts of the structure of modern societies, made possible by the small size and low cost of ICs.

Integrated circuits were made practical by mid-20th-century technology advancements in semiconductor device fabrication. Since their origins in the 1960s, the size, speed, and capacity of chips have progressed enormously, driven by technical advances that fit more and more transistors on chips of the same size – a modern chip may have many billions of transistors in an area the size of a human fingernail. These advances, roughly following Moore's law, make computer chips of today possess millions of times the capacity and thousands of times the speed of the computer chips of the early 1970s.

ICs have two main advantages over discrete circuits: cost and performance. Cost is low because the chips, with all their components, are printed as a unit by photolithography rather than being constructed one transistor at a time. Furthermore, packaged ICs use much less material than discrete circuits. Performance is high because the IC's components switch quickly and consume comparatively little power because of their small size and close proximity. The main disadvantage of ICs is the high cost to design them and fabricate the required photomasks. This high initial cost means ICs are only practical when high production volumes are anticipated.

An integrated circuit is defined as a circuit in which all or some of the circuit elements are inseparably associated and electrically interconnected so that it is considered to be indivisible for the purposes of construction and commerce. Circuits meeting this definition can be constructed using many different technologies, including thin-film transistors, thick-film technologies, or hybrid integrated circuits. However, in general usage *integrated circuit* has come to refer to the single-piece circuit construction originally known as a *monolithic integrated circuit*.

4.2 Invention

Early developments of the integrated circuit go back to 1949, when German engineer Werner Jacobi filed a patent for an integrated-circuit-like semiconductor amplifying device showing five transistors on a common substrate in a 3-stage amplifier arrangement. Jacobi disclosed small and cheap hearing aids as typical industrial applications of his patent. An immediate commercial use of his patent has not been reported. The idea of the integrated circuit was conceived by Geoffrey Dummer (1909–2002), a radar scientist working for the Royal Radar Establishment of the British Ministry of Defence. Dummer presented the idea to the public at the Symposium on Progress in Quality Electronic Components in Washington, D.C. on 7 May 1952. He gave many symposia publicly to propagate his ideas and unsuccessfully attempted to build such a circuit in 1956.

A precursor idea to the IC was to create small ceramic squares (wafers), each containing a single miniaturized component. Components could then be integrated and wired into a bidimensional or tridimensional compact grid. This idea, which seemed very promising in 1957, was proposed to the US Army by Jack Kilby and led to the short-lived Micromodule Program (similar to 1951's Project Tinkertoy). However, as the project was gaining momentum, Kilby came up with a new, revolutionary design: the IC.

Jack Kilby's Original Integrated Circuit

Newly employed by Texas Instruments, Kilby recorded his initial ideas concerning the integrated circuit in July 1958, successfully demonstrating the first working integrated example on 12 September 1958.[11] In his patent application of 6 February 1959, Kilby described his new device as "a body of semiconductor material … wherein all the components of the electronic circuit are completely integrated."[13] The first customer for the new invention was the US Air Force.

Kilby won the 2000 Nobel Prize in Physics for his part in the invention of the integrated circuit.[15] His work was named an IEEE Milestone in 2009. Half a year after Kilby, Robert Noyce at Fairchild Semiconductor developed a new variety of integrated circuit, more practical than Kilby's implementation. Noyce's design was made of silicon, whereas Kilby's chip was made of germanium. Noyce credited Kurt Lehovec of Sprague Electric for the principle of p–n junction isolation, a key concept behind the IC. This isolation allows each transistor to operate independently despite being part of the same piece of silicon. Fairchild Semiconductor was also home of the first silicon-gate IC technology with self-aligned gates, the basis of all modern CMOS integrated circuits. The technology was developed by Italian physicist Federico Faggin in 1968. In 1970, he joined Intel in order to develop the first single-chip central processing unit (CPU) microprocessor, the Intel 4004, for which he received the National Medal of Technology and Innovation in 2010. The 4004 was designed by Busicom's Masatoshi Shima and Intel's Ted Hoff in 1969, but it was Faggin's improved design in 1970 that made it a reality.

