Memory

A memory in a computer is just like a human brain. It is used to store data and instructions. Computer memory is the storage space in the computer, where data is to be processed and instructions required for processing are stored. Once data is stored in the memory of memory box, it holds there till it is replaced by other data in the computer system. The computer cannot function without the memory. So, memory is the key factor of the computer to run smoothly and nicely.

Memory Characteristics

The key characteristics of memory devices or memory system are as follows:

a) Location

b) Capacity

c) Unit of Transfer

d) Access Method

e) Performance

f) Physical type

g) Physical characteristics

h) Organization

I) Mutability

a) Location:

It deals with the location of the memory device in the computer system. There are three possible locations:

- CPU : This is often in the form of CPU registers and small amount of cache.
- Internal or main: This is the main memory like RAM or ROM. The CPU can directly access the main memory.
- External or secondary: It comprises of secondary storage devices like hard disks, magnetic tapes. The CPU doesn’t access these devices directly. It uses device controllers to access secondary storage devices.

b) Capacity:

The capacity of any memory device is expressed in terms of:

i) word size ii) Number of words

Word size: Words are expressed in bytes (8 bits). A word can however mean any number of bytes. Commonly used word sizes are 1 byte (8 bits), 2bytes (16 bits) and 4 bytes (32 bits).

Number of words: This specifies the number of words available in the particular memory device. For example, if a memory device is given as 4K x 16.This means the device has a word size of 16 bits and a total of 4096(4K) words in memory.

c) Unit of Transfer:

It is the maximum number of bits that can be read or written into the memory at a time. In case of main memory, it is mostly equal to word size. In case of external memory, unit of transfer is not limited to the word size; it is often larger and is referred to as blocks.

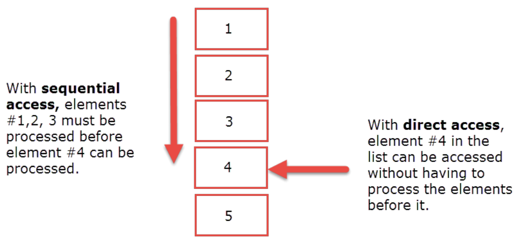
d) Access Methods:

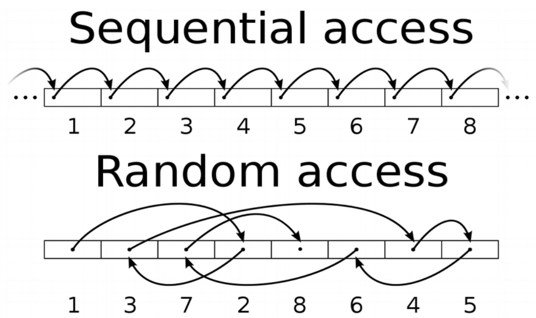
It is a fundamental characteristic of memory devices. It is the sequence or order in which memory can be accessed. There are three types of access methods:

Random Access: If storage locations in a particular memory device can be accessed in any order and access time is independent of the memory location being accessed. Such memory devices are said to have a random access mechanism. RAM (Random Access Memory) IC's use this access method.

Serial Access: If memory locations can be accessed only in a certain predetermined sequence, this access method is called serial access. Magnetic Tapes, CD-ROMs employ serial access methods.

Semi random Access: Memory devices such as Magnetic Hard disks use this access method. Here each track has a read/write head thus each track can be accessed randomly but access within each track is restricted to a serial access.





e) Performance: The performance of the memory system is determined using three parameters

Access Time: In random access memories, it is the time taken by memory to complete the read/write operation from the instant that an address is sent to the memory. For non-random access memories, it is the time taken to position the read write head at the desired location. Access time is widely used to measure performance of memory devices.

Memory cycle time: It is defined only for Random Access Memories and is the sum of the access time and the additional time required before the second access can commence.

Transfer rate: It is defined as the rate at which data can be transferred into or out of a memory unit.

f) Physical type: Memory devices can be either semiconductor memory (like RAM) or magnetic surface memory (like Hard disks).

g) Physical Characteristics:

Volatile/Non- Volatile: If a memory devices continues hold data even if power is

turned off. The memory device is non-volatile else it is volatile.

VOLATILE MEMORY	NONVOLATILE MEMORY
Computer memory that requires constant power to maintain the stored information	Computer memory that can store information even there is no constant power
Requires a consistent flow of power to retain data	Does not require a consistent flow of power to retain data
Affects the system performance	Affects the system storage
Holds data temporary	Holds data permenantly
Faster	Slower
Refers to primary storage type	Refers to secondary storage type
Ex: RAM	Ex: ROM, hard disk, floppy memory, Solid State Drive

h) Organization:

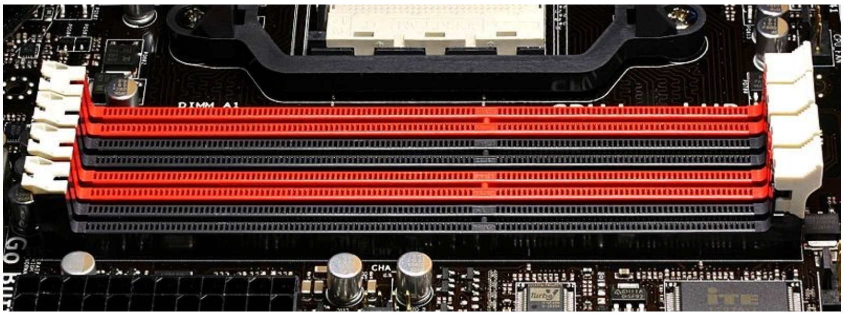
Erasable/Non-erasable: The memories in which data once programmed cannot be erased are called Non-erasable memories. Memory devices in which data in the memory can be erased is called erasable memory.

E.g. RAM(erasable), ROM(non-erasable).

i) Mutability

- Read/Write : Flash Drive, Hard Disk Drive, Solid State Drive, RAM, Cache, Registers
- Read-Only : ROM and its types

Memory Slot



A **memory slot**, **memory socket**, or **RAM slot** is what allows RAM (computer memory) to be inserted into the computer. Depending on the motherboard, there will usually be 2 to 4 memory slots (sometimes more on high-end motherboards) and are what determine the type of RAM used with the computer.

