INTEGRATED CIRCUITS

**Introduction to ICs (Integrated Circuits)**

**Integrated circuit (IC)** is the most significant technological development of the 21st century . It has forever transformed the world of electronics. It has reduced the size of electronics from a refrigerator size to palm size electronics or even less.

Unlike vacuum tubes used in early electronics, ICs dissipates less heat and as consumes less energy compared to vacuum tubes. Its reliability is not to be compared with that of vacuum tubes, it is very reliable. ICs have changed the fate of electronics.

It has cut down the prices of electronics; it also changed the design of electronics from the use of discrete (separate) electronic components to hybrid solid-state devices which combine discrete components with ICs. ICs are so small that you cannot see the connections between them unless with the help of a microscope. Thus ICs are immensely in use in our electronics and almost all control devices.

An IC consists of interconnected transistors, capacitors, resistors, diodes etc. These components are interconnected with an external connecting terminals contained in a small package.

**Classification of ICs (Integrated Circuits)**

Below is the classification of **different types of ICs** basis on their chip size.

* **SSI**: Small scale integration. 3 – 30 gates per chip.
* **MSI**: Medium scale integration. 30 – 300 gates per chip.
* **LSI**: Large scale integration. 300 – 3,000 gates per chip.
* **VLSI**: Very large scale integration. More than 3,000 gates per chip.

**Types of ICs (Integrated Circuits)**

Based on the method or techniques used in manufacturing them,*types of ICs* can be divided into three classes:

1. Thin and thick film ICs
2. Monolithic ICs
3. Hybrid or multichip ICs

#### ****Monolithic ICs****

In monolithic ICs, the discrete components, the active and the passive and also the interconnections between then are formed on a silicon chip. The word monolithic is actually derived from two Greek words “mono” meaning one or single and Lithos meaning stone.

Monolithic ICs are the most common types ICs in use today. Its cost of production is cheap and is reliable. Commercially manufactured ICs are used as amplifiers, voltage regulators, in AM receivers, and in computer circuits. However, despite all these advantages and vast fields of application of monolithic ICs, it has limitations. The insulation between the components of monolithic ICs is poor and also have low power rating.

#### ****Advantages and Applications of ICs****

ICs have advantages over those that are made by interconnecting discrete components some of which are its small size. It is a thousand times smaller than the discrete circuits. It is an all in one (components and the interconnections are on a single silicon chip). It has little weight.

Its cost of production is also low. It is reliable because there is no soldered joints. ICs consumes little energy and can easily be replaced when the need arises. It can be operated at a very high temperature. different types of ICs are widely applied in our electrical devices such as high power amplifiers, voltage regulators, TV receivers and computers etc.

#### ****Limitation for different types of ICs****

Despite the advantages that ICs provide us with, it have limitations some of which are:

* Limited power rating
* It operates at low voltage
* High grade of PNP is not possible
* It produces noise during operation
* Its components such as resistors and capacitors are voltage dependent
* It is delicate i.e it cannot withstand rough handling etc.

The fabrication of integrated circuits consists basically of the following process steps:

* **Lithography:** The process for pattern definition by applying a thin uniform layer of viscous liquid (photo-resist) on the wafer surface. The photoresist is hardened by baking and then selectively removed by the projection of light through a reticle containing mask information.
* **Etching:** Selectively removing unwanted material from the surface of the wafer. The pattern of the photoresist is transferred to the wafer by means of etching agents.
* **Deposition:** Films of the various materials are applied on the wafer. For this purpose mostly two kinds of processes are used, physical vapour deposition (PVD) and chemical vapour deposition (CVD).
* **Chemical Mechanical Polishing:** A planarization technique by applying chemical slurry with etchant agents to the wafer surface.
* **Oxidation:** In the oxidation process oxygen (dry oxidation) or H2O (wet oxidation) molecules convert silicon layers on top of the wafer to silicon dioxide.
* **Ion Implantation:** Most widely used technique to introduce dopant impurities into the semiconductor. The ionized particles are accelerated through an electrical field and targeted at the semiconductor wafer.
* **Diffusion:** A diffusion step following ion implantation is used to anneal bombardment-induced lattice defects.

