Course Contents

Unit-03:Computer Memory (4 Hrs.)

- **Introduction;**
- **Memory Representation;**
- **Memory Hierarchy;**
- **CPU Registers;**
- **Cache Memory; Primary Memory; Secondary Memory;**
- **Access Types of Storage Devices;**
- **Magnetic Tape; Magnetic Disk; Optical Disk; Magneto-Optical Disk;**
- **How the Computer uses its memory**

Memory Representation

Memory Representation;

We store data in computer so it is important to know how different types of data (text, integer etc.) can represent in memory.

Bits, bytes, and words:

The most fundamental unit of computer memory is the bit and it can only take one of two values: it is either 0 or 1.

A collection of 8 bits is called a **byte** and a collection of 4 bytes, or 32 bits, is called a **word**.

Memory Representation

Memory Representation;

The number of bytes and words used for an individual data value will vary depending on the storage format (OS, computer hardware) but in many cases, a single letter or character of text takes up **one byte** and an integer number takes up **one word**. A real or decimal number takes up **one or two words** depending on how it is stored.

For example, the text *"hello"* would take up 5 bytes of storage, one per character. The text *"12345"* would also require 5 bytes. The integer 12,345 would take up 4 bytes (1 word), as would the integers 1 and 12,345,678. The real number 123.45 would take up 4 or 8 bytes, as would the values 0.00012345 and 12345000.0.

Memory Representation

Binary, Octal, and Hexadecimal:

A single byte of memory that contains the letter `A' (ASCII code 65; binary 1000001).

01000001

Octal: A more convenient notation is octal, where each digit represents a value from 0 to 7. Each octal digit is the equivalent of 3 binary digits, so a byte of memory can be represented by 3 octal digits.

Example: the binary code of character `A' splits into triplets of binary digits (from the right) like this: 01 000 001. So the octal digits are 101, commonly written 0101 to emphasize the fact that these are octal digits.

Memory Representation

Binary, Octal, and Hexadecimal:

Hexadecimal: An even more efficient way to represent memory is hexadecimal form. Each digit represents a value between 0 and 16, with values greater than 9 replaced with the characters A to F.

A single hexadecimal digit corresponds to 4 bits, so each byte of memory requires only 2 hexadecimal digits.

The binary form for the character `A' splits into two quadruplets: 0100 0001. The hexadecimal digits are 41

Memory Representation

Numbers: If we use two bits together to store a number, each bit has two possible states, so there are four possible combined states and each state to represent a different number.

- For example, the four possible states for 2 bits are 00, 01, 10, 11 and could store four numbers using two bits: 0, 1, 2, and 3. This representation is called binary notation.
- In general, if we use k bits, each bit has two possible states, and the bits combined can represent 2k possible states, so with k bits, we could represent the numbers 0,1,2 up to 2^k - 1.

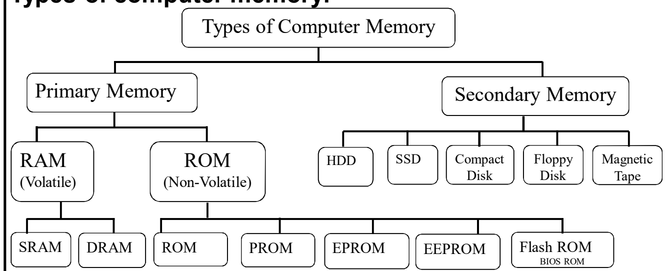
Memory Representation

Integers: Integers are commonly stored using a word of memory, which is 4 bytes or 32 bits, so integers from 0 up to 4,294,967,295 (232 - 1) can be stored. Below are the integers 1 to 5 stored as four-byte values (each row represents one integer).

```
 0 :  00000001 00000000 00000000 00000000  |  1
 4 :  00000010 00000000 00000000 00000000  |  2
 8 :  00000011 00000000 00000000 00000000  |  3
12 :  00000100 00000000 00000000 00000000  |  4
16 :  00000101 00000000 00000000 00000000  |  5
```

