MEMORY AND IO DEVICES

Block Introduction :

In this unit we will focus on : "How actually computer works ?". As we know computer is a Data Processor which process the data into information. But to do this variety of components like memory, storage, input devices and output devices are used. We will focus on these different types of devices, and their role in the computer system.

In the Unit–5, We will see different types of Primary memories. Why the primary memories are essential and what different types of primary memories are there. In the Unit–5 you will also learn the use of Cache memory.

In the Unit–6, We will discuss different types of storages. Basically, main memory is volatile in nature, so that to store the data permanently, computer system uses another memory which is called secondary memory or storage.

To process the data, we need to accept data from the user. To accept the data for the computer system we need to use input devices like keyboard, mouse etc. In the Unit–7 of this block we have discussed different types of Input devices in details.

Finally, after processing the data, Information will be produces by the system. To obtain information from the system user need to use various output devices. In the final unit of this block (Unit–8), we have tried to give idea of different types of output devices.

Block Objectives :

The objective of the block is to aware students, about the how computer actually process the data and produces information. To process the data computer system needs memory and to store data and information permanently system needs storage. After going through Unit : 5 and Unit : 6 of this Block, student will gain sufficient knowledge about different types of primary memories and secondary storages of the computer.

Main objective of this block is to aware students, about different types Memories and IO devices. In the Unit : 4 and Unit : 8 of this block, students will learn what different types of Input and Output devices of the computer system.

Finally, the block will clear the concept of different types memories, different types Input devices and Output devices that you should know before learning any subject of computer science.

Block Structure :

Unit 5 : Memory Organisation – I

Unit 6 : Memory Organisation – II

Unit 7 : Input Devices

Unit 8 : Output Devices

Unit 05

MEMORY ORGANISATION–I

UNIT STRUCTURE

5.0 Learning Objectives :

In this unit, we will discuss about the primary memories of computer system.

After working through this unit, you should be able to :

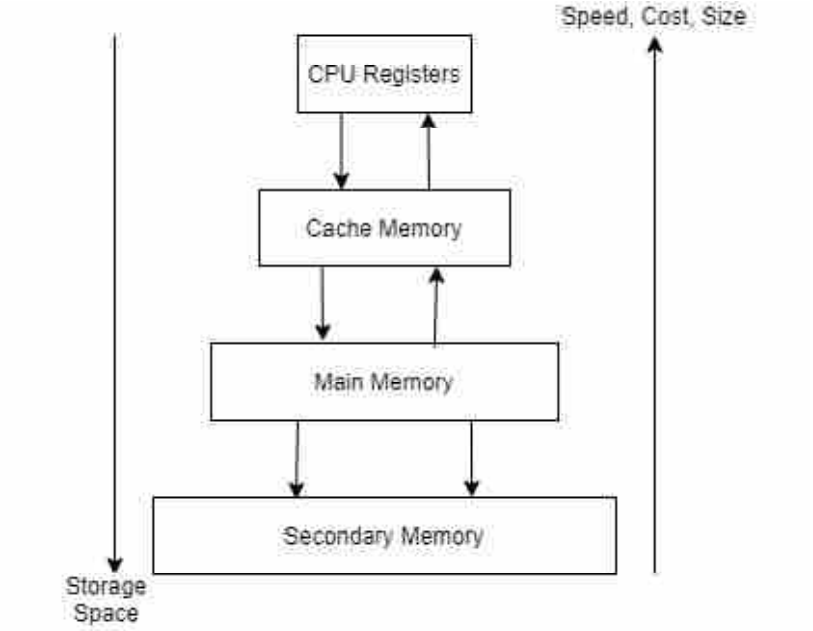
- Learn characteristics of the different memories
- Understand types of memories.
- Know about primary memories.
- Understand the use of cache memory.

5.1 Introduction :

Computers needs to store data inputted by the user, computer process the data and produces information. To store the data, to process it and to store information, computer needs memory storage. A computer system needs variety of storage devices to store data, and instructions given to it. In most cases

computer stores data/information and instructions into the memory. A wide range of memories are available. Unfortunately, faster memories are very costly, it needs continuous power supply and available in larger size. To save cost, physical size and to save data permanently we use secondary memory. On the other hand, CPU is very fast and it always need faster memory. CPU do not deal with slower memory directly.

To deal with this anomaly of access time versus cost, a hierarchy of memories are used in the computer system. This hierarchy enable us to design a computer system which will be cost effective without compromising speed. This hierarchy is shown in the following figure.