**Oxidation:**

* It is a process which converts silicon on the wafer into silicon dioxide.
* The chemical reaction of silicon and oxygen already starts at room temperature but stops after a very thin native oxide film.
* For an effective oxidation rate, the wafer must be settled to a furnace with oxygen or water vapour at elevated temperatures.
* Silicon dioxide layers are used as high-quality insulators or masks for ion implantation.
* The ability of silicon is to form high-quality silicon dioxide.

**Diffusion:**

* Diffusion is the movement of impurity atoms in a semiconductor material at high temperatures.
* The driving force of diffusion is the concentration gradient.
* There is a wide range of diffusivities for the various dopant species, which depend on how easy the respective dopant impurity can move through the material.
* Diffusion is applied to anneal the crystal defects after ion implantation or to introduce dopant atoms into silicon from a chemical vapour source.
* In the last case, the diffusion time and temperature determine the depth of dopant penetration.
* Diffusion is used to form the source, drain, and channel regions in an MOS transistor.
* But diffusion can also be an unwanted parasitic effect because it takes place during all high-temperature process steps.

**Ion Implantation:**

* Ion Implantation is the process of adding impurities to a silicon wafer.
* This is performed with an electric field which accelerates the ionized atoms or molecules so that these particles penetrate into the target material until they come to rest because of interactions with the silicon atoms.
* Ion implantation is able to control exactly the distribution and dose of the dopants in silicon because the penetration depth depends on the kinetic energy of the ions which is proportional to the electric field. The dopant dose can be controlled by varying the ion source.
* Unfortunately, after ion implantation, the crystal structure is damaged this implies worse electrical properties.
* Another problem is that the implanted dopants are electrically inactive because they are situated on interstitial sites.
* Therefore after ion implantation, a thermal process step is necessary which repairs the crystal damage and activates the dopants.

**Photolithography:**

* Lithography is used to transfer a pattern from a photomask to the surface of the wafer.
* Photolithography is the process of creating patterns on a smooth surface (Silicon wafer).
* This is accomplished by selectively exposing parts of the wafer while other parts are protected. The exposed sections are susceptible to doping, removal, or metallization. Specific patterns can be created to form regions of conductors, insulators, or doping. Putting these patterns onto a wafer is called photolithography.
* The pattern defined by the mask is either removed or remained after development, depending if the type of resist is positive or negative.

**Etching:**

* Etching is used to remove material selectively in order to create patterns.
* The pattern is defined by the etching mask, because the parts of the material, which should remain, are protected by the mask.
* The unmasked material can be removed either by wet (chemical) or dry (physical) etching.

# Storage devices

Secondary storage refers to any device that can store data, in addition to main memory. Secondary storage devices are non-volatile and are typically high capacity, portable or both.

Factors affecting the choice of a secondary storage device include:

* speed (how quickly data can be accessed)
* cost per storage unit (i.e. price per gigabyte or megabyte)
* durability (toughness)
* portability (how easy it is to move it from one computer to another)

## Cache

RAM is comparatively slow to access when compared to the speed at which registers work. So, to help speed up the processing time, cache memory is used to store instructions or data that are either frequently used, have recently been used or are about to be used. This means they don't have to be fetched directly from RAM.

**Features of cache:**

* Instructions can be read, or written to
* Faster access speeds than RAM
* Small in capacity compared to RAM
* Stores frequently accessed program instructions
* The larger the cache capacity, the faster the CPU performance

# ****Magnetic Tape Storage: Disadvantages****

## High Initial Investment – Costly Equipment Required

A magnetic tape storage system generally requires purchasing costly, special equipment. An upfront, heavy investment is required when setting up a new system.