Memory Hierarchy

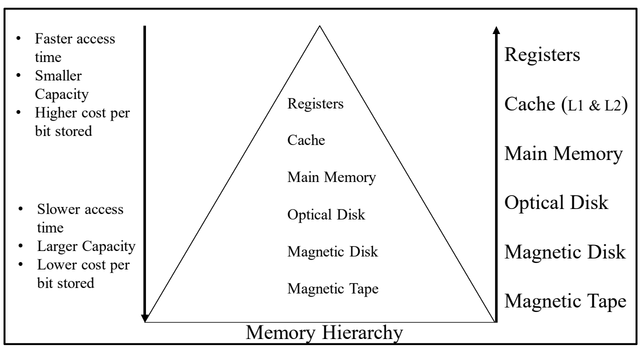
Types of computer memory:



- Very first ROM is also called **Masked ROM**
- Single Data Rate: (SDR) DRAM
- Dual Data Rate :(DDR) DRAM
- DDR2 , DDR3, and DDR4, which offer better performance and are more energy efficient than DDR. Different versions are incompatible, so it is not possible to mix DDR2 with DDR3 DRAM in a computer system.

Computer Architecture

Memory Hierarchy:



Memory Hierarchy

Memory Hierarchy

Memory and its classification:

- Computer memory in generic term is an electronic circuit to store a data in computer.
- It uses a different types of data storage technology including RAM, ROM, flash memory and secondary storage.
- Another way, computer memories are non-volatile and Volatile type
- Non-Volatile means they can store data on a long term basis even when there is no power and volatile which are often faster but lose all the data stored on them as soon as the power is switched off.

Memory Hierarchy

Memory and its classification:

- A computer system is built using a combination of these types of computer memory, and the exact configuration can be optimized to produce the maximum data processing speed or the minimum cost, or some compromise between the two.

Memory Hierarchy

Types of computer memory:

Primary Memory:

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

Secondary Memory:

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

Memory Hierarchy

Types of Primary memory:

- With computer evolution, many computer memory types has been deployed, each with its own strengths and weaknesses.

There are two key types of primary memory:

- RAM = Random Access Memory
- ROM = Read Only Memory

Memory Hierarchy

RAM Computer Memory:

- RAM stems from the fact that data stored in Random Access Memory can be accessed in any random order.
- RAM memory is very fast both in write and read.
- It is volatile (so all data stored in RAM memory is lost when it loses power).
- It is very expensive compared to all types of secondary memory in terms of cost per gigabyte.
- It is because of the relative high cost of RAM compared to secondary memory types that most computer systems use both primary and secondary memory.
- Data that is required for imminent processing is moved to RAM where it can be accessed and modified very quickly, so that the CPU is not kept waiting.
- When the data is no longer required it is shunted out to slower but cheaper secondary memory, and the RAM space that has been freed up is filled with the next chunk of data that is about to be used.

Memory Hierarchy

Types of RAM: DRAM (Dynamic RAM):

- It is the most common type of RAM used in computers.
- The oldest type is known as Single Data Rate (SDR) DRAM
- Newer computers use faster Dual Data Rate (DDR) DRAM.
- DDR comes in several versions including DDR2 , DDR3, and DDR4, which offer better performance and are more energy efficient than DDR.
- It is not possible to mix DDR2 with DDR3 DRAM in a computer system. Different versions are incompatible.

