ECOLE SUPÉRIEURE POLYTECHNIQUE INTERNATIONALE PRIVÉE
DE SFAX

Chapter 2

COMPUTER MEMORY

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PhD in electrical engineering

Digital circuits and computer architecture

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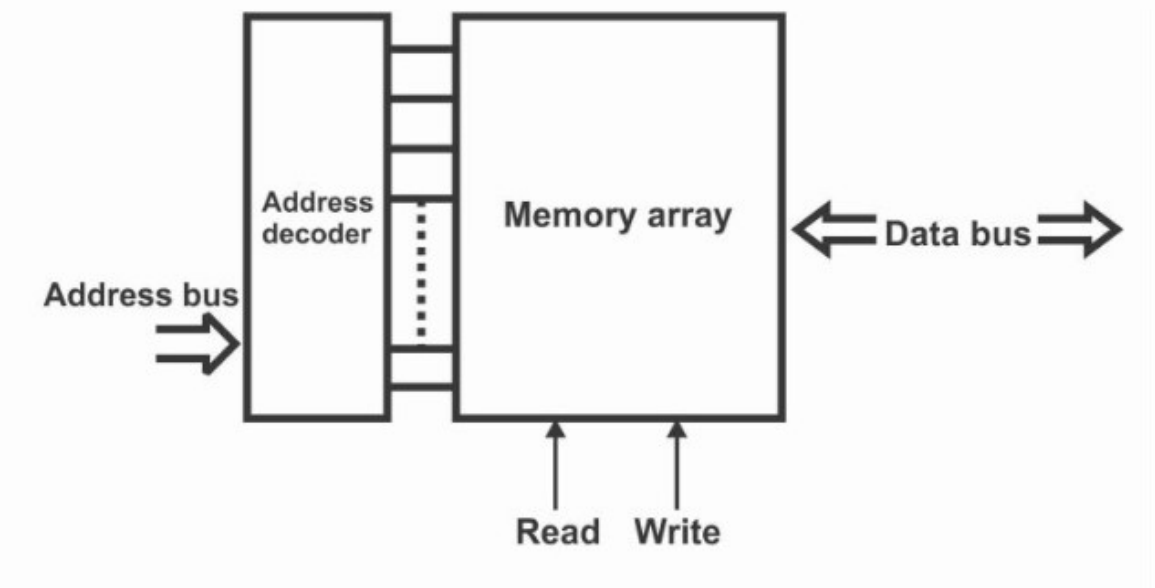
Memory

What is Computer Memory?

Essential component of a computer is the memory which it uses to hold data currently being used by the processor

Computer memory is a data storage unit or a data storage device where data is to be processed and instructions required for processing are stored.

Memory



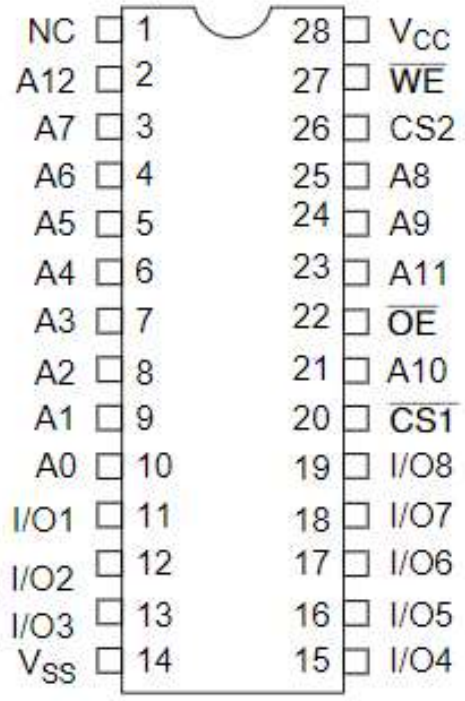
- Data lines (Bus) provide the information to be stored in memory.
- The control inputs specify the direct transfer.
- The k-address lines (Bus) specify the word chosen.
- When there are k address lines, 2^k memory words can be accessed.

Memory

Memory Devices

A digital memory device is an integrated circuit with:

- address pins
- data pins (occasionally there may be separate input and output pins)
- one or more chip select pins (enable controls)
- a read pin
- a write pin



Characteristics of memory devices

1. Location:

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

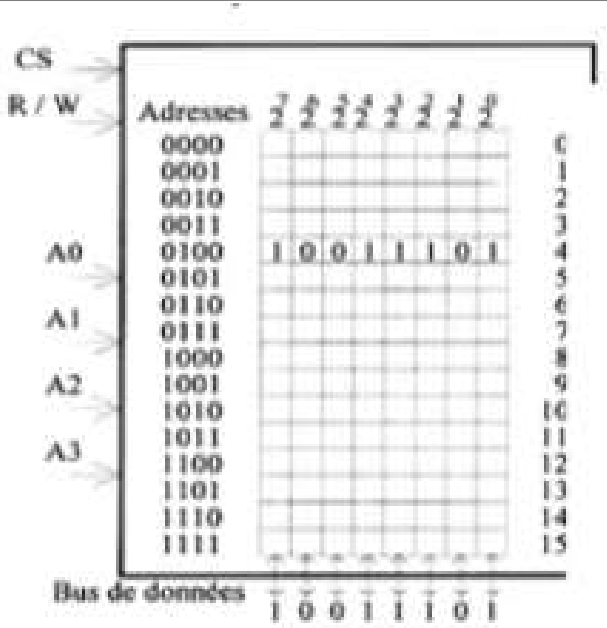
•CPU : This is often in the form of CPU registers and small amount of cache

•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.