Advances

Advances in IC technology, primarily smaller features and larger chips, have allowed the number of transistors in an integrated circuit to double every two years, a trend known as Moore's law. This increased capacity has been used to decrease cost and increase functionality. In general, as the feature size shrinks, almost every aspect of an IC's operation improves. The cost per transistor and the switching power consumption per transistor goes down, while the memory capacity and speed go up, through the relationships defined by Dennard scaling.[19] Because speed, capacity, and power consumption gains are apparent to the end user, there is fierce competition among the manufacturers to use finer geometries. Over the years, transistor sizes have decreased from 10s of microns in the early 1970s to 10 nanometers in 2017 [20] with a corresponding million-fold increase in transistors per unit area. As of 2016, typical chip areas range from a few square millimeters to around 600 mm2, with up to 25 million transistors per mm2.

The expected shrinking of feature sizes and the needed progress in related areas was forecast for many years by the International Technology Roadmap for Semiconductors (ITRS). The final ITRS was issued in 2016, and it is being replaced by the International Roadmap for Devices and Systems. Initially, ICs were strictly electronic devices. The success of ICs has led to the integration of other technologies, in an attempt to obtain the same advantages of small size and low cost. These technologies include mechanical devices, optics, and sensors. Integrated circuits are also being developed for sensor applications in medical implants or other bioelectronic devices. Special sealing techniques have to be applied in such biogenic environments to avoid corrosion or biodegradation of the exposed semiconductor materials. As of 2018, the vast majority of all transistors are fabricated in a single layer on one side of a chip of silicon in a flat 2-dimensional planar process. As it becomes more difficult to manufacture ever smaller transistors, companies are using Multi-chip modules, Three-dimensional integrated circuits, 3D NAND, Package on package, and Through-silicon vias to increase performance and reducing size, without having to reduce the size of the transistors.

4.3 Design

The cost of designing and developing a complex integrated circuit is quite high, normally in the multiple tens of millions of dollars.[34] Therefore, it only makes economic sense to produce integrated circuit products with high production volume, so the non-recurring engineering (NRE) costs are spread across typically millions of production units. Modern semiconductor chips have billions of components, and are too complex to be designed by hand. Software tools to help the designer are essential. Electronic Design Automation (**EDA**), also referred to as Electronic Computer-Aided Design (**ECAD**),[35] is a category of software tools for designing electronic systems, including integrated circuits. The tools work together in a design flow that engineers use to design and analyze entire semiconductor chips.

4.4 Types

Integrated circuits can be classified into analog, digital and mixed signal, consisting of both analog and digital signaling on the same IC. Digital integrated circuits can contain anywhere from one to billions of logic gates, flip-flops, multiplexers, and other circuits in a few square millimeters. The small size of these circuits allows high speed, low power dissipation, and reduced manufacturing cost compared with board-level integration. These digital ICs, typically microprocessors, DSPs, and microcontrollers, work using boolean algebra to process "one" and "zero" signals.

The die from an Intel 8742, an 8-bit microcontroller that includes a CPU running at 12 MHz, 128 bytes of RAM, 2048 bytes of EPROM, and I/O in the same chip. Among the most advanced integrated circuits are the microprocessors or **"cores**", which control everything from personal computers and cellular phones to digital microwave ovens. Digital memory chips and application-specific integrated circuits (ASICs) are examples of other families of integrated circuits that are important to the modern information society.

In the 1980s, programmable logic devices were developed. These devices contain circuits whose logical function and connectivity can be programmed by the user, rather than being fixed by the integrated circuit manufacturer. This allows a single chip to be programmed to implement different LSI-type functions such as logic gates, adders and registers. Programmability comes in at least four forms - devices that can be programmed only once, devices that can be erased and then re-programmed using UV light, devices that can be (re)programmed using flash memory, and field-programmable gate arrays (FPGAs) which can be programmed at any time, including during operation. Current FPGAs can (as of 2016) implement the equivalent of millions of gates and operate at frequencies up to 1 GHz.

