# Unit 5: Memory

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**Bibliography**


Digital fundamentals.

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- Digital Design.

M. Morris Mano. Prentice-Hall

- Introduction to Digital Logic Design.

John P. Hayes. Addison-Wesley

# Basic concepts

- **Memory**: Part of the computer that stores information: instructions and data.

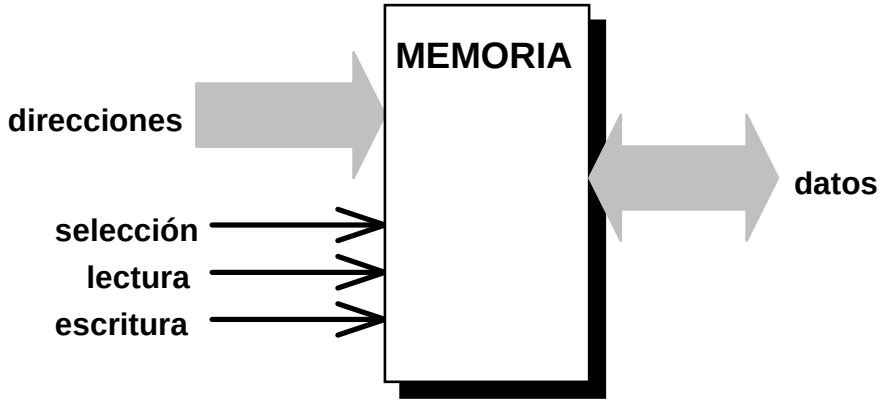
  Organization:

  - **Address:** Identifies memory position
  - **Content:** stored information

- **Memory cell:** Minimum storing element: one bit
- **Word:** group of bits implied in each memory operation (8, 16, 32, 64, ... bits).

  It defines data bus size

- **Basic operations:**
  - Read (R)
  - Write (W)



# Characteristic Parameters (I)

- **Capacity**: Maximum quantity of information that a memory system can store
  - Usual measures:

    Kilobyte (Kb) = $2^{10}$ bytes

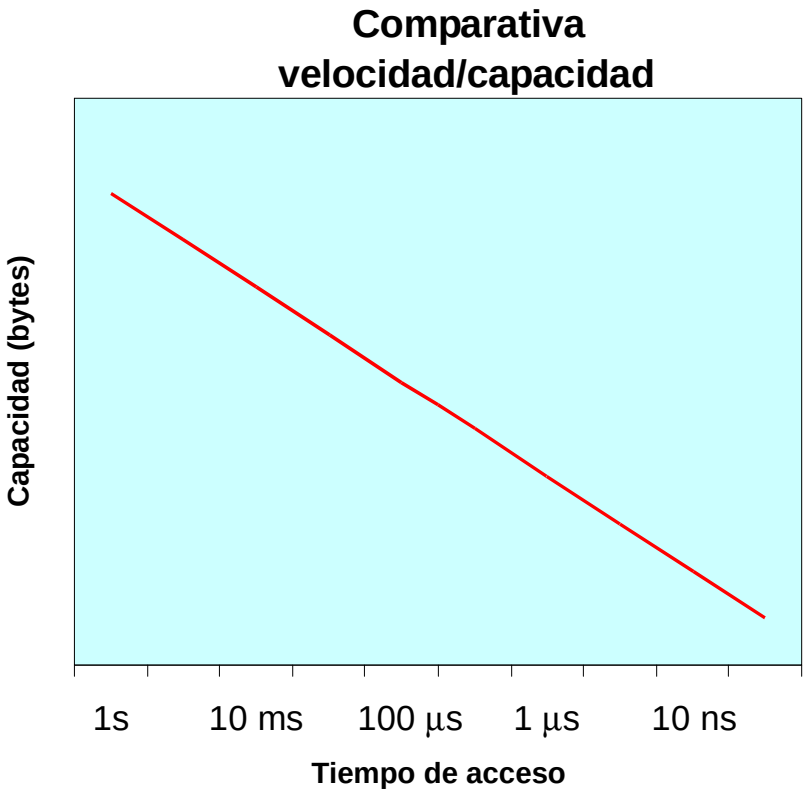
    Megabyte (Mb) = $2^{10}$ Kb = $2^{20}$ bytes