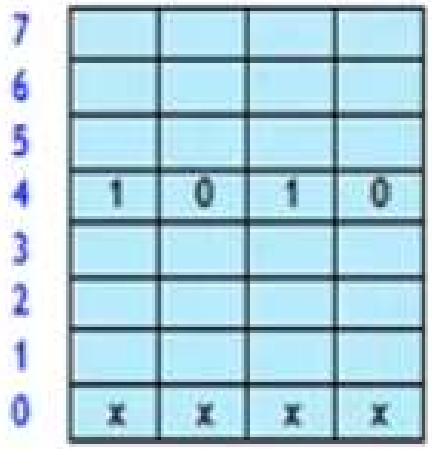
Characteristics of memory devices

2.Capacity:
The capacity of any memory device is expressed in terms of:
Word size: Words are expressed in bytes (8 bits). 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.

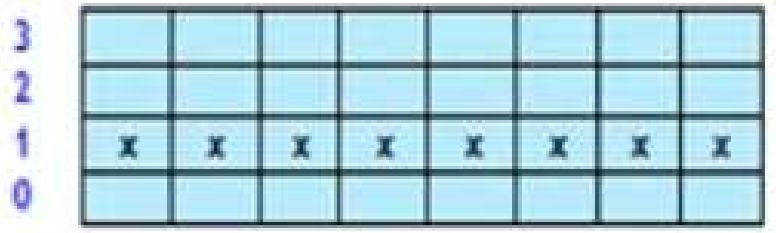


Adress line k: 4
Memory locations 2^4
Data line n: 8 bits
Memory size: 2^4X8=16Bytes=128 bits

Characteristics of memory devices



Memory locations $8 = 2^3$
Adress line : 3
Data line : 4 bits
Memory size : 4 Bytes=32 bits



Memory locations $4 = 2^2$
Adress line : 2
Data line : 8 bits
Memory size : 4 Bytes=32 bits

Characteristics of memory devices

3.Access Time: it is the time taken by memory to complete the read/write operation from the instant that an address is sent to the memory. Access time is widely used to measure performance of memory devices.

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

5.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.

6. 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).

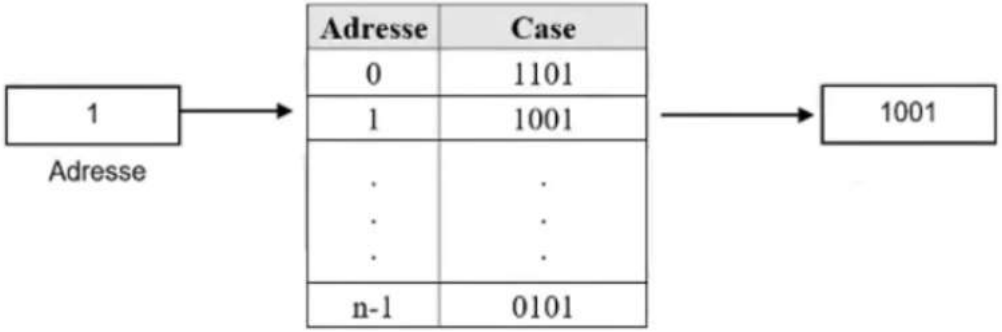
Memory Access Methods

1. Sequential Access

In this method, data is accessed in a sequential manner, with the computer accessing data one piece at a time in a specific order. In these devices, data is stored on a tape in a linear sequence, and the computer must read through the data sequentially to find the desired information. Exp: Magnetic tape storage device

2. Random Access

Random access memory (RAM) allows the computer to access any location in memory directly without having to access the data sequentially. This method allows for quick read and write speeds and is commonly used in the computer's main memory.



Memory Access Methods

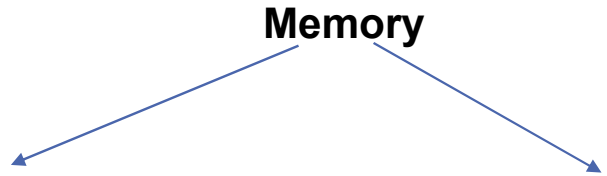
3. Direct Access

Direct access allows the computer to access specific data without having to read through other data first. Hard disk drives and solid-state drives (SSDs) use direct access. In these devices, data is stored in sectors or blocks that can be accessed directly without having to read through other data first.

4. Associative Access

In associative access, data is accessed based on its content rather than its location in memory. Cache memory uses associative access. In cache memory, data is stored based on its content rather than its location in memory, allowing for quick access to frequently used data.

Memory



Primary memory

- It is called main memory in computer
- It communicates directly with the CPU, Cache and Auxiliary memory.
- It keeps data and programs when the process is active to use them.
- When a program or the data is activated for execution, the processor loads instructions from the secondary memory into the main memory and then starts execution.
- Primary memory is of two types: RAM and ROM

Secondary memory

- A memory that has a larger storage capacity and from which data and programs are not lost when the computer is turned off.
- The cost of secondary memory is less as compared to primary memory.
- Hard disk, Compact Disc, USB flash drive

Read-Only Memory (ROM)

ROM:

- A permanent storage type.
- It only reads the stored information, but it does not have the capability to modify or write.
- Includes those programs which run on booting of the system (known as a bootstrap program that initializes OS) along with data like algorithm required by OS.

Types of ROM:

•**PROM:** *Programmable ROM* can be modified once by the user. The user buys a blank PROM and writes the desired content but once written content cannot be altered.