Terminology

Memory Cell – The smallest unit of information. Assumes one of two states we will call 0 and 1. Usually these are grouped in blocks called words. Each cell has a physical address.

Capacity – The number of bits or bytes the memory can hold. Semiconductor devices are typically specified in bits. Memory stores typically in terms of bytes.

Density – A measurement of how much data is stored per unit area or volume.

Access time (speed)– The time, measured from the start of a read cycle, required to read data from a given memory location. We break this down into two components: - Time to locate the required memory cell within the memory array - Time taken for the data to become available from the cell We can classify access time as read cycle and write cycle access times. We can also measure speed by specifying the cycle time – the unit of time which must elapse between two successive read or writes.

Random Access Memory (RAM) - A RAM constitutes the internal memory of the CPU for storing data, program and program result. It is read/write memory. It is called immediate access memory.

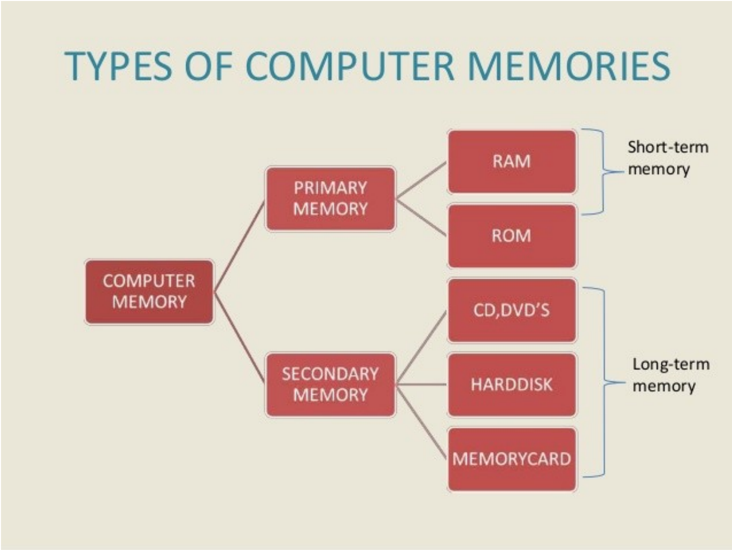
Serial Access Memory- The access time is dependent on the physical location of data within memory. Also known as sequential access memory. Examples : Tape drives, disk drives, CD drives.

Bandwidth- A measure of the speed at which data can be transferred between memory and the host computer and is measured in bytes/second. Items affecting bandwidth : access time of memory, the type of data path between memory and CPU and the interface between memory and CPU. Thus the number of bits that can be transferred in parallel and the speed of the bus are important factors in describing bandwidth.

Latency- The delay between beginning a memory access and the start of the transfer. It is typically substantially longer than the time to transfer a word from a block of memory. - time required to rotate a disk to desired position - time required to take control of the bus

Memory is primarily of three types −

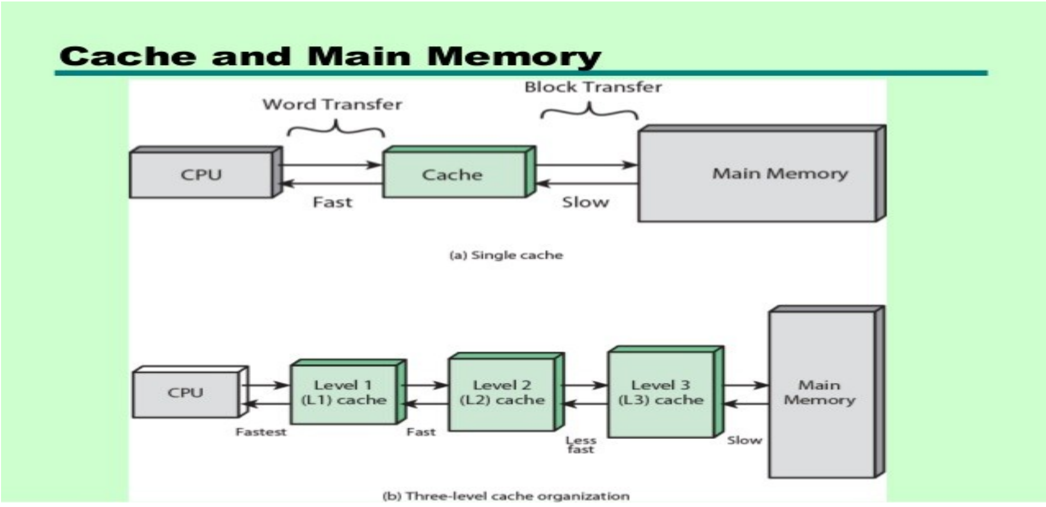
- Cache Memory
- Primary Memory/Main Memory
- Secondary Memory



Cache Memory

The cache is a very high speed, expensive piece of memory, which is used to speed up the memory retrieval process. Due to it's higher cost, the CPU comes with a relatively small amount of cache compared with the main memory. Without cache memory, every time the CPU requests for data, it would send the request to the main memory which would then be sent back across the system bus to the CPU. This is a slow process. The idea of introducing cache is that this extremely fast memory would store data that is frequently accessed and if possible, the data that is around it. This is to achieve the quickest possible response time to the CPU.

The data and instructions are retrieved from RAM when CPU uses them for the first time. A copy of that data or instructions is stored in cache. The next time the CPU needs that data or instructions, it first looks in cache. If the required data is found there, it is retrieved from cache memory instead of main memory. **It speeds up the working of CPU.**



Advantages

The advantages of cache memory are as follows −

- Cache memory is faster than main memory.
- It consumes less access time as compared to main memory.
- It stores the program that can be executed within a short period of time.
- It stores data for temporary use.

Disadvantages

The disadvantages of cache memory are as follows −

- Cache memory has limited capacity.
- It is very expensive.

Primary Memory (Main Memory)

Primary memory holds only those data and instructions on which the computer is currently working. It has a limited capacity and data is lost when power is switched off. It is generally made up of semiconductor device. These memories are not as fast as registers. The data and instruction required to be processed resides in the main memory. It is divided into two subcategories RAM and ROM.

Characteristics of Main Memory

- These are semiconductor memories.
- It is known as the main memory.
- Usually volatile memory.
- Data is lost in case power is switched off.
- It is the working memory of the computer.
- Faster than secondary memories.
- A computer cannot run without the primary memory.