As shown in the figure, if we move toward CPU Register to Secondary memory, storage space will increase. For example, registers are available in Bytes, Cache memory in MBs (Mega Bytes), Main memory is available in GBs (Giga Bytes) and secondary storage like hard–disks of the system are available in TBs (Tera Bytes). Similarly, if we move towards Secondary storage to CPU registers, speed will increase. Secondary memory is slower and CPU Registers are fastest memory. CPU registers are most expensive and take more physical size as they are made from special binary cell circuits called Flip–Flops. If we move towards CPU Register to Secondary memory cost of the memory will be reduced.

❑ **Check Your Progress – 1 :**

1. _____ is the fastest memory.

   [A] Main memory [B] CPU Registers

   [C] Cache memory [D] Secondary memory

2. From the given below, which is less–expensive memory ?

   [A] Main memory [B] CPU Registers

   [C] Cache memory [D] Secondary memory

3. _____ memory is available with Tera–Bytes of storage space.

   [A] Hard Disk [B] RAM

   [C] Cache Memory [D] None of the above

4. _____ memory is made from Flip–Flops.

[A] CPU Registers [B] RAM

[C] Hard–disk [D] Pen–drive

5.2 Categories of Memory :

Memories of a computer system can be categorised in three main groups. There are :

[1] Internal Processor Memory : These consists of a set of memories available in smaller size and higher speed. CPU Registers and Cache memory are internal processor memories as they are present in the chip of CPU. Both memories are made from Flip–Flops. They offer higher speed but available in smaller size. Cache memory is used in the modern computer between CPU Registers and Main memory of the system to reduce speed mismatch problem between them.

[2] Main Memory : Main memory is a large memory that is fast, but not as fast as CPU Registers and Cache memory. CPU of the system can directly access this memory. It is mainly based on Integrated Circuits (ICs).

[3] Secondary Memory : Secondary memory is also called an Auxiliary memory. It is available in larger size. This memory is cheaper compare to all other memories. It is slower than main memory and CPU can not access this memory directly. It normally stores programs, other instructions and data files. Because the CPU can not access this memory directly data, programs or instructions stored in this memory will be transferred into Main memory and then CPU can access it.

5.3 Characteristics of Memory Devices :

To compare different memories usually we compare their characteristics. The terms discussed below are important to compare two memories.

- **Storage Capacity :** Storage capacity of a memory represent memory size. The capacity of internal memory is in words, Bytes or in MBs (Mega Bytes). Main memory is usually available in MBs or in GBs (Giga–Bytes). The capacity of secondary storage is in GBs or TBs (Tera–Bytes).
- **Access Time :** The access time is the time required to access the particular memory. It is a time between the request is made for read/write operation till the time data is made available or written on specific location of the memory. Usually a memory having less access time is a faster memory.
- **Permanent Storage :** Some memories can not store the data permanently as they need continuous power supply. Once you dis–continue power supply or simply switch off the machine, the content stored within the memory is disappeared. Such type of memory is called volatile memory. For example, RAM (Random Access Memory) is volatile memory in nature. Whereas, Hard–disk drive can store the data permanently. Even though you turn off the machine or discontinue the power supply, still the content stored in the Hard–disk drive will remain as it is.
- **Access Mode :** The data stored in the memory is resided at various memory locations. Depends on how can we access data from various memory locations, memories can be divided into three types :
  - **Sequential Access Memory :** Memories which can be accessed in a predefined sequence is called sequential access memory. For

example, songs can be accessed sequentially one after another. A good example of sequential memory is Magnetic Tape. To access the data from particular location we need to rewind or forward. We can not access particular memory location directly. Generally, this type of memories is slower in nature and mostly used for data backup purpose.

- **Random Access Memory :** It is the mode in which any memory location can be accessed in any order within the same amount of time. Memory made by IC technology, which is made from semi–conductor kind of material is known as Random Access Memory. The storage locations from the memory can be read or write, independently from each other. Usually, this type of memories is faster in nature.
- **Direct Access Memory :** Sometimes, the information neither accessed sequentially nor random. In this type of memory, separate heads are there on each track of the disk. Depends on which track has to be read/written particular head will be activated and then the data will be accessed sequentially from that track by rotating the disk.
- **Physical Characteristics :** Depends on the material from which the memory is constructed is a physical characteristic of the memory. Depends on physical characteristic memory can be categorised in four categories, those are : electronic, magnetic, mechanical and optical.