Memory Hierarchy

Types of RAM: DRAM (Dynamic RAM):

DDR3	DDR4
DDR3 stands for Double Data Rate version 3.	Whereas DDR4 stands for Double Data Rate version 4.
The cost of DDR3 is less than DDR4.	While it's cost is higher or more than DDR3.
In DDR3, auto-refresh and self-refresh are performed to refresh its content.	While in DDR4, only self-refresh is performed to refresh its content.
DDR3 consumes low power than DDR2 but less than DDR4.	Whereas DDR4 consumes low power than DDR3.
The speed of DDR3 is slightly slow in comparison of DDR4.	While it's speed is faster than DDR3.
DDR3 has a maximum of 16 GB memory.	While DDR4 has no maximum limit or capability.
The clock speed of DDR3 vary from 800 MHz to 2133 MHz.	While the minimum clock speed of DDR4 is 2133 MHz and it has no defined maximum clock speed.
DDR3 has lower latency than DDR4.	While DDR4 has slightly more latency than DDR3.

Memory Hierarchy

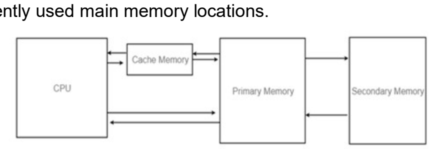
Types of RAM: SRAM (Static RAM):

- SRAM is Faster than DRAM
- More expensive and bulker, having six transistors in each cell.
- For those reasons SRAM is generally only used as a data cache within a CPU itself or as RAM in very high-end server systems.
- A small SRAM cache of the most imminently-needed data can result in significant speed improvements in a system

Memory Hierarchy

Cache Memory:

- Cache Memory is a special very high-speed memory used to speed up and synchronizing with high-speed CPU.
- Cache memory is costlier than main memory or disk memory but economical than CPU registers.
- Cache memory is an extremely fast memory type that acts as a buffer between RAM and the CPU. It holds frequently requested data and instructions so that they are immediately available to the CPU when needed.
- Cache memory is used to reduce the average time to access data from the Main memory. The cache is a smaller and faster memory which stores copies of the data from frequently used main memory locations.



Memory Hierarchy

Keys differences between DRAM and SRAM:

- The key differences between DRAM and SRAM is that SRAM is 2 or 3 times **faster** than DRAM - but more expensive and bulkier.
- SRAM is usually available in **megabytes**, while DRAM is purchased in gigabytes.
- DRAM uses **more energy** than SRAM because it constantly needs to be refreshed to maintain data integrity
- SRAM does not need constant **refreshing** when it is powered up.

Memory Hierarchy

ROM Computer Memory:

- ROM (read-only memory) means data can be read from this type of memory, data cannot normally be written to it.
- It is a very fast type of computer memory which is usually installed close to the CPU on the motherboard.
- ROM is a type of non-volatile memory, which means that the data stored in ROM persists in the memory even when it receives no power. In that sense it is similar to secondary memory, which is used for long term storage.
- When a computer is turned on, the CPU can begin reading information stored in ROM without the need for drivers or other complex software to help it communicate.
- The ROM usually contains "bootstrap code" which is the basic set of instructions a computer needs to carry out to become aware of the operating system stored in secondary memory, and to load parts of the operating system into primary memory so that it can start up and become ready to use.
- ROM is also used in simpler electronic devices to store firmware which runs as soon as the device is switched on.

Memory and its classification

Types of ROM:

- **ROM**(or **Masked ROM)** Preprogrammed set of data or instructions are stored in ROM. The contents of such ROMs have to be specified before chip production. ROM is available in several different types, including PROM, EPROM, EEPROM and Flash ROM.
- **PROM** (Programmable Read-Only Memory), and it is different from true ROM. ROM is programmed during the manufacturing process, a PROM is manufactured in an empty state and then programmed later using a PROM programmer or burner.
- **EPROM** (Erasable Programmable Read-Only Memory) and data stored in an EPROM can be erased and the EPROM reprogrammed. Erasing an EPROM involves removing it from the computer and exposing it to ultraviolet light before re-burning it.