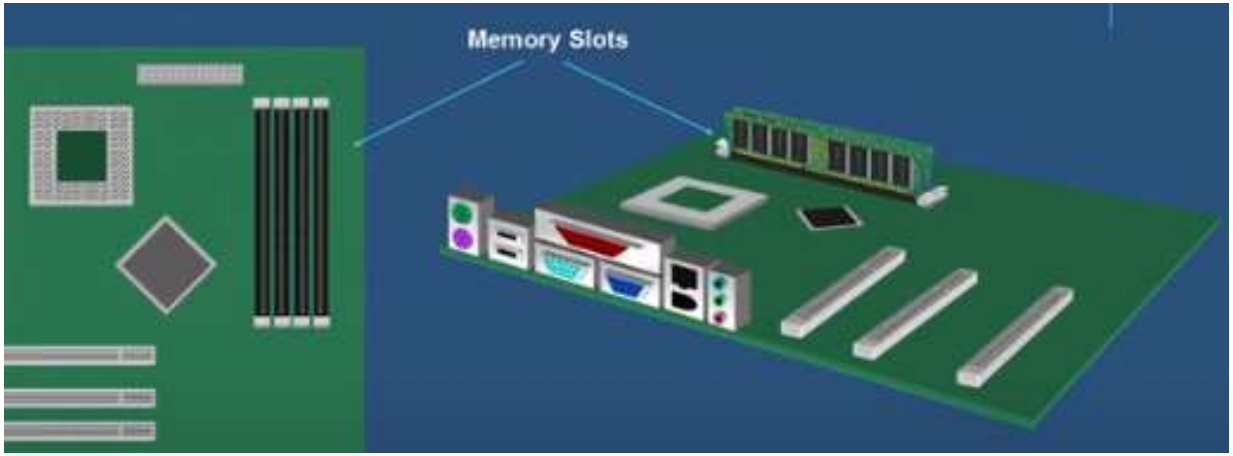
•**EPROM:** *Erasable and Programmable ROM* Content can be changed by erasing the initial content which can be done by exposing EPROM to UV radiation. This exposure to ultra-violet light dissipates the charge on ROM and content can be rewritten on it.

•**EEPROM:** *Electrically Erasable and Programmable ROM* is an electrically erasable and programmable ROM. This allows data to be erased using a high-voltage electrical charge. After this, it can be reprogrammed up to thousands of times.

Random Access Memory (RAM)

- Volatile : Any data held in RAM is normally lost when the computer is turned off.
- Stored on the motherboard in moudules that are called DIMMs (*Dual Inline Memory Module)*
- Can have 168, 184, 240 or 288 pins
- The processor stores data in RAM and retrieves data from it.
- The more RAM a computer has, the faster the computer programs will run.

Random Access Memory (RAM)



RAM is installed on the motherboard in the memory slots.

The average motherborad will have between 2 and 4 memory slots.

Random Access Memory (RAM)

RAM requires constant electrical power to store data

RAM

Dynamic RAM or DRAM

- It is made up of capacitors
- It needs to periodically refresh in a few milliseconds to retain data

Static RAM or SRAM

- It keeps the data as long as power is supplied to the system.
- uses Sequential circuits to store a bit
- It is expensive and hence only used where speed is the utmost priority

Dynamic RAM (DRAM)

SDRAM : *Synchronous Dynamic Random Access Memory*

Used today in RAM DIMMs

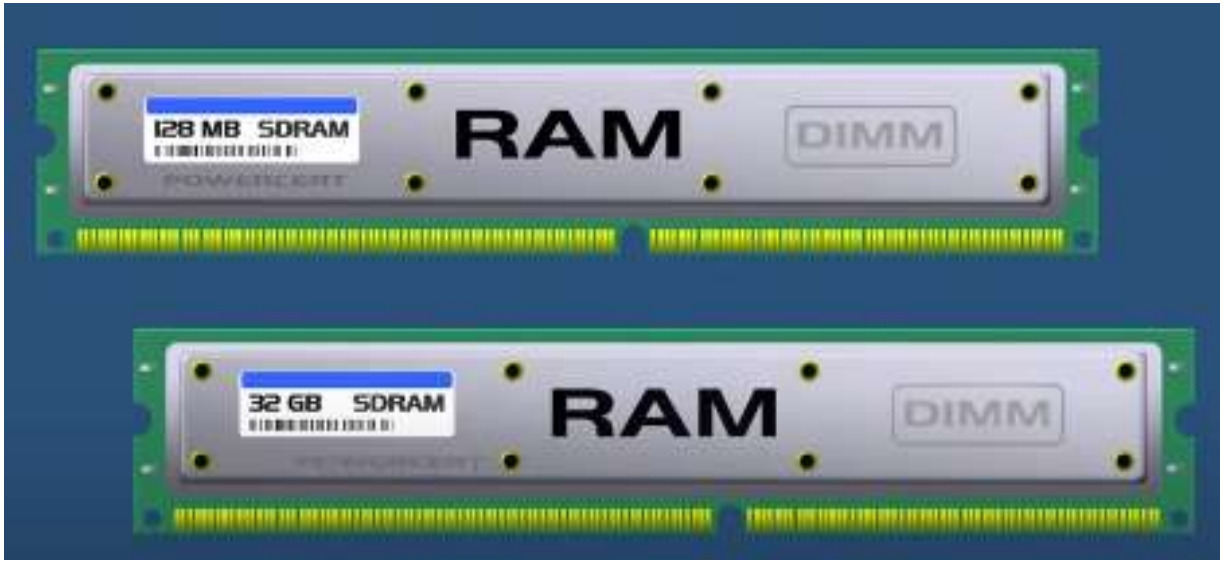
DRAM operates Asynchronously with the system clock

SDRAM operates Synchronously with the system clock

SDRAM is faster than DRAM
All signals are aligned with system clock for better controlling time.