Secondary Memory

This type of memory is also known as external memory or non-volatile. It is slower than the main memory. These are used for storing data/information permanently. CPU directly does not access these memories, instead they are accessed via input-output routines. The contents of secondary memories are first transferred to the main memory, and then the CPU can access it. For example, disk, CD-ROM, DVD etc.

Characteristics of Secondary Memory

- These are magnetic and optical memories.
- It is known as the backup memory.
- It is a non-volatile memory.
- Data is permanently stored even if power is switched off.
- It is used for storage of data in a computer.
- Computer may run without the secondary memory.
- Slower than primary memories.

RAM

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.

RAM is of two types −

- Static RAM (SRAM)
- Dynamic RAM (DRAM)

Static RAM (SRAM)

The word **static** indicates that the memory retains its contents as long as power is being supplied. However, data is lost when the power gets down due to volatile nature. SRAM chips use transistors and no capacitors. Transistors do not require power to prevent leakage, so SRAM need not be refreshed on a regular basis.

SRAM uses more chips than DRAM for the same amount of storage space, making the manufacturing costs higher. SRAM is thus used as cache memory and has very fast access.

Characteristic of Static RAM

- Long life
- No need to refresh
- Faster
- Used as cache memory
- Large size
- Expensive
- High power consumption

Dynamic RAM (DRAM)

DRAM, unlike SRAM, must be continually **refreshed** in order to maintain the data. This is done by placing the memory on a refresh circuit that rewrites the data several hundred times per second. DRAM is used for most system memory as it is cheap and small. All DRAMs are made up of memory cells, which are composed of one capacitor and one transistor.

Characteristics of Dynamic RAM

- Short data lifetime
- Needs to be refreshed continuously
- Slower as compared to SRAM
- Used as RAM
- Smaller in size
- Less expensive
- Less power consumption

Static RAM	Dynamic RAM
➢ SRAM uses transistor to store a single bit of data	➢ DRAM uses a separate capacitor to store each bit of data
➢ SRAM does not need periodic refreshment to maintain data	➢ DRAM needs periodic refreshment to maintain the charge in the capacitors for data
➢ SRAM's structure is complex than DRAM	➢ DRAM's structure is simplex than SRAM
➢ SRAM are expensive as compared to DRAM	➢ DRAM's are less expensive as compared to SRAM
➢ SRAM are faster than DRAM	➢ DRAM's are slower than SRAM
➢ SRAM are used in Cache memory	➢ DRAM are used in Main memory

RAM Memory Technology

- **SIMM (Single In-line Memory Modules)**

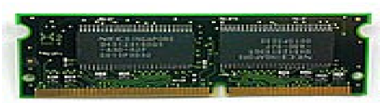
SIMMs are used to store a single row of DRAM, EDO (extended-data-out RAM) or BEDO (burst extended-data-out RAM) chips where the module is join onto a printed circuit board. Simply, a SIMM is a module containing one or several RAM chips on a small circuit board with pins that connect to the computer motherboard. One SIMM can contain several chips. When we add more memory to a computer, most likely we are adding a SIMM.
The first SIMMs transferred 8 bits of data at a time and contained 30 pins. When CPU's began to read 32-bit chunks, a wider SIMM was developed and contained 72 pins.72 pin SIMM are 3/4" longer than 30 pin SIMMs and have a notch in the lower middle of the PCB. SIMMs install at a slight angle.

- **DIMM (Dual In-line Memory Modules)**

DIMMs allow the ability to have two rows of DRAM, EDO or BEDO chips. They are able to contain twice as much memory on the same size circuit board. DIMMs contain 168 pins and transfer data in 64 bit chunks. DIMMs install straight up and down and have two notches on the bottom of the PCB.

SODIMM (Small Outline DIMM)

SODIMMs are commonly used in notebooks and are smaller than normal DIMMs. There are two types of SO DIMMs. Either 72 pins and a transfer rate of 32 bits or 144 pins with a transfer rate of 64 bits.



- **RIMM (Rambus In-line Memory Modules)**

Rambus Incorporated, in conjunction with Intel has created new technology, Direct RDRAM, to increase the access speed for memory. RIMMs appeared on motherboards sometime during 1999. The in-line memory modules are called RIMMs. They have 184 pins and provide 1.6 GB per second of peak bandwidth in 16 bit chunks. As chip speed gets faster, so does the access to memory and the amount of heat produced. An aluminum sheath, called a heat spreader, covers the module to protect the chips from overheating.

RAM Speed depends on –

- Access Time,
- Megahertz (MHz),
- Bytes Per Second

Other types of RAM

SDRAM (Synchronous DRAM)

SDRAM is a generic name for various kinds of dynamic random access memory (DRAM) that are synchronized with the clock speed that the microprocessor is optimized for. This tends to increase the number of instructions that the processor can perform in a given time. The speed of SDRAM is rated in Mhz rather than in nanoseconds(ns) . This makes it easier to compare the bus speed and the RAM chip speed.

SDRAM is not an extension of older EDO DRAM but a new type of DRAM altogether. SDRAM started out running at 66 MHz, while older fast page mode DRAM and EDO max out at 50 MHz. SDRAM is able to scale to 133 MHz (PC133) officially, and unofficially up to 180MHz or higher. As processors get faster, new generations of memory such as DDR and RDRAM are required to get proper performance.

DDR (Double Data Rate SDRAM)

Double Data Rate SDRAM is a double data rate (DDR) synchronous dynamic random-access memory class of memory integrated circuits used in computers. DDR SDRAM, also called DDR1 SDRAM, has been superseded by DDR2 SDRAM, DDR3 SDRAM and DDR4 SDRAM. None of its successors are forward or backward compatible with DDR1 SDRAM, meaning DDR2, DDR3, and DDR4 memory modules will not work in DDR1-equipped motherboards, and vice versa.

DDR basically doubles the rate of data transfer of standard SDRAM by transferring data on the up and down tick of a clock cycle. DDR memory_operating at 333MHz actually operates at 166MHz * 2 (aka PC333 / PC2700) or 133MHz*2 (PC266 / PC2100). DDR is a 2.5 volt technology that uses 184 pins in its DIMMs. It is incompatible with SDRAM physically, but uses a similar parallel bus, making it easier to implement than RDRAM, which is a different technology.