Memory and its classification

- **EEPROM** (Electrically Erasable Programmable Read-Only Memory). Distinction between EPROM and EEPROM is that the latter can be erased and written to by the computer system it is installed in. EEPROM is not strictly read-only. However in many cases the write process is slow, so it is normally only done to update program code such as firmware or BIOS code on an occasional basis.
- Flash ROM: Also called Flash BIOS or flash memory. This memory should be constantly powered and act as non-volatile memory in computer. Function of Flash ROM are
  - Power On Self Test(POST) – Checks the major hardware components
  - BIOS Setup program – built in utility in BIOS which control how the computer works i.e. system settings, find bootable devices, interrupt handlers and device drivers
  - Bootstrap loader: is a program to start the computer software for operation when the power is ON.

Memory Hierarchy

Differences between RAM and ROM:

ROM	RAM
Non-volatile	Volatile
Fast to read	Fast to read and write
Usually used in small quantities	Used as system memory to store data (including program code) that the CPU needs to process imminently
Cannot be written to quickly	Write quickly
Used to store boot instructions or firmware	
Relatively expensive per megabyte stored compared to RAM	Relatively cheap per megabyte stored compared to ROM, but relatively expensive compared to secondary memory

Memory Hierarchy

Types of Secondary memory:

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

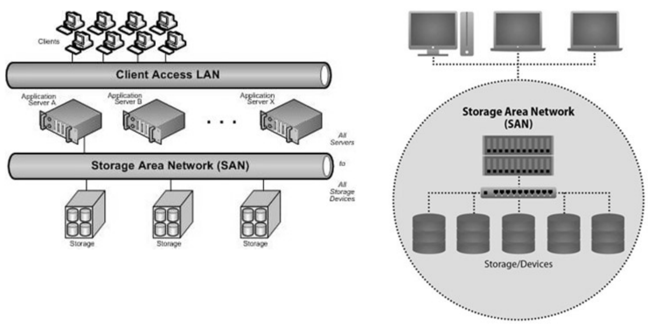
- Hard disk drives
- Solid State Drives (SSDs)
- Optical (CD or DVD) drives
- Tape drives

Secondary memory also includes:

- Storage arrays including 3D NAND flash arrays connected over a Storage Area Network (SAN)
- Storage devices which may be connected over a conventional network (known as network attached storage, or NAS)
- Cloud storage can also be called secondary memory.

Memory and its classification

Storage Area Network (SAN) **:**

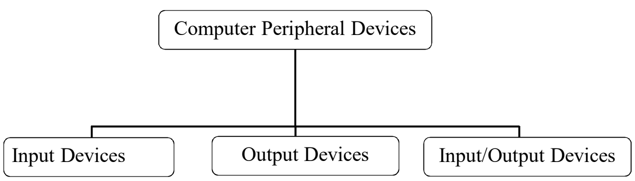


Memory and its classification

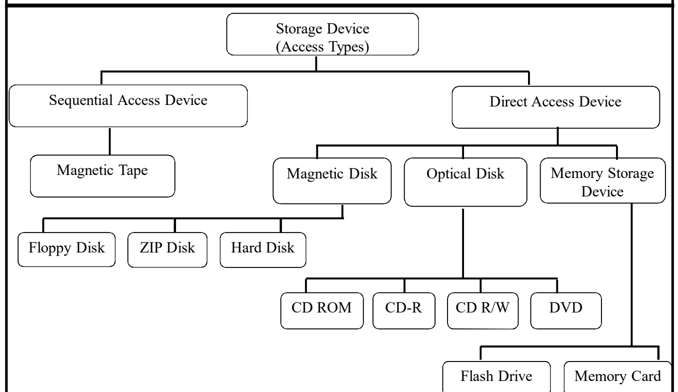
Network Attached Storage (NAS) : NAS systems are networked appliances which contain one or more storage drives, often arranged into logical, redundant storage containers or RAID. Network-attached storage removes the responsibility of file serving from other servers on the network.