## Slow to Find Data

When examining magnetic tape storage advantages and disadvantages, it is important to remember that magnetic tape is a sequential access device. It has no addressing mechanism. Data access is far slower than random access devices, such as hard disks. To find a specific block of data in magnetic tape, all data blocks before it need to be accessed first.

Consider listening to audio files from a cassette tape. (A cassette uses magnetic tape.) After listening to the 15th audio file, it is not possible to select and play, for instance, the third file. The tape has to manually rewind from the end of the 15th audio file, through the 14th, 13th,12th… until it reaches the start of the third file.

Furthermore, the loading of a magnetic tape cassette and the positioning of the tape head takes longer than corresponding processes in hard disk technology,

## Susceptible to Physical and Environmental Damage

Another disadvantage of magnetic tape as a storage medium is its susceptibility to physical and environmental damage. This may lead to data loss, data alteration, and/or permanent tape damage. In some cases, the entire tape role becomes useless after damage to some area/s of the tape.

Possible damaging factors include:

* High temperature
* High humidity
* Proximity to strong magnetic fields
* Mechanical shock and improper handling
* Dust

Evidently, these factors can be minimized with proper processes and control.

## Difficult to Recover Specific/Individual Files

As explained, magnetic tape storage is a sequential access device. It is difficult to find and/or recover a specific or individual file in a backup. Magnetic tape must be searched from one end to find the specified file for recovery.

Partial data restoration is difficult with this storage medium. Restoring a backup of the whole system is ideal with magnetic tape storage. Disk and cloud storage does not face this disadvantage.

OPERATIONAL AMPLIFIERS

Operational Amplifier, also called an Op-Amp, is an integrated circuit, which can be used to perform various linear, non-linear, and mathematical operations it can be operated both with AC and DC signals. it is a two-input single-output differential voltage amplifier which is characterized by high gain, high input impedance and low output impedance.

### Characteristics of Operational Amplifier

Some of the characteristics of an operational amplifier are as follows:

1. The value of the input impedance is high.
2. The value of the impedance at the output is low.
3. The frequency range of the amplifying signals is from zero Hz to 1 Mega Hz.
4. The value of the offset voltages and the currents are low.
5. The gain of the voltage is high.

DIODES

A diode may be the simplest of all semiconductor components, however, it performs many critical functions, including the control of the flow of an electrical current. Here’s a brief overview of the humble diode and what it is commonly used for.

A diode is a device that allows current to flow in one direction but not the other. This is achieved through a built-in electric field. Although the earliest diodes consisted of red-hot wires running through the middle of a metal cylinder which itself was located inside of a glass vacuum tube, modern diodes are [semiconductor](https://www.power-and-beyond.com/global-semiconductor-market-where-we-are-and-where-we-are-headed-a-905781/) diodes. As the name suggests, these are made from [semiconductor materials](https://www.power-and-beyond.com/is-gallium-nitride-gan-the-silicon-of-the-future-a-893761/), primarily doped silicon.

Conducting an electric current in one direction

diodes are vital to modern electronics.  
Some of their most common applications include [turning AC to DC](https://www.power-and-beyond.com/dc-or-ac--quo-vadis-electrical-connectors-a-885333/), isolating signals from a supply, and mixing signals. A diode has two ‘sides’ and each side is doped differently. One side is the “p-side”, this has a positive charge.  
The other side is the “n-side”, this has a negative charge. Both of these sides are layered together to form what is known as the “n-p junction” where they meet.

When a negative charge is applied to the [n-side and a positive to the p-side](https://www.power-and-beyond.com/understanding-the-difference-between-n-and-p-type-semiconductors-a-905805/), electrons ‘jump’ over this junction and current flows in one direction only. This is the diode’s core property; conventional current flows from the positive side to the negative side in that direction only. At the same time, electrons flow in a single direction only from the negative side to the positive side. This is because electrons are negatively charged and are attracted to the positive end of a battery.