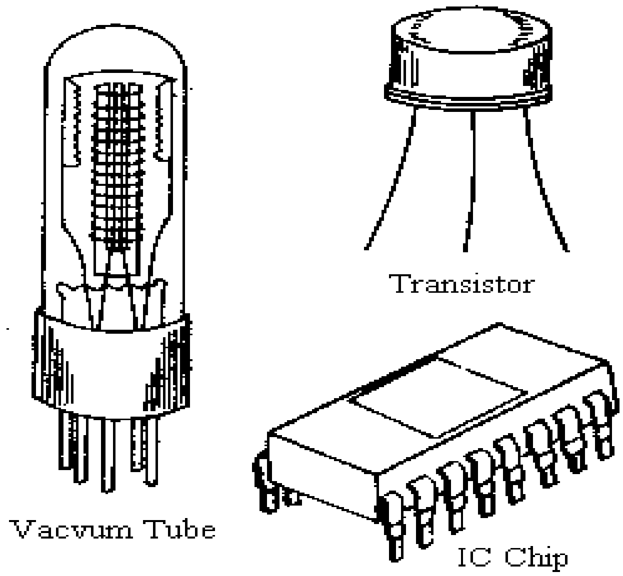
Analog ICs, such as sensors, power management circuits, and operational amplifiers (op-amps), work by processing continuous signals. They perform analog functions such as amplification, active filtering, demodulation, and mixing. Analog ICs ease the burden on circuit designers by having expertly designed analog circuits available instead of designing and/or constructing a difficult analog circuit from scratch.
ICs can also combine analog and digital circuits on a single chip to create functions such as analog-to-digital converters and digital-to-analog converters. Such mixed-signal circuits offer smaller size and lower cost, but must carefully account for signal interference. Prior to the late 1990s, radios could not be

fabricated in the same low-cost CMOS processes as microprocessors. But since 1998, a large number of radio chips have been developed using CMOS processes. Examples include Intel's DECT cordless phone, or 802.11 (Wi-Fi) chips created by Atheros and other companies.]
Modern electronic component distributors often further sub-categorize the huge variety of integrated circuits now available:

- Digital ICs are further sub-categorized as logic ICs, memory chips, interface ICs (level shifters, serializer/deserializer, etc.), Power Management ICs, and programmable devices.
- Analog ICs are further sub-categorized as linear ICs and radio frequency (RF) ICs.
- Mixed-signal integrated circuits are further sub-categorized as data acquisition ICs (including A/D converters, D/A converter, digital potentiometers) and clock/timing ICs.

4.5 Generations
In the early days of simple integrated circuits, the technology's large scale limited each chip to only a few transistors, and the low degree of integration meant the design process was relatively simple. Manufacturing yields were also quite low by today's standards. As the technology progressed, millions, then billions of transistors could be placed on one chip, and good designs required thorough planning, giving rise to the field of electronic design automation, or EDA.

Acronym	***Name***	***Year***	***Transistor count***	***Logic gates number***
SSI	*small-scale integration*	*1964*	*1 to 10*	*1 to 12*
MSI	*medium-scale integration*	*1968*	*10 to 500*	*13 to 99*
LSI	*large-scale integration*	*1971*	*500 to 20 000*	*100 to 9999*
VLSI	*very large-scale integration*	*1980*	*20 000 to 1 000 000*	*10 000 to 99 999*
ULSI	*ultra-large-scale integration*	*1984*	*1 000 000 and more*	*100 000 and more*