Input devices, Output devices, Interfaces

Input devices, Output devices, Interfaces:



Input devices, Output devices, Interfaces



Input devices, Output devices, Interfaces

Input devices, Output devices, Interfaces:

- An input device sends information to a computer system for processing, and an output device reproduces or displays the results of that processing.
- Input devices only allow for input of data to a computer and output devices only receive the output of data from another device.
- Most devices are only input devices or output devices, as they can only accept data input from a user or output data generated by a computer.
- However, some devices can accept input and display output, and they are referred to as I/O devices (input/output devices).

Input devices, Output devices, Interfaces

Input devices:

An input device can send data to another device, but it cannot receive data from another device. Examples of input devices include the following.

- Keyboard and Mouse - Accepts input from a user and sends that data (input) to the computer. They cannot accept or reproduce information (output) from the computer.
- Microphone - Receives sound generated by an input source, and sends that sound to a computer.
- Webcam - Receives images generated by whatever it is pointed at (input) and sends those images to a computer.

Input devices, Output devices, Interfaces

Types of input devices:

- Audio conversion device
- Barcode reader
- Biometrics (e.g., fingerprint scanner).
- Business card reader
- Digital camera and digital camcorder.
- EEG (electroencephalography)
- Finger (with touch screen or Windows Touch).
- Gamepad, joystick, paddle, steering wheel, and Microsoft Kinect.
- Gesture recognition
- Graphics tablet
- Keyboard
- Light gun
- Light pen
- Magnetic ink (like the ink found on checks).
- Magnetic stripe reader
- Medical imaging devices (e.g., X-ray, CAT scan, and ultrasound images).
- Microphone (using voice speech recognition or biometric verification).
- MIDI keyboard
- MICR
- Mouse, touchpad, or other pointing devices.
- OMR (optical mark reader)
- Paddle
- Pen or stylus
- Punch card reader
- Remote
- Scanner
- Sensors (e.g., heat and orientation sensors).
- Sonar imaging devices
- Stylus (with touch screen).
- Touch screen
- Voice (using voice speech recognition or biometric verification).
- Video capture device
- VR helmet and gloves
- Webcam
- Yoke

Input devices, Output devices, Interfaces

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Computer Architecture

Output devices:

An output device can receive data from another device and generate output with that data, but it cannot send data to another device. Examples of output devices include the following.

- **Monitor** - Receives data from a computer (output) and displays that information as text and images for users to view. It cannot accept data from a user and send that data to another device.
- **Projector** - Receives data from a computer (output) and displays, or projects, that information as text and images onto a surface, like a wall or a screen. It cannot accept data from a user and send that data to another device.
- **Speakers** - Receives sound data from a computer and plays the sounds for users to hear. It cannot accept sound generated by users and send that sound to another device.

Input devices, Output devices, Interfaces

Types of output devices

- **3D Printer**
- **Braille embosser**
- **Braille reader**
- **COM (Computer Output Microfilm)**
- **Flat-panel**
- **GPS**
- **Headphones**
- **Monitor**
- **Plotter**
- **Printer (dot matrix printer, inkjet printer, and laser printer)**
- **Projector**
- **Sound card**
- **Speakers**
- **SGD (Speech-generating device)**
- **TV**
- **Video card**

Input devices, Output devices, Interfaces

Input/output devices:

An input/output device can receive data from users, or another device (input), and send data to another device (output). Examples of input/output devices include the following.

- CD-RW drive and DVD-RW drive - Receives data from a computer (input), to copy onto a writable CD or DVD. Also, the drive sends data contained on a CD or DVD (output) to a computer.
- USB flash drive - Receives, or saves, data from a computer (input). Also, the drive sends data to a computer or another device (output).

Note: Drives such as a CD-ROM, DVD, floppy diskette drive, and USB flash drive are also considered storage devices.