❑ **Check Your Progress – 2 :**

1. _____ memory is available in smaller size (in Bytes).

   [A] RAM [B] Registers [C] Memory card [D] Hard–disk

2. As per the physical characteristic memory can be _____.

   [A] Electronic [B] Optical [C] Magnetic [D] All of the above

3. In _____ memory data can be access directly from particular memory location.

   [A] Random Access [B] Direct Access

   [C] Sequential Access [D] None of the above

Different types of memories can be classified into two major categories :

[1] **Primary Memory :** Primary memory usually made from semi–conductor typed material. Usually, it is available in the form of electronic chip. This memory is faster memory. A Computer system consists of RAM (Random Access Memory) and ROM (Read Only Memory) which are the examples of Primary memory. In this chapter we will focus only on primary memories used in computer system.

[2] **Secondary Memory :** Secondary memory can be a magnetic or optical memory. For example, Floppy disk, Hard–disk, CD–ROM (Compact Disk Read Only Memory), DVD (Digital Versatile Disk) etc. With the advancement in the technology, now a days some secondary memories which is made from electronic circuits are also available for example memory card, pen drive or SSD Hard–disk. Compare to the primary memory secondary memory can store the data permanently. It is cheaper than primary memory and available with large size storage capacity. We

will discuss different types of secondary memories in the next unit of this block.

5.4 Primary Memories :

Primary memories are often called as main memory of the system, which stores instructions and data during processing of microcomputers. Primary memory stores the data inputted by the user and the processed data called information. It is also used to store intermediate results produces during data processing by CPU. Primary memory is an essential component in any digital computer since it is needed for storing the programs that are executed by the CPU. The CPU of the system can directly communicate with the primary memory as they offer higher speed than secondary memory. There are two types of primary memory : [1] RAM : Random Access Memory and [2] ROM : Read Only Memory.

❑ **Check Your Progress – 3 :**

1. _____ is a primary memory.

   [A] Read Only Memory [B] CD–ROM

   [C] DVD [D] Hard–disk

2. Compare to. primary memory, secondary memory is _____.

   [A] Cheaper [B] Available with large storage

   [C] Slower in speed [D] All of the above

3. CPU directly interact with _____.

   [A] Primary memory [B] Secondary memory

   [C] Both [A] and [B] [D] None of the above

5.5 RAM : Random Access Memory :

Random Access Memory chip is made with Metal Oxide Semiconductor (MOS). It allows to select any location on the memory chip randomly and can be used that location to store or retrieve, data or instructions directly. A memory unit is a collection of storage registers with the associated circuits, needed to transfer information in and out of the registers. These memory registers can be accessed for information transfer as required and hence the name Random Access Memory abbreviated as RAM.

A memory unit of RAM stores data, instructions and information in the form of binaries in the group of bits called words. Each word is store in a separate register. A word in memory is an entity of n–bits that moves in and out from the memory unit. A word (group of bits) of 8–bits is called byte. Data in any format (Text, Numbers, Image, Video or Audio) are stored in the RAM using binary coded representation. Random Access Memory can be divided in two types :

5.5.1 Dynamic RAM :

In the chip of Dynamic RAM multiple cells are there which are stores the data in the form of binary–coded. Each cell of Dynamic RAM can store 1–bit of data. Each cell is made by a transistor. We have already discussed that transistors are two–state device which can be charged or discharged. Depending upon it's charged and discharged state binary bit 1 or 0 is to be assumed.

Transistors which are placed in the Dynamic RAM chip are loose their content with time. To preserve the data in these binary cells Dynamic RAM has refresh circuitry. This circuitry read the content of each cells many times in a

second. This will refresh the content stored in each binary cell of Dynamic RAM chip, so that the content stored in the cell will remain as it is. Due to this reason this memory is a volatile memory. Once you discontinue the power supply or turn off the machine, content stored within the cells will be erased and Dynamic RAM chip will become clear (has no data).

Dynamic RAM has overhead of refresh circuitry, and also volatile in nature. Even though, these drawbacks it is widely used in digital computer because of it's cost–effectiveness. The following figures gives you the idea how Dynamic RAM looks like.