SSI, MSI and LSI

The first integrated circuits contained only a few transistors. Early digital circuits containing tens of transistors provided a few logic gates, and early linear ICs such as the Plessey SL201 or the Philips TAA320 had as few as two transistors. The number of transistors in an integrated circuit has increased dramatically since then. The term "large scale integration" (LSI) was first used by IBM scientist Rolf Landauer when describing the theoretical concept;[59] that term gave rise to the terms "small-scale integration" (SSI), "medium-scale integration" (MSI), "very-large-scale integration" (VLSI), and "ultra-large-scale integration" (ULSI). The early integrated circuits were SSI. SSI circuits were crucial to early aerospace projects, and aerospace projects helped inspire development of the technology. Both the Minuteman missile and Apollo program needed lightweight digital computers for their inertial guidance systems. Although the Apollo guidance computer led and motivated integrated-circuit technology,[60] it was the Minuteman missile that forced it into mass-production. The Minuteman missile program and various other United States Navy programs accounted for the total $4 million integrated circuit market in 1962, and by 1968, U.S. Government spending on space and defense still accounted for 37% of the $312 million total production.

The demand by the U.S. Government supported the nascent integrated circuit market until costs fell enough to allow IC firms to penetrate the industrial market and eventually the consumer market. The average price per integrated circuit dropped from $50.00 in 1962 to $2.33 in 1968.[61] Integrated circuits began to appear in consumer products by the turn of the 1970s decade. A typical application was FM inter-carrier sound processing in television receivers.

The first MOS chips were small-scale integration chips for NASA satellites. The next step in the development of integrated circuits, taken in the late 1960s, introduced devices which contained hundreds of transistors on each chip, called "medium-scale integration" (MSI). In 1964, Frank Wanlass demonstrated a single-chip 16-bit shift register he designed, with a then-incredible 120 transistors on a single chip. MSI devices were attractive economically because while they cost a little more to produce than SSI devices, they allowed more complex systems to be produced using smaller circuit boards, less assembly work because of fewer separate components, and a number of other advantages. Further development, driven by the same economic factors, led to "large-scale integration" (LSI) in the mid-1970s, with tens of thousands of transistors per chip.

The masks used to process and manufacture SSI, MSI and early LSI and VLSI devices (such as the microprocessors of the early 1970s) were mostly created by hand, often using Rubylith-tape or similar.[64] For large or complex ICs (such as memories or processors), this was often done by specially hired professionals in charge of circuit layout, placed under the supervision of a team of engineers, who would also, along with the circuit designers, inspect and verify the correctness and completeness of each mask. Integrated circuits such as 1K-bit RAMs, calculator chips, and the first microprocessors, that began to be manufactured in moderate quantities in the early 1970s, had under 4,000 transistors. True LSI circuits, approaching 10,000 transistors, began to be produced around 1974, for computer main memories and second-generation microprocessors. Some SSI and MSI chips, like discrete transistors, are still mass-produced, both to maintain old equipment and build new devices that require only a few gates. The 7400 series of TTL chips, for example, has become a de facto standard and remains in production.

VLSI

Upper interconnect layers on an Intel 80486DX2 microprocessor die. The final step in the development process, starting in the 1980s and continuing through the present, was "very-large-scale integration" (VLSI). The development started with hundreds of thousands of transistors in the early 1980s. As of 2016, transistor counts continue to grow beyond ten billion transistors per chip.

Multiple developments were required to achieve this increased density. Manufacturers moved to smaller design rules and cleaner fabrication facilities so that they could make chips with more transistors and maintain adequate yield. The path of process improvements was summarized by the International Technology Roadmap for Semiconductors (ITRS), which has since been succeeded by the International Roadmap for Devices and Systems (IRDS). Electronic design tools improved enough to make it practical to finish these designs in a reasonable time. The more energy-efficient CMOS replaced NMOS and PMOS, avoiding a prohibitive increase in power consumption. Modern VLSI devices contain so many transistors, layers, interconnections, and other features that it is no longer feasible to check the masks or do the original design by hand. Instead, engineers use EDA tools to perform most functional verification work.[65]

In 1986 the first one-megabit random-access memory (RAM) chips were introduced, containing more than one million transistors. Microprocessor chips passed the million-transistor mark in 1989 and the billion-transistor mark in 2005.[66] The trend continues largely unabated, with chips introduced in 2007 containing tens of billions of memory transistors.