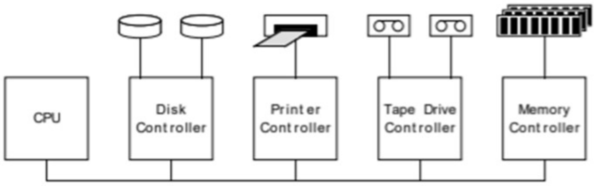
Input devices, Output devices, Interfaces

Input - Output Interface:

- Input Output Interface provides a method for transferring information between internal storage and external I/O devices.
- Peripherals connected to a computer need special communication links for interfacing them with the central processing unit.
- The purpose of communication link is to resolve the differences that exist between the central computer and each peripheral.

Input devices, Output devices, Interfaces

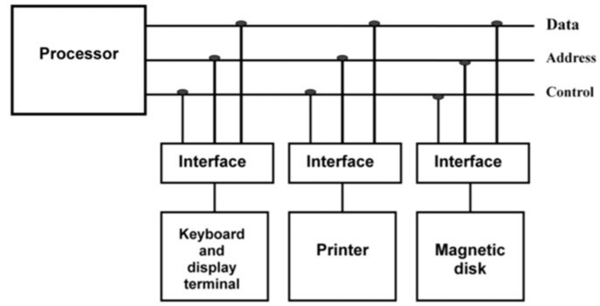
Input - Output Interface:



CPU and device controllers all use a common bus for communication

Input devices, Output devices, Interfaces

Input - Output Interface:



Connection of I/O bus to input-output devices

Input devices, Output devices, Interfaces

Input - Output Interface:

The Major Differences are:-

1. Peripherals are electromechnical and electromagnetic devices and CPU and memory are electronic devices. Therefore, a conversion of signal values may be needed.
2. The data transfer rate of peripherals is usually slower than the transfer rate of CPU and consequently, a synchronization mechanism may be needed.
3. Data codes and formats in the peripherals differ from the word format in the CPU and memory.
4. The operating modes of peripherals are different from each other and must be controlled so as not to disturb the operation of other peripherals connected to the CPU.

To Resolve these differences, computer systems include special hardware components between the CPU and Peripherals to supervises and synchronizes all input and out transfers

- These components are called Interface Units because they interface between the processor bus and the peripheral devices.

Input devices, Output devices, Interfaces

Input - Output Devices:

1. **Access Types Storage Devices**
   1. **Sequential Access**
   2. **Direct Access**
2. **Input Devices**
   1. **Human Data Entry Devices**
   2. **Source data Entry Devices**
   3. **Optical Input Devices**
3. **Output Devices**
   1. **Hard Copy Devices**
   2. **Soft Copy Devices**

Input devices, Output devices, Interfaces

Input - Output Devices:

1. **Access Types Storage Devices**
   1. **Sequential Access**
      1) **Magnetic Tape**
   2. **Direct Access**
      1) **Magnetic Disk**
      2) **Floppy Disk**
      3) **Hard Disk**
      4) **ZIP Disk (Magneto-Optical Disk)**
      5) **Optical Disk**
         1) **CD-R, CD-R/W, DVD-R, DVD-R/W**

Input devices, Output devices, Interfaces

Input - Output Devices:

1. **Access Types Storage Devices**
   1. **Sequential Access : Sequential access means the data is written or read in sequence one after another and can't go directly to the desired location without going through all preceding locations.**

Example: Magnetic Tape

A magnetic tape is a storage medium that allows for data archiving, collection, and backup. At first, the tapes were wound in wheel-like reels, but then cassettes and cartridges came along, which offered more protection for the tape inside.

Input devices, Output devices, Interfaces

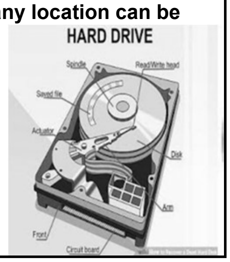
Input - Output Devices:

1. Access Types Storage Devices

2. Direct Access : Direct access devices are the ones in which any piece of data can be retrieved in a non-sequential manner by locating it using the data's address. The device is called random access because any data from any location can be read or written directly.

Example: Magnetic Disk

Data keeps in magnetized materials. Magnetic storage offers high storage capacity, reliability, and the capacity to directly accessing data. Data can be accessed randomly from magnetic disk.