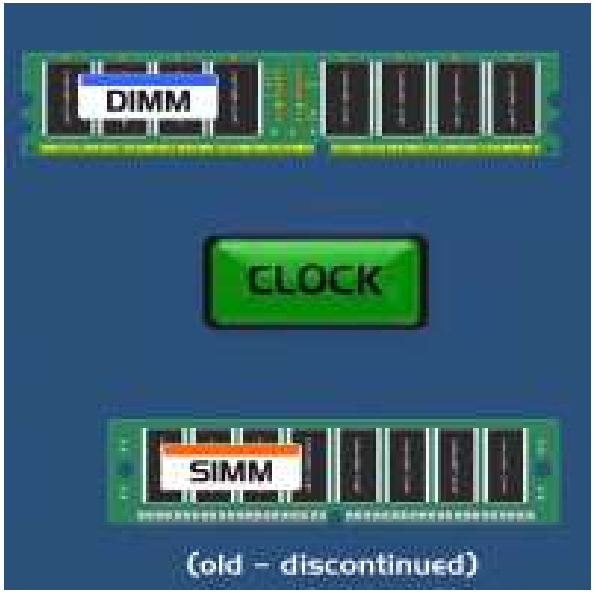
Dynamic RAM (DRAM)

DIMMs have different memory sizes, the range can be from 128 MB to 32 GB per DIMM



Dynamic RAM (DRAM)

- The term 64 or 32 bit data path refers to the numbrer of bits of data that are tranffered in 1 clock cycle
- The more bits that are transferred in 1 clock cycle the faster the computer will be



DIMM (Dual Inline Memory Module : Transfers 64 bits at a time

8 bits= 1 byte
64 data path 64/8=8 bytes wide data path (bus)

SIMM (Single Inline Memory Module) : Transfers 32 bits at a time

DIMMs are faster than SIMMs as they can trasferer twice the amount of data per clock cycle

Dynamic RAM (DRAM)

Examples of SDRAM:

PC 100
100 MHz is the speed at which it operates
8 byte wide bus
Bandwith: 100 X 8 = 800 MB/s (It can transfere data at maximum rate of 800 megabytes per second)

PC 133
133 MHz is the speed at which it operates
8 byte wide bus
Bandwith: 133 X 8 = 1066 MB/s (It can transfere data at maximum rate of 1066 megabytes per second)

Dynamic RAM (DRAM)

RDRAM (*Rambus Dynamic Random Access Memory)*

- RIMM : Rumbus Inline Memory Module

- It has 184 pins
- Looks similar to DIMMs
- Bottom nutches are near the center of the module

- It is developed by Rambus inc

RDRAM speed was at 800MHz (SDRAM speed was 133MHz)

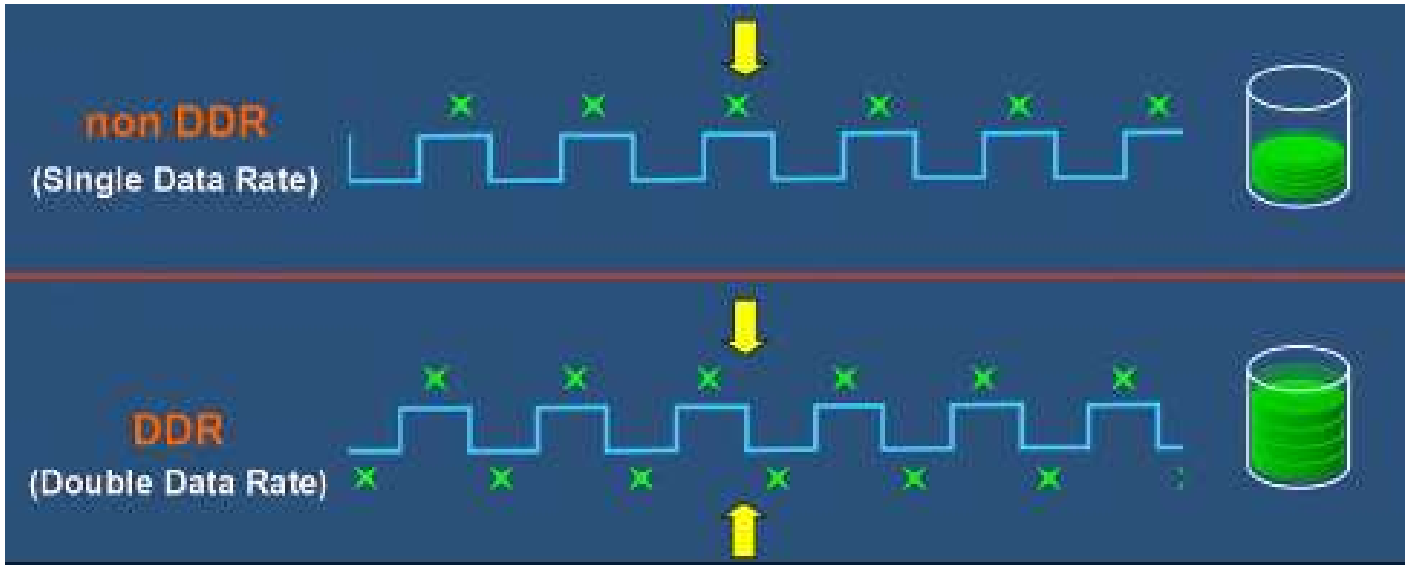
It has only 2 bytes wide bus (SDRAM has 8 bytes wide bus)

Bandwith 800 X 2 = 1600 MB/s

Dynamic RAM (DRAM)