ULSI, WSI, SoC and 3D-IC

To reflect further growth of the complexity, the term ULSI that stands for "ultra-large-scale integration" was proposed for chips of more than 1 million transistors. Wafer-scale integration (WSI) is a means of building very large integrated circuits that uses an entire silicon wafer to produce a single "super-chip". Through a combination of large size and reduced packaging, WSI could lead to dramatically reduced costs for some systems, notably massively parallel supercomputers. The name is taken from the term Very-Large-Scale Integration, the current state of the art when WSI was being developed.

A system-on-a-chip (SoC or SOC) is an integrated circuit in which all the components needed for a computer or other system are included on a single chip. The design of such a device can be complex and costly, and building disparate components on a single piece of silicon may compromise the efficiency of some elements.[needs update?] However, these drawbacks are offset by lower manufacturing and assembly costs and by a greatly reduced power budget: because signals among the components are kept on-die, much less power is required (see Packaging).[70] Further, signal sources and destinations are physically closer on die, reducing the length of wiring and therefore latency, transmission power costs and waste heat from communication between modules on the same chip. This has led to an exploration of so-called Network-on-Chip (NoC) devices, which apply system-on-chip design methodologies to digital communication networks as opposed to traditional bus architectures.

CHAPTER FIVE
STORAGE MEDIA

5.1 INTRODUCTION

In the olden days, if a computer user holds a huge amount of data, it would be difficult for him to back up the whole data, as the only medium then was the floppy disk which consists a little beyond a megabyte of data. But with the advent of technology, users can store according to the capacities of their data. In this chapter we shall be exploring the various types of storage media available in our modern-day computer.

5.2 STORAGE MEDIA

There are basically two methods of data storage in modern day computer system; these are:

(i) Primary Storage (or Main Memory)

(ii) Secondary storage.

The term **memory** identifies data storage that comes in the form of chips while **storage** is used for memory existing on tapes or disks. Also, we usually use memory for physical memory such as RAM (Random Access Memory). In this chapter we shall discuss in details the various types of storage media applicable to computer system especially secondary storage devices such as tape, hard disk, optical disk, floppy disk and other external hard drives storage devices.

5.3 PRIMARY STORAGE (OR MAIN MEMORY)

The primary storage or main memory which can also be referred to as core storage performs a significant role in the operation of the processor as it represents the internal storage areas in a computer system. It is where information and programs are stored for immediate processing, and the data in this memory is almost instantly accessible to processor. For this reason the main memory is also called **Immediate Access Storage (IAS).**

The main storage of computer is divided into two namely:

1. Random Access Memory (RAM)
2. Read Only Memory (ROM)

1. **Random Access Memory** (RAM)

As the name entails, this memory can be accessed randomly. It forms the major proportion of the memory and it is used to hold data and programs that are currently in use. The contents of the RAM become lost once the power is turned off so the RAM is said to be volatile. This is referred to as **volatility of RAM**.

2. Read Only Memory (ROM)

This forms a small proportion of the main storage, which is used by computers manufacturers to hold instructions or program used in performing some operations like starting up the computer and general system check. Programs stored in the ROM are not volatile and cannot be written to.

There are three variations of ROM namely:

(i) **PROM (Programmable Read Only Memory**): This version of memory chip can be programmed by the user. And once this is done the data remains permanent. Mistakes in the unit cannot be corrected.

(ii) **EPROM (Erasable Programmable Read Only Memory*):*** In this version, chips may be erased and reprogrammed. In order to erase the program in the EPROM, it has to be removed from the computer.

(iii) **EEPROM (Electrically Erasable Programmable Read Only Memory**)*:* The information in the ROM can be changed using programs without necessarily removing the chip from the system. The **EAROM** (Electrically Alterable Read Only Memory) is basically the same as EEPROM.