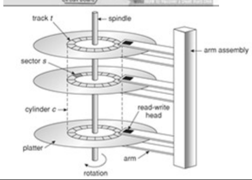


Input devices, Output devices, Interfaces

Input - Output Devices:

Magnetic Disk:

- Data can be accessed randomly from magnetic disk.
- Magnetic disk holds more data in small place and attains faster data access.
- It is a thin, circular metal plate / plotter coated with magnetic material such as iron oxide or ferrous oxide on the both side which can be magnetized.
- Data transfer rate higher than Tape system.
- Very large amount of data can be stored in a small space.
- Erased and reused many times.
- Cost is more expensive than tape system



Input devices, Output devices, Interfaces

Input - Output Devices:

Optical Disk:

- Uses optical storage techniques and technology to read and write data.
- Uses laser beams (transmitted from a laser head mounted on an optical disk drive) to read and write data.
- Primarily used as a portable and secondary storage device and has a relatively longer lifespan.
- Compact disks (CD-R, CD-R/W), digital versatile/video disks (DVD-R, DVD-R/W) and Blu-ray disks are currently the most commonly used forms of optical disks.

Input devices, Output devices, Interfaces

Input - Output Devices:

Blu-ray Disk:

- Use Blu-ray technology (blue-violet laser) is used to read Blu-ray disks.
- Compared to a DVD's red laser, a blue laser permits more information to be stored at a greater density.
- DVD can store 15 GB per layer, a Blu-ray disk can store 25 GB per layer, and dual-layer disks can hold up to 50 GB.

Optical disks are generally used to:

- Distribute software to customers
- Store large amounts of data such as music, images and videos
- Transfer data to different computers or devices
- Back up data from a local machine

Input devices, Output devices, Interfaces

Input - Output Devices:

***Blu-Ray Disk (BD)*:**

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Input devices, Output devices, Interfaces

Magnetic Vs Optical disk:

Magnetic	Optical
1. Stores data in magnetic form.	1. Stores data as dents by using a laser.
2. Data is affected by magnetic field.	2. Data is not affected by magnetic field.
3. High storage capacity.	3. Less storage capacity.
4. Does not use laser to read and write.	4. Uses a laser to read and write.
5. Easy to modify data.	5. Difficult to modify data.

Input devices, Output devices, Interfaces

2. Input Devices
   1. Human Data Entry Devices
      1) Keyboard
      2) Pointing Device (Mouse)
      3) Trackball
      4) Joystick
      5) Digitizing Tablet
      6) Pick Devices (Light Pen, Touch Screen)
   2. Source data Entry Devices
      1) Audio Input Device
      2) Video Input Device

Input devices, Output devices, Interfaces

2. Input Devices
   3. Optical Input Devices
      1) Scanner (Hand-held Scanner, Flat-bed Scanner)
      2) OCR (Optical Character Recognition)
      3) MICR (Magnetic Ink Character Recognition)
      4) OMR (Optical Mark Recognition)
      5) Barcode Reader

Input devices, Output devices, Interfaces

3. Output Devices
   1. Hard Copy Devices
      1) Printer
      2) Plotter
      3) Computer Output on Microfilm (Microfiche)
   2. Soft Copy Devices
      1) Monitor
      2) Visual Display Terminal
      3) Video Output (CRT, LCD, LED)
      4) Audio Response

Input devices, Output devices, Interfaces

1. Human Data Entry Devices

Input devices that require data to be entered manually to the computer are identified as Human Data Entry Devices. The data may be entered by typing or keying in or by pointing a device to a particular location.

1) Keyboard
2) Pointing Device (Mouse)
3) Trackball
4) Joystick
5) Digitizing Tablet
6) Pick Devices (Light Pen, Touch Screen)
7) Video Input Device

Input devices, Output devices, Interfaces

2. Source Data Entry Devices

Source Data Entry Devices are used for audio input, video input and to enter the source document directly to the computer. Source data entry devices don’t require data to be typed-in, keyed-in, or pointed to a particular location.