5.5.2 Static RAM :

Static RAM chips are also volatile in nature but as they are supplied power, they do not need special regenerator or refresh circuits to retain the data stored in it. Compare to Dynamic RAM, Static RAM takes more transistors and other electronic components to store a bit. Due to that reason static RAM is more costly than Dynamic RAM. Static RAMs are more reliable than Dynamic RAM, but because of it is costly, it is used in specialised applications while Dynamic RAMs are used as a primary storage in most of the computers.

We can summarize types of RAM as :

- Two common types of RAM are dynamic RAM and static RAM.
- Dynamic RAM (DRAM) chips must be reenergized constantly or they lose their contents. Many variations of DRAM chips exist, most of which are faster than the basic DRAM.
- Static RAM chips are faster and more reliable than any variation of DRAM chips. These chips do not have to reenergized as often as DRAM chips; hence the term, static SRAM chips, however they are more expensive than DRAM chips. SRAM is used in cache memory.

SDRAM (Synchronous RAM)	• Synchronized to the system clock • Much faster than DRAM
DDR SDRAM (Double Data Rate SDRAM)	• Transfer data twice, instead of once, for each clock cycle • Faster than SDRAM
DDR2	• Second generation of DDR • Faster than DDR
DDR3	• Third generation of DDR • Designed for computers with multi-core processors • Faster than DDR2
DDR4	• Fourth generation of DDR • Faster than DDR3
RDRAM (Rambus DRAM)	• Much faster than SDRAM

❑ **Check Your Progress – 4 :**

1. _____ RAM is costly used in specialised applications.

   [A] Static [B] Dynamic

   [C] Serial [D] None of the above

2. _____ RAM is cheaper used as a primary storage of modern computers.

   [A] Static [B] Dynamic

   [C] Both [A] and [B] [D] None of the above

3. _____ RAM is faster than DDR4.

   [A] SD–RAM [B] DDR3

   [C] RD–RAM [D] DDR SD–RAM

5.6 ROM : Read Only Memory :

A Read Only Memory, as name suggest used only for reading purpose. ROM does not have a writing capability. This implies that the binary information stored in a Read Only Memory is made permanent during the production of the hardware chip. Once the memory chip is produced at that time the program (set of instructions) will be written on it and it can not be altered after. RAM is a general–purpose memory allow to change the content during the computational process of the system, whereas a ROM is restricted to only reading the words that are permanently written in the memory module.

The most important ROM chip, which is available in every computer system is BIOS (Basic Input Output System). BIOS is a kind of ROM in which a specialised program called BOOT STRAP LOADER is written. Every time when you turn on your computer, the program written on BIOS starts its execution. BIOS is responsible to load operating system from secondary memory to primary memory called Booting process.

Some important points about the Read Only Memories are :

- Read Only Memory (ROM) refers to memory chip storing permanent data and instructions. The data on most ROM chips cannot be modified – hence, the name read–only.
- ROM is non–volatile, which means its contents are not lost when power is removed from the computer.
- Manufacturers of ROM chips often record data, instructions, or information on the chips when they manufacture the chips. These ROM chips, called firmware, contain permanently written data, instructions, or information, such as a computer or mobile device's start–up instructions.

5.6.1 PROM :

PROM stands for Programmable Read Only Memory. Unlike ROM at the time of manufacturing, manufacturer of the chip do not write any program on the chip. That means the blank chip is available in the market. You can buy the chip from any vendor and can program it as per your need (it is not that much easy, as it needs specialized hardware to write the chip). But once the chip is written, the content written on the chip can not be altered. As it allows the user to write customized program on it once, it is called a Programmable ROM.

5.6.2 EPROM :

EPROM stands for Erasable Programable Read Only Memory. This a special type of ROM, which allows to erase the content stored in it and programmed it again with the help of special equipment. An EPROM has a window on its top, which if exposed to ultraviolet light, allows data to be erased. Most EPROM's have a label covering the window.

5.6.3 EEPROM :

EEPROM stands for Electrically Erasable Programmable Read Only Memory. EPROM allows to erase the content from the chip using ultraviolet rays. But when ultraviolet rays are applied to the chip, it will erase the content of entire chip. EPROM does not allow, to erase the content or rewrite the content on a particular part of the chip. EEPROM on the other hand allow to select particular content of the chip to erase and rewrite electronically.

5.6.4 Flash EPROM :

This is latest type of ROM which is becoming very popular. But running a special program, a manufacturer can make changes to the flash EPROM while it remains in the PC.