DDR – Double Data Rate

- It sends double the aount of data in each clock signal

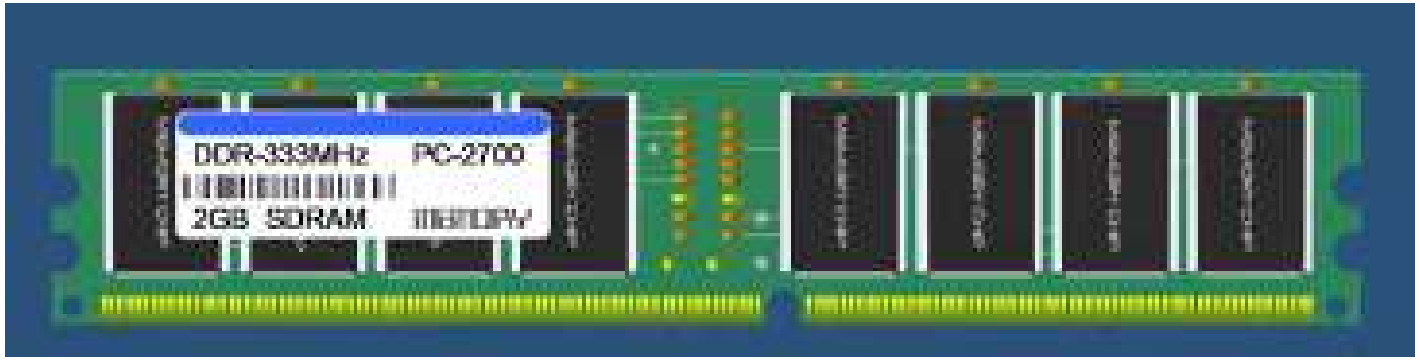


DDR RAM modules can send twice the amount of data since it takes advantages of both rasing and falling edge of clock signal.

Dynamic RAM (DRAM)

DDR – Double Data Rate

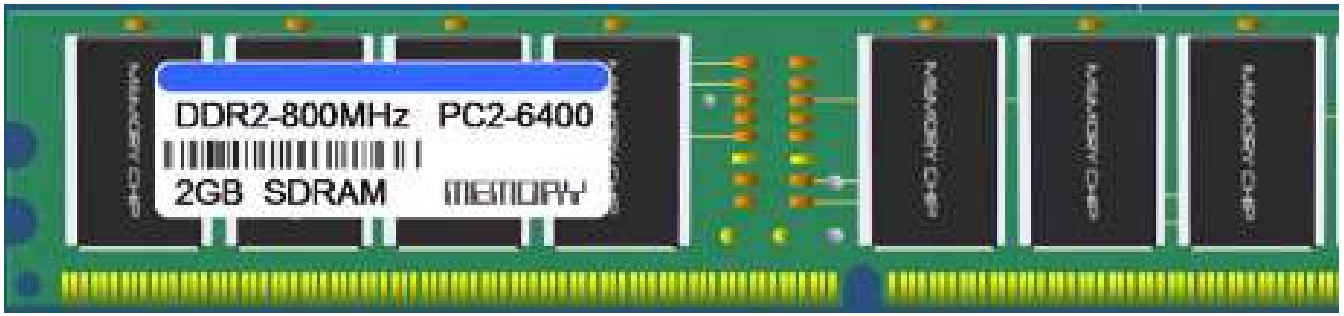
- **DDR 333 PC 2700**



- DDR may include both the clock speed and the total bandwith in its name
- 333 MHz X 8 Bytes=2700 MB/s
- Voltage 2.5 V

Dynamic RAM (DRAM)

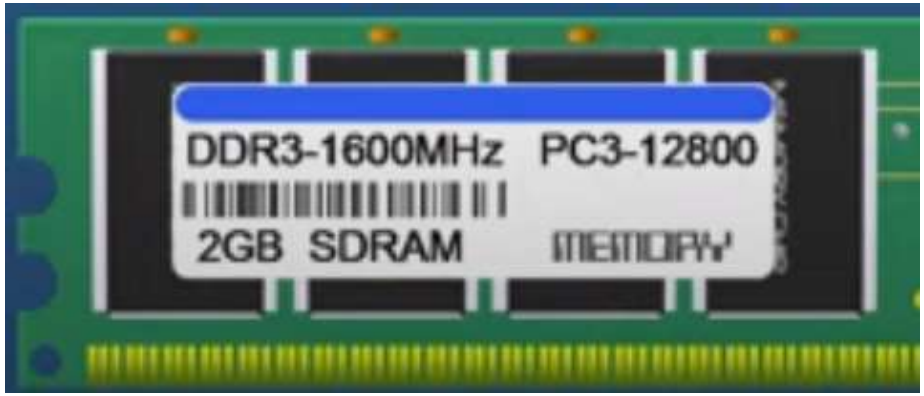
DDR2



- DDR2 is faster than DDR because it allows for higher bus speed
- Has 240 pins compared to DDR (184 pins)
- It incules ‘2’ in its label
- Voltage 1.8 V

Types of Dynamic RAM (DRAM)