### What are diodes used for?

Diodes are extremely useful components and are widely used in modern technology.

### Light-emitting diodes (LEDs)

Perhaps the most widely known modern application for diodes is in [LEDs](https://www.power-and-beyond.com/led-lights-and-how-to-power-them-a-953608/). These use a special kind of doping so that when an electron crosses the n-p junction, a photon is emitted, which creates light. This is because LEDs glow in the presence of a positive voltage. The type of doping can be varied so that any frequency (colour) of light can be emitted, from infrared to ultraviolet.

### Power conversion

Although LEDs may be the most widely known application to the average person, the most common application is by far the use of diodes for the rectification of [AC](https://www.power-and-beyond.com/what-is-alternating-current-a-907931/) power to DC power. Using diodes, different types of [rectifier](https://www.power-and-beyond.com/what-are-diodes-and-rectifiers-a-909411/) circuits can be created, the most basic of which are half wave, full wave centre tapped, and full bridge rectifiers. These are extremely important in electronics power supplies --- for example, a laptop’s charger --- where an [AC](https://www.power-and-beyond.com/back-to-basics-what-is-alternating-current-a-907931/) current, which comes from the mains power supply, must be converted to a DC current which can then be stored.

### Over-voltage protection

Sensitive electronic devices need to be protected from surges in voltage, and the diode is perfect for this. When used as voltage protection devices, diodes are nonconducting, however, they immediately short any high-voltage spike by sending it to the ground where it cannot harm sensitive integrated circuits. For this use, specialized diodes known as “transient voltage suppressors” are designed. These can handle large power spikes over short time periods which would normally damage sensitive components.

**ADVANTAGES OF MAGNETIC TAPE**

## Low Cost

Since magnetic tape does not require power when it is stored, it is a data storage medium that requires a very low running cost when considering the cost of electricity, the cost of air conditioners, and equipment costs at a power facility. In addition, since its unit price per capacity is lower than that of hard disks, the higher the number of cartridges is, the lower the unit price of the entire system will be.

## Secure and Safe

Data loss/leakage accidents due to blackouts, hacking, or theft, etc. occur all around the world. Magnetic tape, which stores data offline, is a data storage medium that has a lower risk of these accidents and is also optimal as a measure for BCP (business continuity planning).  
It is also suitable for remote storage to protect important data from disasters and other risks, because it allows offline storage and is portable.

## Optimal for Long-term Storage

While the life of a hard disk is said to be about several years, magnetic tape has been proven in an accelerated evaluation test to maintain its performance for over 30 years. In addition, since magnetic tape has lower failure and error rates and higher reliability than hard disks, it is appreciated to be the best data storage medium for long-term storage.

## High Capacity

Compared to hard disks whose recording density has almost reached the limit, the recording density of magnetic tape is still increasing, and next-generation technologies have been demonstrated. In addition, the recording area can be expanded by making the tape thinner and longer, so further increases in capacity can be expected.

## Memory Hierarchy

The memory in a computer can be divided into five hierarchies based on the speed as well as use. The processor can move from one level to another based on its requirements. The five hierarchies in the memory are registers, cache, main memory, magnetic discs, and magnetic tapes. The first three hierarchies are volatile memories which mean when there is no power, and then automatically they lose their stored data. Whereas the last two hierarchies are not volatile which means they store the data permanently.

A memory element is the set of [storage devices](https://www.elprocus.com/an-overview-of-bio-battery-working-principle-types-applications/) which stores the binary data in the type of bits. In general, [the storage of memory](https://www.elprocus.com/different-types-of-memory-modules-used-embedded-system/) can be classified into two categories such as volatile as well as non- volatile.

## Memory Hierarchy in Computer Architecture

The **memory hierarchy design** in a computer system mainly includes different storage devices. Most of the computers were inbuilt with extra storage to run more powerfully beyond the main memory capacity. **memory hierarchy diagram** is a hierarchical pyramid for computer memory.