Rambus DRAM (RDRAM)

Stands for "Rambus Dynamic Random Access Memory." It is a type of RAM made by Rambus and is the fastest type of computer memory available. Typical SDRAM can transfer data at speeds up to 133 MHz, while standard RDRAM can crank it up over 1 GHz. Though some motherboards can use RDRAM as system memory, it is so fast, most boards cannot fully benefit from the speed. Because of this, RDRAM is typically used for video memory on graphics acclerator cards, for cache memory (located on the CPU), and for system memory in high-performance workstations and servers.

An improvement to RDRAM called Direct Rambus (DRDRAM) allows for even faster data transfer rates. DRDRAM uses a 16-bit bus and can transfer data at a speeds of 1.6 GHz.

Despite it's higher price, Intel has given RDRAM it's blessing for the consumer market, and it will be the sole choice of memory for Intel's Pentium 4. RDRAM is a serial memory technology that arrived in three flavors, PC600, PC700, and PC800. PC800 RDRAM has double the maximum throughput of old PC100 SDRAM, but a higher latency. RDRAM designs with multiple channels, such as those in Pentium 4 motherboards, are currently at the top of the heap in memory throughput, especially when paired with PC1066 RDRAM memory.

Fast Page Mode DRAM

FPM DRAM was the most common kind of DRAM in personal computers. It allows faster access to data in the same row or page. Page-mode memory works by eliminating the need for a row address if data is located in the row previously accessed. It is sometimes called *page mode memory.* A row access strobe (RAS) signal is kept active while the column access strobe signal changes to read a sequence of contiguous memory cells. This reduces access time and lowers power requirements. Clock timings for FPM DRAM are typically 6-3-3-3 (meaning 3 clock cycles for access setup, and 3 clock cycles for the first and each of three successive accesses based on the initial setup). FPM RAM is being replaced by newer types of memory, such as SDRAM(Synchronous DRAM).

SDRAM

Short for Synchronous DRAM, a type of DRAM that can run at much higher clock speeds than conventional memory. SDRAM actually synchronizes itself with the CPU's bus and is capable of running at 133 MHz, about three times faster than conventional FPM RAM, and about twice as fast EDO DRAM and BEDO DRAM. SDRAM is replacing EDO DRAM in many newer computers.

EDO RAM

Short for E*xtended* D*ata* O*ut* D*ynamic* R*andom* A*ccess* M*emory,* a type of DRAM that is faster than conventional DRAM. Unlike conventional DRAM which can only access one block of data at a time, EDO RAM can start fetching the next block of memory at the same time that it sends the previous block to the CPU. EDO DRAM is like FPM DRAM with some cache built into the chip. Like FPM DRAM, EDO DRAM maxes out at about 50 MHz. Early on, some system makers claimed that if you used EDO DRAM you didn't need L2 cache in your computer to get sufficient performance. They were wrong. It turns out that EDO DRAM works along with L2 cache to make things even faster, but if we lose the L2 cache, we lose a lot of speed.

EDO RAM speeds up the memory cycle, with improvements in memory performance of as much as 40 percent. But EDO is effective only up to a bus speed of 66 MHz, and that's quickly being bypassed by the most recent crop of AMD and Intel processors.

BEDO RAM (Burst Extended Data Out RAM)

As the need for faster access to DRAM has increased, technologies have been developed to provide it. One such technology is known as bursting, in which large blocks of data are sent and processed in the form of an uninterrupted "burst" of smaller units. What this means to DRAM is that the burst carries details not only about the address of the first page, but also of the next few. BEDO RAM can handle four data elements in one burst, and this allows the final three elements to avoid experiencing the delays of the first - all the addresses are ready to be processed. BEDO RAM exists because SDRAM manufacturers were uninterested in pricing SDRAM to be competitive with EDO RAM; as a result, more work was done with EDO to add bursting technologies for speed rivaling that of SDRAM. Hence BEDO RAM.

Shadow RAM

When your computer starts up (boots), minimal instructions for performing the startup procedures and video controls are stored in ROM (Read Only Memory) in what is commonly called BIOS. ROM executes slowly. Shadow RAM allows for the capability of moving selected parts of the BIOS code from ROM to the faster RAM memory.

VRAM (Video RAM)

VRAM is a video version of FPM and is most often used in video accelerator cards. Because it has two ports, It provides the extra benefit over DRAM of being able to execute simultaneous read/write operations at the same time. One channel is used to refresh the screen and the other manages image changes. VRAM tends to be more expensive.

Determining your Computer RAM Type

1. Type

- FPM – Fast Page - If you have a Intel 80486 microprocessors, you probably have FPM
- EDO – Extended Data Out - If you have an early Pentium system, you probably have EDO
- SDRAM - If you have a Pentium or Celeron system purchased in 1999, you probably have SDRAM

2. Sockets

Memory modules plug into a socket on the motherboard. There are three socket types.

- SIMM – 30 pin – 3 inches in length
- SIMM – 72 pin – 4 inches in length
- DIMM – 168 pin – 5 inches in length

Most older Intel 80486 microprocessors machines will use 30 pin modules. Later model of Intel 80486 microprocessors and Pentium machines will probably use 72 pin modules. More recent Pentium machines may have 168 pin.