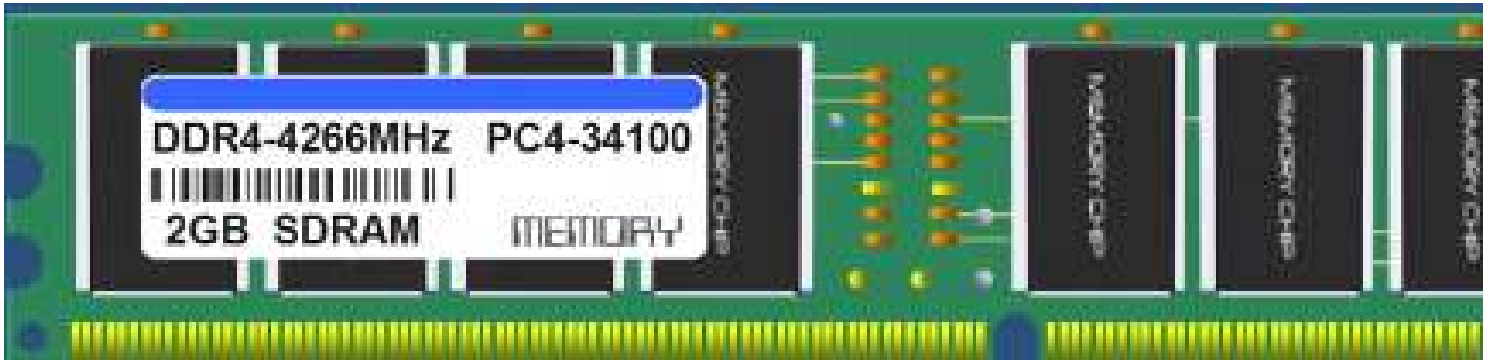
DDR3



- DDR3 is faster than DDR2 because it allows for higher bus speed
- It has 240 pins
- It incules ‘3’ in its label
- Voltage 1.5 V

Types of Dynamic RAM (DRAM)