5.7 Cache Memory :

Cache memories are small fast memories placed between the processor and the main memory of the system. Cache memory is faster than main memory. Then one question will arise in your mind that, why do we need main memory ? Well it because of cost. For example, 128KB or 256KB size of cache memory is sufficient for the Intel Pentium based machine having 4 to 128 MB of RAM or even more. Thus, small cache memories are sufficient to provide fast speed of memory retrieval without spending more cost for the memory. Based on 'principle of locality' if particular memory location is accessed at a time then it is highly likely that its near by locations will be accessed in the near future. Cache memory contains a copy of that particular portion of main memory. When particular memory location to be read/write, it has to be first searched in the cache memory. If the data is available in the cache, CPU will directly used it. If it is not, CPU that particular data will search in the main memory. From the main memory the data will be copied in the cache memory and then CPU will access it. The reason of bringing the data into cache is again principal of locality of reference. We can expect the same data can be accessed again, in the near future.

For example, if memory read cycle takes 100 nano second and a cache memory takes, 20 nano second. Suppose user access the same piece of data for 4 times then,

The time taken with cache memory	= (100 + 20) ns For the first read operation	+ (20 * 3) For last 3 read operation
	= 120 + 60 = 180 ns	
Time taken without cache memory	= 100 * 4 ns = 400 ns	

Clearly, we can see that if the same piece of data is accessed by the user for 4 times, then total time taken to access the data in the system having cache memory is 180ns, where as the same task will be done in the system, which does not have cache memory takes 400ns.

❑ **Check Your Progress – 5 :**

1. _____ memory is placed between CPU and main memory.

   [A] RAM [B] Cache

   [C] Flash memory [D] EEPROM

2. _____ is a type of ROM, allows to erase the data electronically.

   [A] EPROM [B] EEPROM [C] PROM [D] Flash memory

3. _____ is a blank chip, in which you can write customized content into it for only one time.

   [A] EPROM [B] EEPROM [C] PROM [D] Flash memory

4. Special type of ROM, responsible to start the computer system and load the operating system (booting).

   [A] EPROM [B] BIOS [C] PROM [D] Flash memory

5.8 Let Us Sum Up :

In this chapter we have seen hierarchy of memories is used in a computer system. Mainly, memory can be divided into two categories. Primary memories are those which can usually made by electronic circuits, faster and high–cost. Usually, in most computer systems, Dynamic – Random Access Memory (D–RAM) is used as a main memory which is of volatile in nature. To store the data permanently secondary memories are used. We have discussed important characteristics of memory which can be used to compare memories. Finally, we have ended our discussion with cache memory, and learn how a small size of cache memory can increase the speed of the system. In fact, in this unit we have discussed primary memories. Secondary memories we will discuss in the next unit in detail.

5.0 Glossary :

RAM : Random Access Memory. It is a primary memory of the system. It is also known as main memory.

ROM : Read Only Memory. It is a primary memory used to read the instructions. The content resided in it is not be alterable.

PROM : Programable ROM. It allows to write customizable content in it. Once it has been written it will behave like a ROM and it will become non–alterable.

EPROM : Erasable PROM. Content of the ROM can be erased using ultraviolet rays.

EEPROM : Electrically Erasable PROM.

BIOS : Basic Input Output System. A kind of ROM helps system to load operating system in the main memory from secondary memory (Booting).

SDRAM : Synchronous Dynamic RAM.

DDR SDRAM : Double Data Rate SDRAM

5.10 Suggested Answers For Check Your Progress :

❑ **Check Your Progress 1 :**

1. [B] 2. [D] 3. [A] 4. [A]

❑ **Check Your Progress 5 :**

1. [B] 2. [D] 3. [A]

❑ **Check Your Progress 3 :**

1. [A] 2. [D] 3. [A]

❑ **Check Your Progress 4 :**

1. [A] 2. [B] 3. [D]

❑ **Check Your Progress 5 :**

1. [B] 2. [B] 3. [C] 4. [B]

5.11 Assignment :

1. Write a short note on Random Access Memory.
2. What is ROM ? List and explain different types of ROM you know.

5.12 Activity :

➢ Draw the Block–Diagram of RAM and ROM.

5.13 Case Study :

Make a small note with diagram which explains Addressing block of RAM.

5.14 Further Reading :

1. Computer Fundamentals by P.K.Sinha and Priti Sinha.
2. Discovering Computers 2016 by Shelly Cashman Series. CENGAGE publications.
3. Computer Fundamentals by Pearl Software, Khanna Book Publishing.