3. Amount

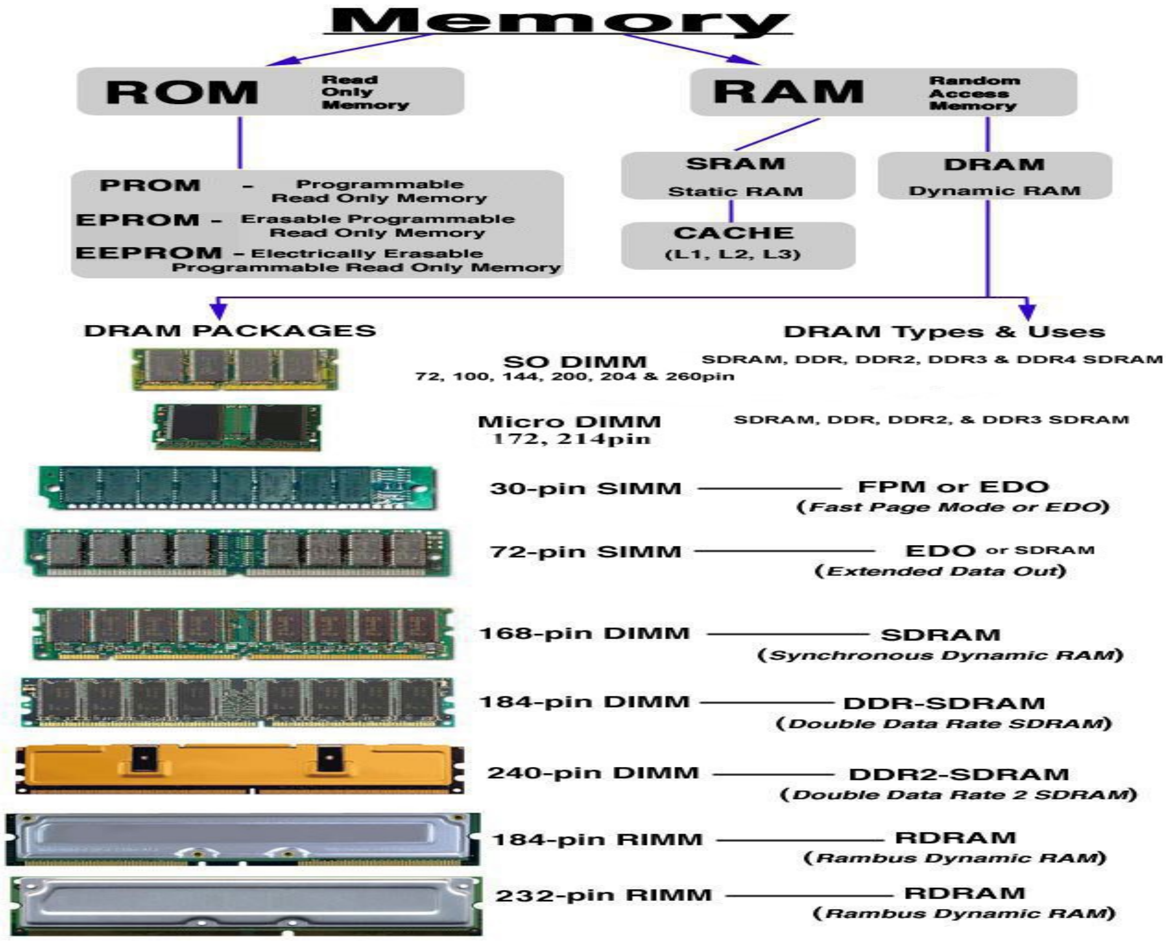
Memory sizes increase by the power of 2. This results in sizes of 1, 2, 4, 8, 16, 32, 64, 128, 256 MBs.

- On some older Intel 80486 microprocessors machines, one memory module can be added at a time.
- On most Pentium machines, modules must be added in pairs.
- Each pair must be of the same size.
- SDRAM modules can be added one at a time.

For example, if you have 8 MBs of memory on a Pentium, you have two 4 MB modules. To increase to 16 MBs, you need to add two more 4 MB modules. To increase to 24 MBs, you need to add two 8 MB modules.

4. Module

A module is a separate unit of software or hardware. Typical characteristics of modular components include portability, which allows them to be used in a variety of systems, and interoperability, which allows them to function with the components of other systems. The term was first used in architecture. We can determine the type of module by the number of pin used. Eg: 30 pin modules, 72 pin modules etc.



Memory Redundancy

One important aspect to consider in memory is what level of redundancy you want. There are a few different levels of redundancy available in memory. Depending on your motherboard, it may support all or some of these types of memory:

a. The cheapest and most prevalent level of redundancy is **non-parity memory**. When you have non-parity memory in your machine and it encounters a memory error, the operating system will have no way of knowing and will most likely crash, but could corrupt data as well with no way of telling the OS. This is the most common type of memory, and unless specified, that's what you're getting. It works fine for most applications.

b. The second level of redundancy is **parity memory** (also called true parity). Parity memory has extra chips that act as parity chips. Thus, the chip will be able to detect when a memory error has occurred and signal the operating system.

c. The third level of redundancy is **ECC** (Error Checking and Correcting). This requires even more logic and is usually more expensive. Not only does it detect memory errors, but it also corrects bit ECC errors. Some motherboards enable you to have ECC memory.

Read Only Memory(ROM)
The memory from which we can only read but cannot write on it. This type of memory is non-volatile. The information is stored permanently in such memories during manufacture. A ROM stores such instructions that are required to start a computer. This operation is referred to as **bootstrap**. ROM chips are not only used in the computer but also in other electronic items like washing machine and microwave oven.

Advantages of ROM

The advantages of ROM are as follows −

- Non-volatile in nature
- Easy to test
- More reliable than RAMs
- Static and do not require refreshing
- Contents are always known and can be verified

Types:

PROM (Programmable Read Only Memory)

A memory chip on which data can be written only once. Once a program has been written onto a PROM, it remains there forever. Unlike RAM, PROMs retain their contents when the computer is turned off. The difference between a PROM and a ROM (read-only memory) is that a PROM is manufactured as blank memory, whereas a ROM is programmed during the manufacturing process. To write data onto a PROM chip, we need a special device called a PROM programmer or PROM burner. The process of programming a PROM is sometimes called burning the PROM.

EPROM (Erasable and Programmable Read Only Memory)

EPROM can be erased by exposing it to ultra-violet light for a duration of up to 40 minutes. Usually, an EPROM eraser achieves this function. During programming, an electrical charge is trapped in an insulated gate region. The charge is retained for more than 10 years because the charge has no leakage path. For erasing this charge, ultra-violet light is passed through a quartz crystal window. This exposure to ultra-violet light dissipates the charge. During normal use, the quartz window is sealed with a sticker.

EEPROM (Electrically Erasable and Programmable Read Only Memory)

EEPROM is programmed and erased electrically. It can be erased and reprogrammed about ten thousand times. Both erasing and programming take about 4 to 10 ms (millisecond). In EEPROM, any location can be selectively erased and programmed. EEPROMs can be erased one byte at a time, rather than erasing the entire chip. Hence, the process of reprogramming is flexible but slow.

EAPROM (Electronically Alterable Programmable Read-Only Memory)

A form of PROM in which the contents of selected memory locations can be changed by applying suitable electric signals and its individual bits can be re-programmed during the course of system operation.