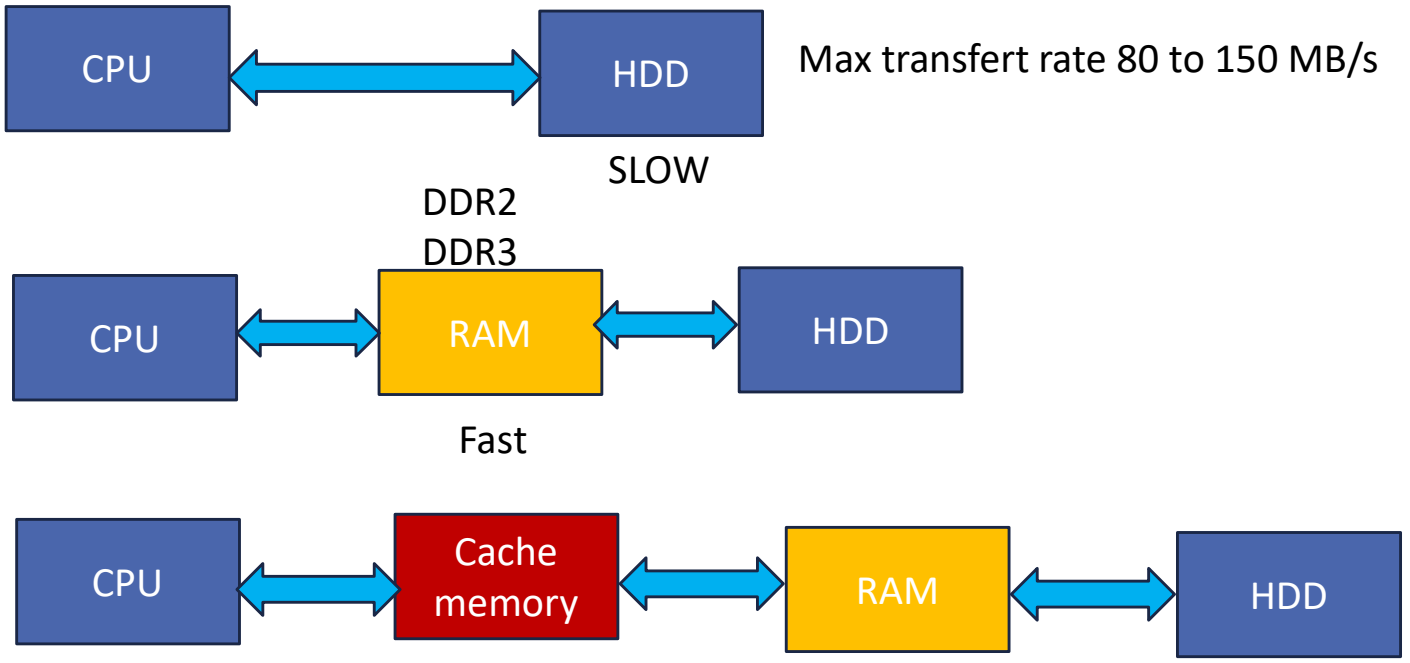
DDR4



- It has 288 pins
- It offers higher range of speed than DDR3
- Voltage 1.2 V

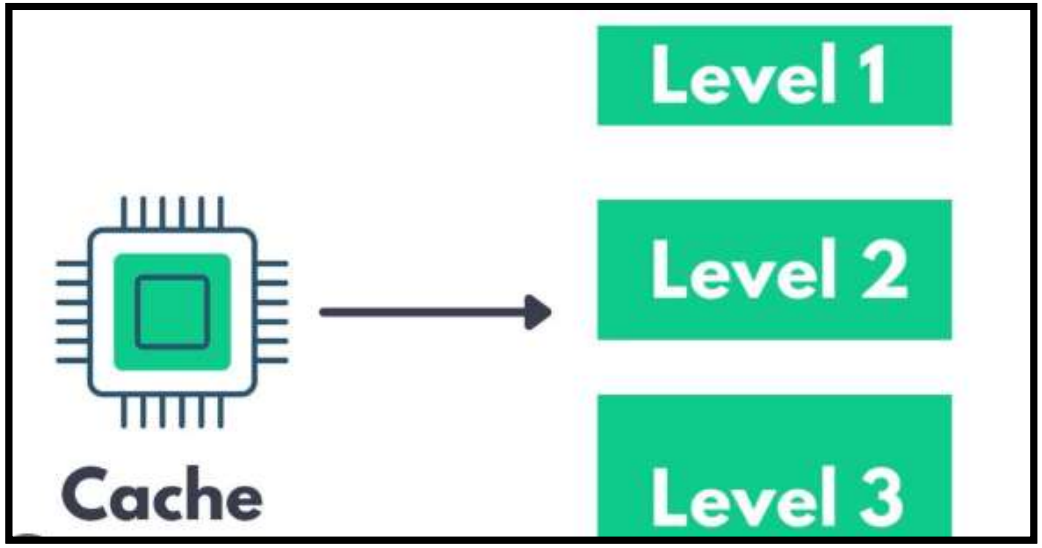
Cache memory

Clock of CPU 1 GHz to 4GHz



Cache memory

- Cache Memory is a special very high-speed memory.
- The cache is a smaller and faster memory that stores copies of the data from frequently used main memory locations.
- There are various different independent caches in a CPU, which store instructions and data.
- The most important use of cache memory is that it is used to reduce the average time to access data from the main memory.
- Cache memory is fast and **expensive**.



Memory size 2KB to 64 KB

Memory size 256KB to 512 KB

Memory size 1MB to 8MB

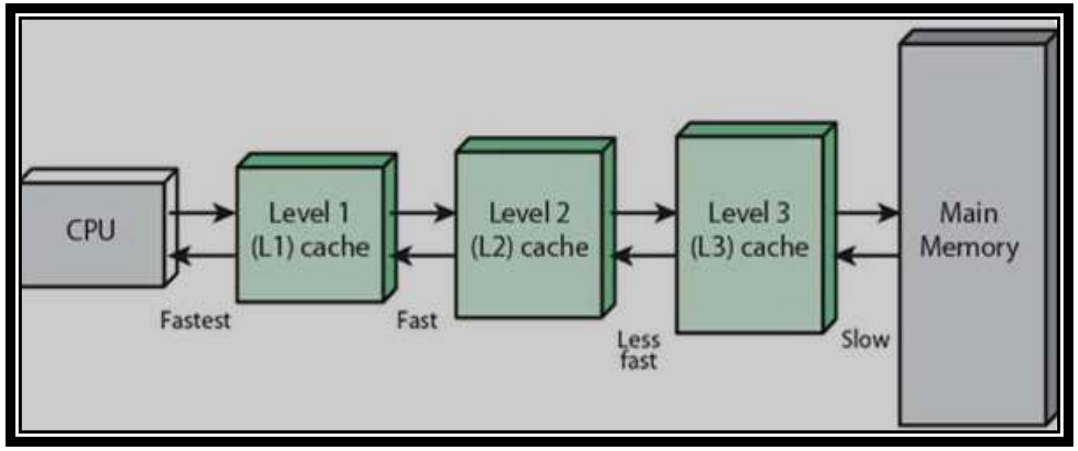
Cache memory

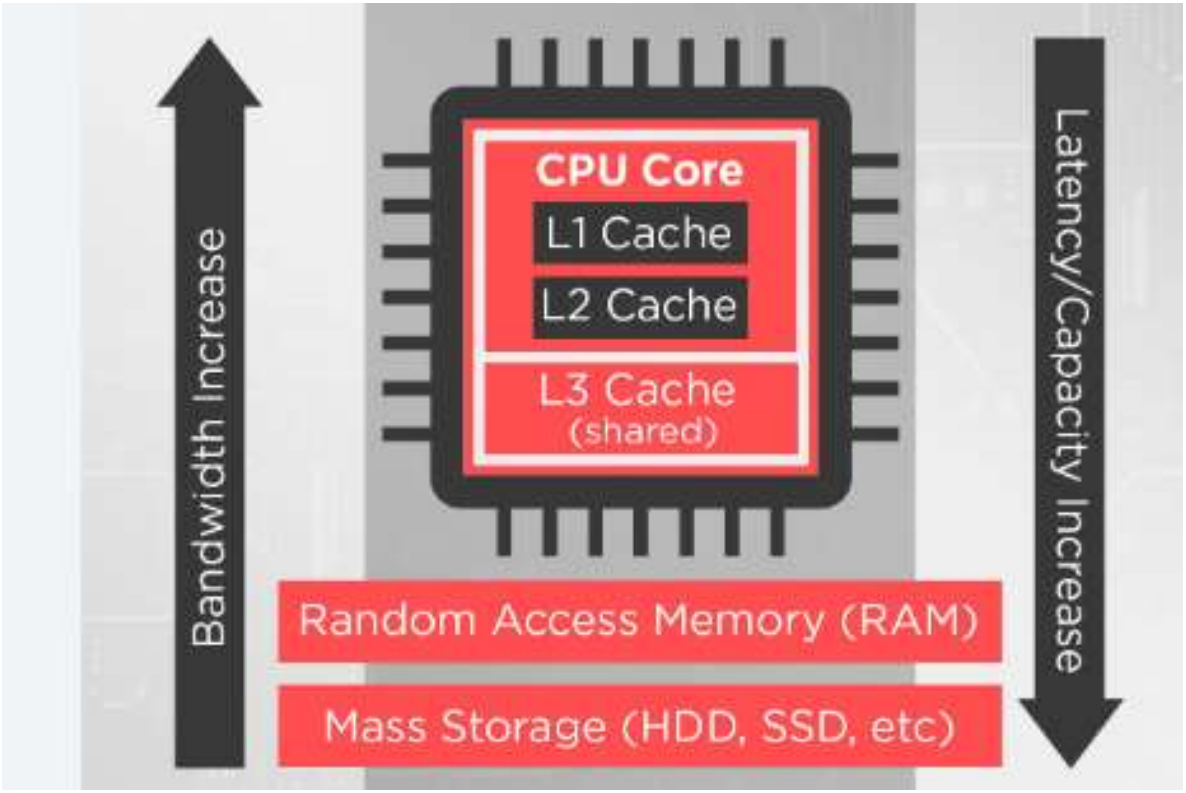
L1 cache, or primary cache, is extremely **fast** but relatively small, and is usually embedded in the processor chip as CPU cache.