1) Audio Input Device
2) Video Input Device

Input devices, Output devices, Interfaces

3. Optical Input Devices

Optical or optical technology refers to anything that relates to light or vision, whether it be visible light or infrared light that performs a specific function. So optical input devices allow computer to use light as a source of input.

1) Scanner (Hand-held Scanner, Flat-bed Scanner)
2) OCR (Optical Character Recognition)
3) MICR (Magnetic Ink Character Recognition)
4) OMR (Optical Mark Recognition)
5) Barcode Reader

How the computer uses the memory

How the CPU Uses Memory:

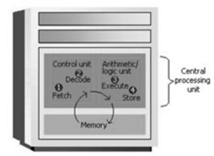
- Computer memory refers to the area where data and programs are stored. Memory is not part of the CPU, but the CPU must interact closely with it.
- There are two types of computer memory: **primary, or main**, and **secondary**. The CPU relies heavily on main memory for storing program instructions and the data on which the instructions operate on. Main memory is temporary in nature and only holds instructions and data for a program while the program is executing. Secondary memory is the more permanent storage provided by hard drives and flash drives.
- A component of the CPU known as the control unit is responsible for moving instructions and data from secondary storage into main memory prior to instruction execution. The control unit also moves the results of an instruction to secondary storage.

How the computer uses the memory

How the CPU Uses Memory:

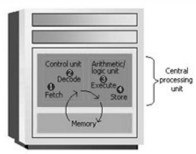
Before an instruction can be executed, program instructions and data must be placed into memory from an input device or a secondary storage device
Once the necessary data and instruction are in memory, the central processing unit performs the following four steps for each instruction:

Steps in next slide….



How the computer uses the memory

Steps:



1. The control unit fetches (gets) the instruction from memory.
2. The control unit decodes the instruction (decides what it means) and directs that the necessary data be moved from memory to the arithmetic/logic unit. These first two steps together are called instruction time, or I-time.
3. The arithmetic/logic unit executes the arithmetic or logical instruction. That is, the ALU is given control and performs the actual operation on the data.
4. The ALU unit stores the result of this operation in memory or in a register. Steps 3 and 4 together are called execution time, or E-time.

8085 CPU Block Diagram

8085 Block Diagram:

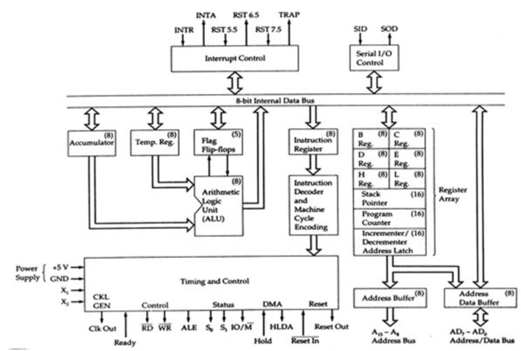


Figure: Intel 8085 CPU Block Diagram

How CPU Works

How a Computer Processor Works:

Example:

MVI A, 7F	**Copy value 7F from memory to accumulator register "A"**
ADI	Add 0F with accumulator and save in register "A"

MEMORY	
Memory Address	Memory Contents
1000	3E = 0011 01110
1001	7F = 0111 1111
1002	C6 =1100 0110
1002	0F = 0000 1111

Opcode	Operand	Machine code/Hex code	Byte description
MVI	A, 7FH	3E	First byte
		7F	Second byte
ADI	0FH	C6	First byte
		0F	Second byte

Table 4 Examples of three byte instructions

Opcode	Operand	Machine code/Hex code	Byte description
JMP	9050H	C3	First byte
		50	Second byte
		90	Third byte
LDA	8850H	3A	First byte
		50	Second byte
		88	Third byte