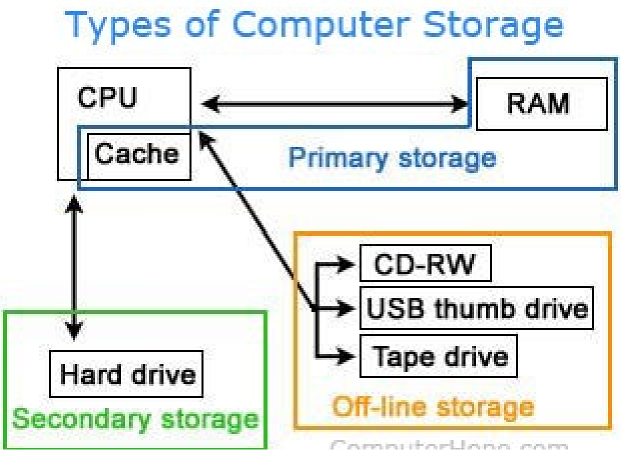
Flash Memory

Flash memory is a non-volatile memory chip used for storage and for transferring data between a personal computer (PC) and digital devices. It has the ability to be electronically reprogrammed and erased. It is often found in USB flash drives, MP3 players, digital cameras and solid-state drives.

Flash memory is a type of EEPROM, but may also be a standalone memory storage device such as a USB drive. Flash memory is a distinct type of EEPROM, which is programmed and erased in large blocks.

Secondary Storage

Also referred as external memory, **secondary memory**, and **auxiliary storage**, a **secondary storage device** is a non-volatile device that holds data until it is deleted or overwritten. Secondary storage refers to storage devices and media that are not constantly accessible by a computer system. Examples include external hard drives, portable flash drives, CDs, and DVDs. These devices and media must be either plugged in or inserted into a computer in order to be accessed by the system. Because secondary storage technology is not always connected to the computer, it is commonly used for backing up data.

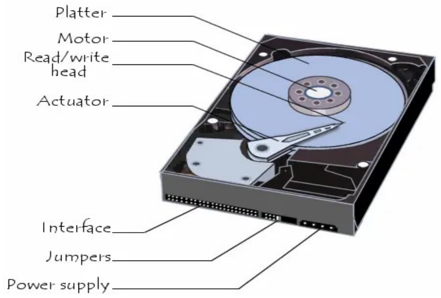


Magnetic Storage Systems

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 used in computer systems, includes:

◆ **Hard Disk**

Hard drives consist of stacks of non-removable platters coated with magnetic materials – each with its own read/write head as shown in the photo.



Hard disk drives are built into desktops and laptops.

The capacity of a hard disk is measured in gigabytes. It holds much more data than a CD-ROM. Hard disk drives use random/direct access to locate data stored on the disk.

Advantages of Hard disks

1. Large storage capacity.

2. They read and write data very quickly.

3. They can hold large quantities of data.

◆ **Floppy Disk**

A **floppy disk** is a magnetic storage medium for computer systems. The floppy disk is composed of a thin, flexible magnetic disk sealed in a square plastic carrier. In order to read and write data from a floppy disk, a computer system must have a floppy disk drive (FDD). A floppy disk is also referred to simply as a floppy. Since the early days of personal computing, floppy disks were widely used to distribute software, transfer files, and create back-up copies of data. When hard drives were still very expensive, floppy disks were also used to store the operating system of a computer.

Floppy disks are **less popular** because :-

- They are **easily damaged.**
- Have a **limited storage capacity** in that they can only hold 1.44MB.

◆ **Zip Drive or Superdisks**

Are very similar to floppy disks. Again they are plastic disks coated with magnetic material. The difference between them is that zip disks can **store much more than floppy disk**. Like Floppy disks, zip disks need a **specialised zip drive** to read and write to the disk.

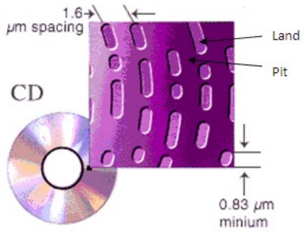
◆ **Magnetic Tape**

Made of a long plastic strip coated with magnetic material, tape is mostly used for making backups. It can store lots of data, but this data is **slower to access**, because of having to wind through to the information you need slows down the access time. This makes it **impractical for use as main storage. One great advantage of magnetic tape is its cheapness.**

Magnetic tape uses **sequential or serial access** to locate data stored on the tape.

Optical Storage Systems

The optical storage systems use the laser light as the optical medium to retrieve as well as record data. The optical storage devices are either read-only or writable.



◆ **Compact Disk - Read Only Memory (CD-ROM)**

CD-ROM drives use a combination of lasers and sensors to read the data stored on the surface of the disks. CD-ROMs are read-only devices. Like hard disk drives, CD drives use **direct/random access** to read data.

◆ **Digital Versatile Disk - Read Only Memory (DVD ROM)**

A DVD-ROM drive is similar to a CD-ROM drive in that it uses a combination of lasers and sensors to read the data. **DVD ROMs are also read only.**

<u>Solid State Storage Devices</u>

In contrast to magnetic and optical forms of backing storage, these devices have **no moving parts** and so are called 'solid state'. Instead, they use a special kind of **programmable ROM memory chip** on which data is stored. **Very different to usual memory**, these kind of chip remember the data even when the power has been turned off. Solid state storage is made from silicon microchips . Because there are no moving parts, SSDs require less power and produce far less heat than spinning hard disk drives or magnetic tape.

◆ **USB Flash Drives**

Universal Serial Bus (USB) is a type of socket or port in computer systems that allow USB type devices to connect to it. One of which is the USB Flash Drive – sometimes called pen drive.

USB Flash drives come in various sizes. They are very useful and a simple way of backing up and transporting data. Because of the USB connection they will work on any computer with a USB port and have really replaced floppy discs as a method of moving files from one computer system to another.

◆ **Memory Cards**

Like USB Flash drives, these solid state devices come in various sizes. They connect differently and need a card reader to 'read' their contents.

Storage Evaluation Criteria

Access Mode : random access mode, sequential access mode, direct access mode

Access Time : The time taken by the processor in completing the requests made by the user for performing the read and write operations.

Storage Capacity : The size of the memory available for storing the data, and measured in terms of bytes.

Storage Type: Temporary and permanent memory.