L2 cache, or secondary cache, is often more capacious than L1. L2 cache may be embedded on the CPU, or it can be on a separate chip.

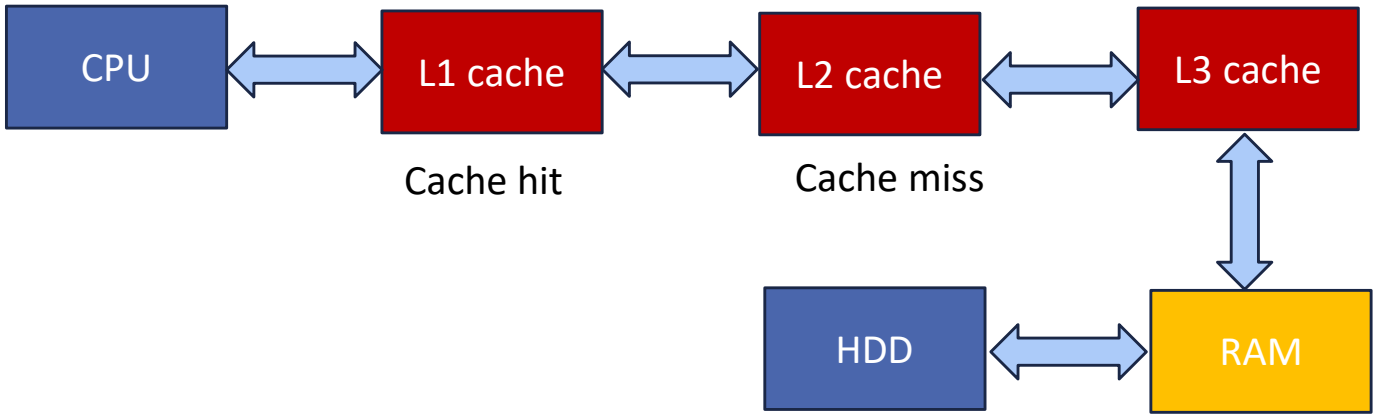
Level 3 (L3) cache is specialized memory developed to improve the performance of L1 and L2. L1 or L2 can be significantly faster than L3

With multicore processor, each core can have dedicated L1 and L2 cache, but they can share an L3 cache.




Bandwidth Increase
CPU Core
L1 Cache
L2 Cache
L3 Cache
(shared)
Random Access Memory (RAM)
Mass Storage (HDD, SSD, etc)
Latency/Capacity Increase

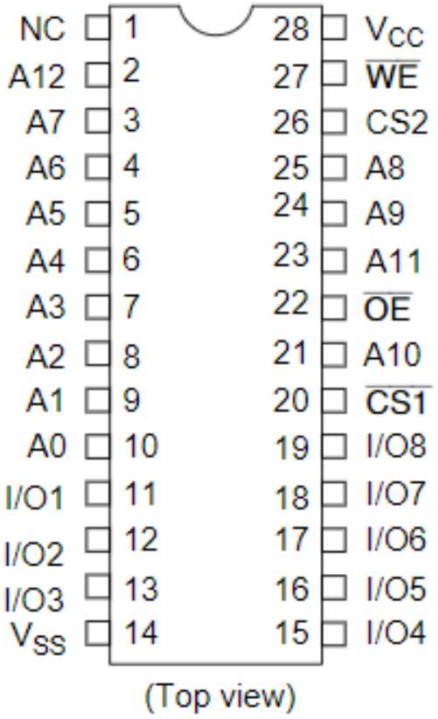
Process flow



Question 1

Considering 6264 memory given by the following figure,

a) Find the number of adress lines and the number of locations
b) Find the data line
c) Calculate the memory size



Question 2

1. For A adress line and D data line, calculate memory size for each case:

a) A=20, D=8

b) A=30, D=16

c) A=30, D=32

2. Find the number of adress line and data line of 16MBytes memory

Question 3

1.If the adress line is A= 32, find:

a) the number of memory blocks (number of locations) if one block contains 1 Byte

b) the number of memory blocks (number of locations) if one block contains 32 bits

2.Give the size of the memory in each case

Question 4

A computer has memory locations that have the following hexadecimal adress: from $(200)_{16}$ to $(3FF)_{16}$ and from $(4000)_{16}$ to $(7FD0)_{16}$.

Find total number of locations

Question 5

A memory system of size 16KBytes is required to be designed using memory chips which has 12 adress lines and 4 data lines each.

Find the number of chip required to design the memory?

Question 6:
How many memory chips are required for a memory capacity of 2KiloBytes?
a)512 X 8 bits
b) 2048 X 4 bits
c) 256 X 4 bits

Q.1: What is Volatile and Non Volatile memory?

Answer:

Volatile memory is used to store information based on power supply. If the power supply is off, all the data and information on this memory will be lost. For example, RAM (Random Access Memory). Whereas non-volatile memory is used to store information even when the power supply is off. For example, ROM (Read Only Memory).

Q.3: Explain any four differences between RAM and ROM?

Answer:

RAM	*ROM*
It stands for Random access memory.	*It stands for read only memory.*
It is the fastest memory.	*It is slower memory as compare to RAM.*
It is volatile memory.	*It is non-volatile memory.*
In this memory, data will erase when the power is off	*In this memory, data will not erase even if the power is off*