The designing of the memory hierarchy is divided into two types such as primary (Internal) memory and secondary (External) memory.

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**Primary Memory**

The primary memory is also known as internal memory, and this is accessible by the processor straightly. This memory includes main, cache, as well as CPU registers.

**Secondary Memory**

The secondary memory is also known as external memory, and this is accessible by the processor through an input/output module. This memory includes an optical disk, magnetic disk, and magnetic tape.

### Characteristics of Memory Hierarchy

The memory hierarchy characteristics mainly include the following.

**Performance**

Previously, the designing of a computer system was done without memory hierarchy, and the speed gap among the main memory as well as the CPU registers enhances because of the huge disparity in access time, which will cause the lower performance of the system. So, the enhancement was mandatory. The enhancement of this was designed in the memory hierarchy model due to the system’s performance increase.

**Ability**

The ability of the memory hierarchy is the total amount of data the memory can store. Because whenever we shift from top to bottom inside the memory hierarchy, then the capacity will increase.

**Access Time**

The access time in the memory hierarchy is the interval of the time among the data availability as well as request to read or write. Because whenever we shift from top to bottom inside the memory hierarchy, then the access time will increase

**Cost per bit**

When we shift from bottom to top inside the memory hierarchy, then the cost for each bit will increase which means an internal Memory is expensive compared with external memory.

### Memory Hierarchy Design

The memory hierarchy in computers mainly includes the following.

**Registers**

Usually, the register is a static RAM or SRAM in the processor of the computer which is used for holding the data word which is typically 64 or 128 bits. The program counter [register is the most important](https://www.elprocus.com/know-about-types-of-registers-in-8051-microcontroller/" \t "_blank) as well as found in all the processors. Most of the processors use a status word register as well as an accumulator. A status word register is used for decision making, and the accumulator is used to store the data like mathematical operation. Usually, computers like **[complex instruction set computers](https://www.elprocus.com/difference-between-risc-and-cisc-architecture/" \t "_blank)** have so many registers for accepting main memory, and **[RISC- reduced instruction set](https://www.elprocus.com/what-is-risc-and-cisc-architecture-and-their-workings/" \t "_blank)** computers have more registers.

**Cache Memory**

Cache memory can also be found in the processor, however rarely it may be another **[IC (integrated circuit)](https://www.elprocus.com/how-integrated-circuits-work-physically/" \t "_blank)** which is separated into levels. The cache holds the chunk of data which are frequently used from main memory. When the processor has a single core then it will have two (or) more cache levels rarely. Present multi-core processors will be having three, 2-levels for each one core, and one level is shared.

**Main Memory**

The main memory in the computer is nothing but, the memory unit in the CPU that communicates directly. It is the main storage unit of the computer. This memory is fast as well as large memory used for storing the data throughout the operations of the computer. This memory is made up of RAM as well as ROM.

**Magnetic Disks**

The magnetic disks in the computer are circular plates fabricated of plastic otherwise metal by magnetized material. Frequently, two faces of the disk are utilized as well as many disks may be stacked on one spindle by read or write heads obtainable on every plane. All the disks in computer turn jointly at high speed. The tracks in the computer are nothing but bits which are stored within the magnetized plane in spots next to concentric circles. These are usually separated into sections which are named as sectors.

**Magnetic Tape**

This tape is a normal magnetic recording which is designed with a slender magnetizable covering on an extended, plastic film of the thin strip. This is mainly used to back up huge data. Whenever the computer requires to access a strip, first it will mount to access the data. Once the data is allowed, then it will be unmounted. The access time of memory will be slower within magnetic strip as well as it will take a few minutes for accessing a strip.

**Advantages of Memory Hierarchy**

The need for a memory hierarchy includes the following.

* Memory distributing is simple and economical
* Removes external destruction
* Data can be spread all over
* Swapping will be more proficient