Cost: The cost of the storage device used in the computer system for holding the data.

Input Devices

Depending upon the type or method of input, the input device may belong to one of the following categories:

(1) Keyboard

(2) Pointing devices

(3) Scanning devices

(4) Optical recognition devices

(5) Digital camera

(6) Voice recognition devices

(7) Media input devices

Keyboard

Keyboard is the most commonly used input device. We can use a keyboard to type data and text and execute commands. A standard keyboard consists of the following groups of keys:

(1) Alphanumeric keys: The alphanumeric keys include the number keys and alphabet keys. These keys are arranged in the same style as in the normal typewriters, popularly known as QWERTY layout;

(2) Function keys: Arranged in a row on the top of the keyboard. Help perform specific tasks, such as searching a file or refreshing a web page;

(3) Central keys: Used for controlling the movement of cursor and screen display. Include arrow keys, modifier keys such as SHIFT, ALT, CTRL;

(4) Numeric keypad: Located on the right side of the keyboard. This looks like a calculator's keypad;

(5) Special purpose keys: Escape, Insert, Delete, Print Screen, Pause, Tab, Spacebar;

Pointing Devices

Pointing devices are the input devices that are generally used for moving the cursor to a particular location to point an object on the screen. With the help of pointing devices, we can easily select the icons, menus, windows, etc on the Graphical User Interface. Some of the commonly used pointing devices are:

(1) Mouse

(2) Trackball

(3) Light pen

(4) Joystick

(5) Touchscreen

Scanning devices

Scanning devices are the input devices that can electronically capture text and images, and convert them into computer readable form.

The basic task of a scanning devices is to convert an image or the textual data into digital data, i.e., in the form of boxes, where each box represents either zero or one. The resultant matrix is known as bit map and is displayed on the screen.

The scanning devices can be differentiated from each other on the basis of the following characteristics:

Resolution: the closeness of the pixels in the bit map, and vary from 72 to 600 dots per inch (dpi);

Size: The small sized scanning device can scan approximately two to five inches of the document, whereas the large sized one can scan approximately up to forty inches of the document.

Optical Recognition Devices

Optical Mark Recognition (OMR) devices: help in obtaining the data from the marked fields. These devices prove to be of great use in recognizing characters in question sheets, enrollment forms, registration forms, employee payroll, etc. Most popularly, the OMR devices are used for scanning the documents having multiple choices as in the question papers used in schools, colleges, etc.

Digital Camera

A digital camera is a handheld electronic device that is used to capture the image of an object electronically. The digital camera consists of a built-in computer, which helps in recording the images electronically. The following are the main features of the digital camera:

Capturing and storing thousands of images on a single memory chip

Editing as well as deleting the images

Recording the video clip with sound

Showing the just recorded video clip on the camera screen

Voice Recognition System

The voice recognition devices generally record the voice of a person and transform it into electrical signals. The electrical signals are then converted into the machine readable code. The voice recognition system only recognizes the voice of the speaking person rather than what he speaks.

Voice recognition software on computers requires that analog audio be converted into digital signals, known as analog to digital conversion.

The voice recognition devices are used for various purposes such as dictation, training air-traffic controllers, etc. These systems allow users to communicate with computers directly without using a keyboard or mouse.

Data Acquisition Sensors

Sensors are the devices that are used for detecting and measuring the physical quantities, such as heat, temperature, and converting them into electrical signals. The sensors are most commonly used in data acquisition systems.

The data acquisition system collects the electrical signals from various devices and converts them into the digital signals for further assessment.

Media Input Devices

The input devices, which are generally used in media for communicating with the mass audiences, are known as media input devices. The following are the most popularly used media input devices: Microphone, Webcam, Graphics tablet etc.

Some Extra Terms:

Processor Frequency

Microprocessor frequency specifies the operating (internal) frequency of CPU's core. The higher the frequency is for a given CPU , the faster the processor is. Processor frequency and CPU efficiency both affects system performance. CPU efficiency, specifies how many Instructions Per Clock (IPC) the CPU can process. Knowing these two parameters it's easy to calculate total number of instructions per second that can be processed by CPU: Frequency * IPC. All processor manufactures tried to improve their performance by improving the IPC, and, whenever possible, by increasing processor frequency.

The CPU frequency is measured in Hertz. The frequency can also be expressed in:

- Kilohertz, or kHz, equals to 1,000 Hertz
- Megahertz, or MHz, equals to 1,000,000 Hertz or 1,000 kHz
- Gigahertz, or GHz, equals to 1,000,000,000 Hertz, or 1,000,000 kHz, or 1,000 MHz.

First microprocessors ran at frequencies close to 1 MHz. Modern microprocessors run at frequencies exceeding 3 GHz, or 3,000,000,000 Hertz.

CPU

The frequency at which a processor (CPU) operates is determined by applying a clock multiplier to the front-side bus (FSB) speed in some cases. For example, a processor running at 3200 MHz might be using a 400 MHz FSB. This means there is an internal clock multiplier setting (also called bus/core ratio) of 8. That is, the CPU is set to run at 8 times the frequency of the front-side bus: 400 MHz × 8 = 3200 MHz. Different CPU speeds are achieved by varying either the FSB frequency or the CPU multiplier, this is referred to as Overclocking or Underclocking.

Overclocking

In computing, **overclocking** is the practice of increasing the clock rate of a computer to exceed that certified by the manufacturer. Commonly operating voltage is also increased to maintain a component's operational stability at accelerated speeds. Semi conductor operated at higher frequencies and voltages increase power consumption and heat. An overclocked device may be unreliable or fail completely if the additional heat load is not

removed or power delivery components cannot meet increased power demands. Many device warranties state that overclocking and/or over-specification voids any warranty.
The purpose of overclocking is to increase the operating speed of a given component. Normally, on modern systems, the target of overclocking is increasing the performance of a major chip or subsystem, such as the main processor or graphics controller.

Throttling

Adjusting the clock speed of the CPU. Also called "dynamic frequency scaling," CPU throttling is commonly used to automatically slow down the computer when possible to use less energy and conserve battery, especially in laptops and other portable devices. CPU throttling can also be adjusted manually to make the system quieter, because the fan can then run slower.