The **cache** is another part of the memory that has a small capacity but extremely fast that saves a second copy of the pieces of data most recently read from or written to main memory.

5.4 SECONDARY STORAGE

This is an external storage device usually used to store large volume of information outside the computer in a non-volatile state. It is also referred to as **auxiliary storage device** or **backing storage**; and has a higher storage capacity but a slower access time than main memory.

The most common types of auxiliary storage devices are:

(i) Magnetic Disks
(ii) Magnetic Tapes
(iii) Optical Disk
(iv) USB Flash Drive

5.4.1 Magnetic Disk

This is the commonest and reusable secondary storage medium. This disk has a magnetizable surface on which data is stored in concentric rings called **tracks**. You may probably have seen the gramophone record, which is circular in shape like a disk and coated with magnetic material. Magnetic disks used in computer are made based on the same principle and rotates with very high speed inside the computer drive. Data are stored on both surfaces of the disk. Magnetic disks are the most popular for direct access storage device. There are different kinds of magnetic disks; these are:

(1) Floppy Disks
(2) Hard Disks
(3) Zip Disk

1. Floppy Disks

A floppy disk is a removable storage device made from a material akin to that of radio cassette, but thicker to improve its strength. It is so called floppy because it flops if is waved (especially the 5 ¼ inches type). Floppy disks have less storage capacity and slower to access than hard disks, but less expensive and portable.

Types of Floppy Disks:

(i) 5 ¼ inches (or 5.25”) diskette: The common sizes are 360KB (Double Density) and 1.2MB (High Density)

(ii) 3½ inches or (3.5”) diskette: The common sizes are 720 KB (Double Density) and 1.44MB (High Density).

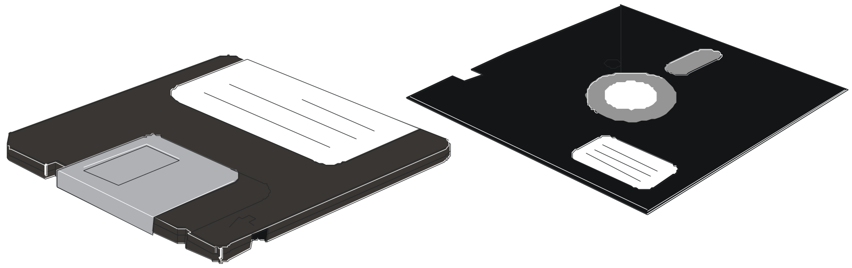


Figure 5.1 3½ and 5¼ Inches Diskettes

2. Hard Disk

This is a magnetic disk on which data or program can be stored in a computer system. The word hard is used to distinguish it from floppy disk. Hard disk has the capability to store more data and is faster than floppy disks in terms of access time.

The performance of hard disk can be enhanced by using a device package called RAID (Redundant Array of Inexpensive Disks). This device can pack up more than one hundred smaller disk drives with a controller chip and specialized software in a single large unit to deliver data over multiple paths simultaneously. Hard disk has the capacity to store many hundreds of megabytes or gigabytes and it is sometimes referred to as **Winchester disk.**

Figure 5.2 Hard Disk

3. Zip Drives

A zip drive is a 3.5" removable and high-capacity disk drive developed by the Iomega Corporation. It is thicker than the common floppy disk and comes in various memory capacity modes such as: 100MB, 250MB and 750Mb. Zip disk is derived from the technology that uses the concepts of hard disk design. Zip drive was introduced in 1994 by Iomega and became popularly used in 1995.

The original zip drive had a data transfer rate of 1 megabyte/s and the time taken was 28 milliseconds compared with 1.4 megabyte floppy of 500Kbit/s transfer rate and several hundred millisecond average seek time. However, there were plans to produce a lower cost 25 MB version that would work in the same way with 100 MB.

The zip's write protection is implemented on the software level instead of being enforced mechanically on the hardware. The disk indicates the write protection status, which the software driver then enforces to the operating system. This means that data must be loaded in a drive and accessed on a computer to turn write protection on or off.

Figure 5.3 Zip Disk

5.4.2 Magnetic Tapes

This is an expensive and old secondary storage medium used in storing large volumes of information sequentially. It is made of a magnetically coated strip of plastic on which data can be encoded. The magnetic tapes used for computers are similar to that of tapes or cassettes used to store music.

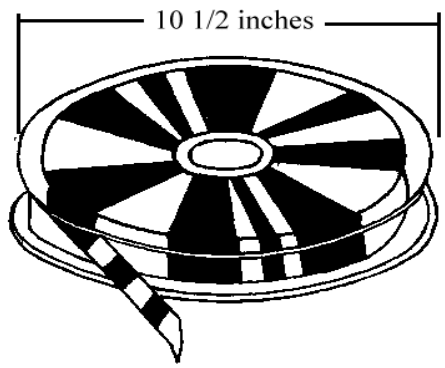


Figure 5.4 Magnetic Tape

A typical magnetic tape like the one in figure 4.4 is a 10-inch diameter reel of tape, 2400 feet long and is able to hold 800, 1600 or 6250 characters in each inch of its length. The maximum capacity of such tape is 180 million characters. Thus, magnetic tape allows data to be stored more compactly. Also, the cost of storing characters on magnetic tape is very less when compared with other storage devices.

5.4.3 Optical Disks

They are storage media that can store massive amount of data not only text, but also pictures, sound and full motion video in a highly compact form. Data are recorded on optical disks when a laser light burns microscopic pits on to the spinning disk, while data are read by having a low power laser beam from an optical head scan of the disk. The optical disks can store more data than the floppy disks. The main types of optical disks are:

1. CD-ROM (Compact Disk Read Only Memory)

The CD ROM is a kind of disk drive used for backing up data. Just like the audio CDs, CD-ROM come with data already encoded into them permanently; no new data can be written to it but can be read any number of times. CD-ROM is less vulnerable than floppy disks to magnetism, dirt or rough handling.

Figure 5.5 Compact Disk

2. WORM (Write Once Read Many)

This type of disk allows data to be written once to any of it, and once written the data cannot be erased but can be read many times. After this the WORM behaves just like a CD-ROM.

3. CD-RW (CD-ReWritable)

This is a new type of CD disk that allows users to write onto it in multiple sessions. The CD-ReWritable is very useful for applications requiring large volume of storage.

4. Magneto –Optical (MO) or Erasable Optical (EO) Disks

These are also the same as the re-writable disks but different in name variation and technical details, like the magnetic disk, MO can be read and written to.

5. Digital Versatile Disk (DVD)

Now becoming more popular is the Digital Versatile Disks (DVDs) also called **Digital Video Disk**. They are optical disks having the same size as the CD-ROM but of higher capacity. DVDs were initially used to store movies and multimedia applications that use large amounts of video and graphics. They are now replacing the CD-ROMs because it can store large amounts of digital text, graphics, and video data.

DVD was essentially used in videos for the purpose of increasing its clarity. And the name was initially the Digital Video Disk. But because the DVD found its application in the computers it is also referred to as the Digital Versatile Disk. The technology is similar to that used in the CD ROM. Both the CD ROM and the DVD are similar in nature and are optical disks. But the major distinction is that in terms of the storage capacity, the DVD has more storage capacity than that of the CD's. And the maximum capacity of the storage in the CD that has an extended memory is about 800 megabytes of data. But in the case of the DVD the same single DVD that has a physical size as equal to that of the CD that is currently available is 4.7 gigabytes. Even the newly available DVD's has the storage capacity of about 40 gigabytes. Some of the DVD's that are now available are dual sided. That is the information can be stored on both the sides of the disk

5.4.4 Universal Serial Bus Flash Drive

This is a relatively new technology storage device with high storage capacity ranging from 32MB to 2 GB when it newly came. It is becoming much popular because of its physical size and compactness. It is the smallest of all storage devices known in computer. The USB flash drives are also available in the form of the mp3 or mp4 player and come along with radio and FM players.