Branch Instructions

A **branch** is an instruction in a computer program that can cause a computer to begin executing a different instruction sequence and thus deviate from its default behavior of executing instructions in order. **Branch** (or *branching)* may also refer to the act of switching execution to a different instruction sequence as a result of executing a branch instruction. Branch instructions are used to implement control flow in program loops and conditionals (i.e. , executing a particular sequence of instructions only if certain conditions are satisfied).
A branch instruction can be either an *unconditional branch*, which always results in branching, or a *conditional branch*, which may or may not cause branching depending on some condition.

A branch instruction can change the program counter (PC) of a CPU . The program counter stores the memory address of the next instruction to be executed. Therefore, a branch can cause the CPU to begin fetching its instructions from a different sequence of memory cells.

When a branch is *taken*, the CPU's program counter is set to the argument of the jump instruction. So, the next instruction becomes the instruction at that address in memory. Therefore, the flow of control changes.

When a branch is *not taken*, the CPU's program counter is unchanged. Therefore, the next instruction executed is the instruction after the branch instruction. Therefore, the flow of control is unchanged.

Parity bits

A parity bit is a bit appended to a data of binary bits to ensure that the total number of 1’s in the data are even or odd. Parity bits are used for error detection. There are two types of parity bits:

1. **Even parity bit:**

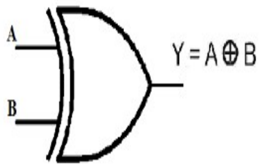
   In the case of even parity, for a given set of bits, the number of 1’s are counted. If that count is odd, the parity bit value is set to 1, making the total count of occurrences of 1’s an even number. If the total number of 1’s in a given set of bits is already even, the parity bit’s value is 0.

2.**Odd Parity bit –**

In the case of odd parity, for a given set of bits, the number of 1’s are counted. If that count is even, the parity bit value is set to 1, making the total count of occurrences of 1’s an odd number. If the total number of 1’s in a given set of bits is already odd, the parity bit’s value is 0.

Gray Code

Decimal Number	4 bit Binary Number ABCD	4 bit Gray Code $G_1G_2G_3G_4$
0	0 0 0 0	0 0 0 0
1	0 0 0 1	0 0 0 1
2	0 0 1 0	0 0 1 1
3	0 0 1 1	0 0 1 0
4	0 1 0 0	0 1 1 0
5	0 1 0 1	0 1 1 1
6	0 1 1 0	0 1 0 1
7	0 1 1 1	0 1 0 0
8	1 0 0 0	1 1 0 0
9	1 0 0 1	1 1 0 1
10	1 0 1 0	1 1 1 1
11	1 0 1 1	1 1 1 0
12	1 1 0 0	1 0 1 0
13	1 1 0 1	1 0 1 1
14	1 1 1 0	1 0 0 1
15	1 1 1 1	1 0 0 0



INPUT		OUTPUT
A	B	Y
0	0	0
0	1	1
1	0	1
1	1	0

<u>Difference between combinational and sequential circuit</u>

Combinational circuits are defined as the time independent circuits which do not depends upon previous inputs to generate any output are termed as combinational circuits. **Sequential circuits** are those which are dependent on clock cycles and depends on present as well as past inputs to generate any output.

Combinational Circuit –

1.In this output depends only upon present input.

2.Speed is fast.

3.It is designed easy.

4.There is no feedback between input and output.

5.This is time independent.

6.Elementary building blocks: Logic gates

7.Used for arithmetic as well as boolean operations.

8.Combinational circuits don’t have capability to store any state.

9.These circuits do not have any memory element.

10.It is easy to use and handle.

11.**Examples –**Encoder, Decoder, Multiplexer, Demultiplexer

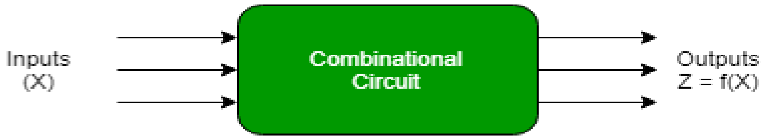


Figure: Combinational Circuits

Sequential Circuit –

1.In this output depends upon present as well as past input.

2.Speed is slow.

3.It is designed tough as compared to combinational circuits.

4.There exists a feedback path between input and output.

5.This is time dependent.

6.Elementary building blocks: Flip-flops

7.Mainly used for storing data.

8.Sequential circuits have capability to store any state or to retain earlier state.

9.As sequential circuits are clock dependent they need triggering.

10.These circuits have memory element.

11.It is not easy to use and handle.

12. **Examples –** Flip-flops, Counters

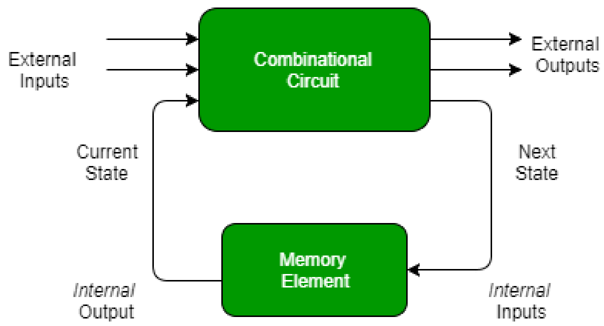


Figure: Sequential Circuit

Heat Sink

A heat sink is a thermal conductive metal device designed to absorb and disperse heat away from a high temperature object such as a computer processor. Usually heat sinks are outfitted with built-in fans to help keep both the CPU and the heat sink at an appropriate temperature. Heat sinks are made out of metal, such as a copper or aluminum alloy, and are attached to the processor. Most heat sinks have fins, thin slices of metal connected to the base of the heat sink, which help spread heat over a large area.

The combination of a heat sink and fan (HSF) is referred to as an active heat sink, while a heat sink without a fan is a passive heat sink. In addition to the HSF, a heat sink compound is sometimes used. This is a coating between the device and the heat sink to improve thermal conduction.

Heat sinks are commonly used in all CPUs and are also used in refrigeration and air conditioning systems, GPUs and video card processors.

Memory Capacity

Unit	*Description*
1 bit	1 binary digit
1 nibble	4 bits
1 byte	8 bits
1 kilobyte	1,024 bytes
1 megabyte	1,048,576 bytes
	1 million bytes
1 gigabyte	1,073,741,824 bytes
	1 billion bytes
1 terabyte	1 trillion bytes