The USB flash drives generally use protocol for the USBs to interoperate along with the PC's and other devices that have the USB port. This device can easily be connected to the computer through the USB port as it is one of the plug and play devices.

Flash drives are very fragile and should be handled with care; because once the device falls it can easily sustain physical damage. As a matter of fact efforts and much research work are taking place in this area for the improvement of the technology.

Figure 5.6 Flash Drive

5.5 COMPUTER STORAGE CAPACITY

The storage capacities of a computer system are expressed in terms of bytes. A byte is a group of bits (1byte = 8 bits). And data is stored in computer in binary digits (0's and1's). The various units used to measure the storage capacity of a computer system and its storage devices are:

Term	Meaning
1. Bit	A bit is either 0 or 1
2. Byte (B)	String of eight bits
3. Kilobyte (KB)	1,000 bytes (actually 1,024 bytes)
4. Megabyte (MB)	Approximately 1,000,000 bytes (1024 Kilobytes)
5. Gigabyte	(1,024 Megabytes, or 1,048,576 Kilobytes)
6. Terabyte	(1,024 Gigabytes)
7. Petabyte	(1,024 Terabytes, or 1,048,576 Gigabytes)
8. Exabyte	(1,024 Petabytes)
9. Zettabyte	(1,024 Exabytes)
10. Yottabyte	(1,204 Zettabytes, or 1,208,925,819,614,629,174,706,176 bytes)

5. 6 BACKUP AND RECOVERY

In order to ensure that data is not lost irretrievably after a fault on the storage media such as the disk or tape, or if any of these media crashes, it is a common practice to backup database in a secured medium from time to time and stored off-site. In between these dumps records of every transaction that affects the database such as insertion, deletion and editing are kept. If a file database becomes faulty or failure occurs afterward, the saved document can be recreated from the retrieved dumped-file.

The lack of backup is potentially devastating to an organization in the event of loss or damage to data. The organization would lose information regarding its customers and their policies making it impossible to know if a customer has a policy or not. Data that are not frequently used on the computer system are moved from primary storage areas such as hard disk to off-line storage, such as CD-ROMs. This off-line storage process is referred to as **archive**. Archives maintain legally acceptable business history and free up primary storage space for current history, which requires fast and frequent access.

Reason for Backup

There are so many reasons that are responsible for data loss like human errors, viruses, application problems, operating system failure, and many more. Backup plays a very crucial role in business organization that spends a lot of time on the computer for their business transactions. According to opinion polls there are no appropriate steps to preserve data loss that is the greatest mistake. Although some people still follow the old paradigm of 'it can never happen to me'. However, this idea should change as data loss can be encountered at any time and by anyone. So, no matter what happens to your computer, you should always backup your data because the most important files that are used by the organization which cannot be retrieved may cause a severe problem, as a result backing up files and documents are very necessary.

REVIEW QUESTIONS ON CHAPTER FIVE

1. (a) Compare and contrast the 'main-storage' and the auxiliary storage of a computer information processing system.
   (b) Why are auxiliary storage devices necessary in the computer?

2. (a) Define a secondary storage device. Give another name for the secondary storage device.
   (b) Distinguish between primary and secondary storage devices.

3. (a) Briefly explain secondary storage and state its functions?
   (b) Explain the following types of secondary storage:
   (i) Magnetic disk (ii) Magnetic tape (iii) Optical disk
   (c) State two advantages that zip disk have over floppy disk.

4. (a) The use of flash drive is becoming more popular than the conventional floppy disks. As a computer student state two reasons why you will prefer flash drive to floppy disks.
   (b) Why is it important to always backup your jobs at the close of the day's events?