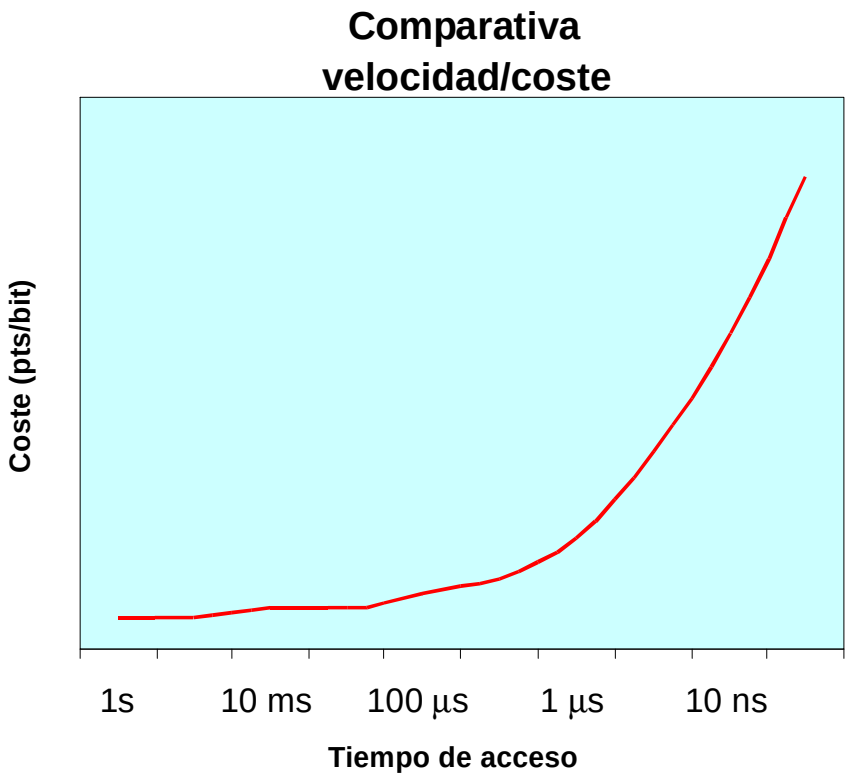
    Gigabyte (Gb) = $2^{10}$ Mb = $2^{30}$ bytes

    Terabyte (Tb) = $2^{10}$ Gb = $2^{40}$ bytes

- **Velocity** or **access time:** Elapsed time since the moment a memory address is provided until the data contained in it is accessible
- **Memory cycle:** Elapsed time between two consecutive memory accesses.
- **Bit cost:** Total memory cost divided by its capacity in bits

# Characteristic Parameters (II)

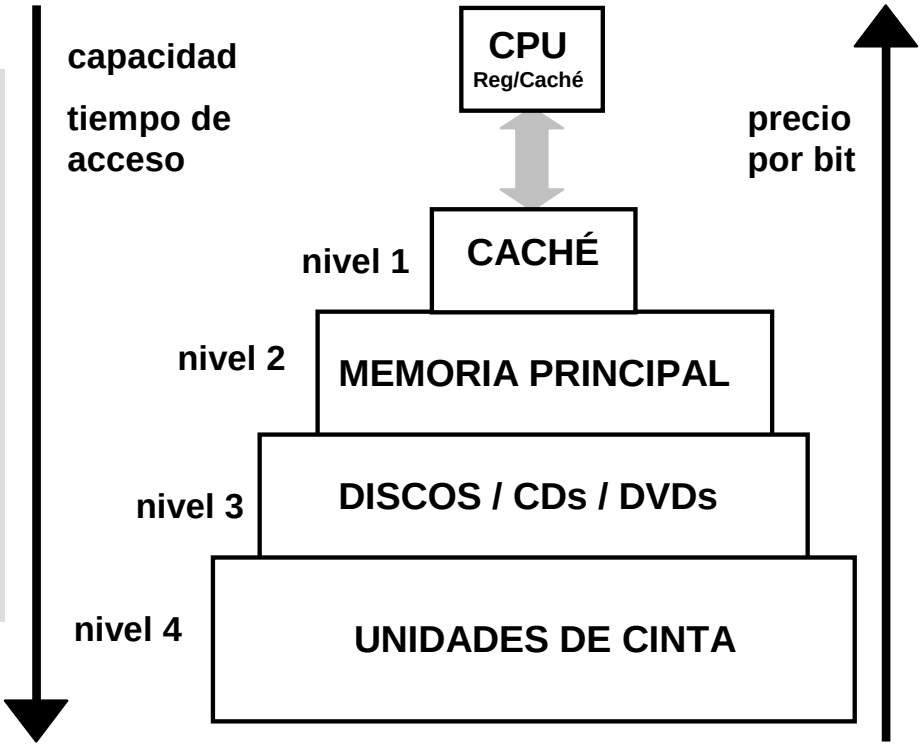


# Memory hierarchy

**Hierarchy**:

- CPU registers
- Internal cache
- External cache
- Principal memory (RAM)
- External/secondary storing devices (Hard Discs, CDs, DVDs, pen drive, magnetic tapes, etc…)



# Memory Technologies

**RAM** *Random Access Memory* **(volatile, read/write)**

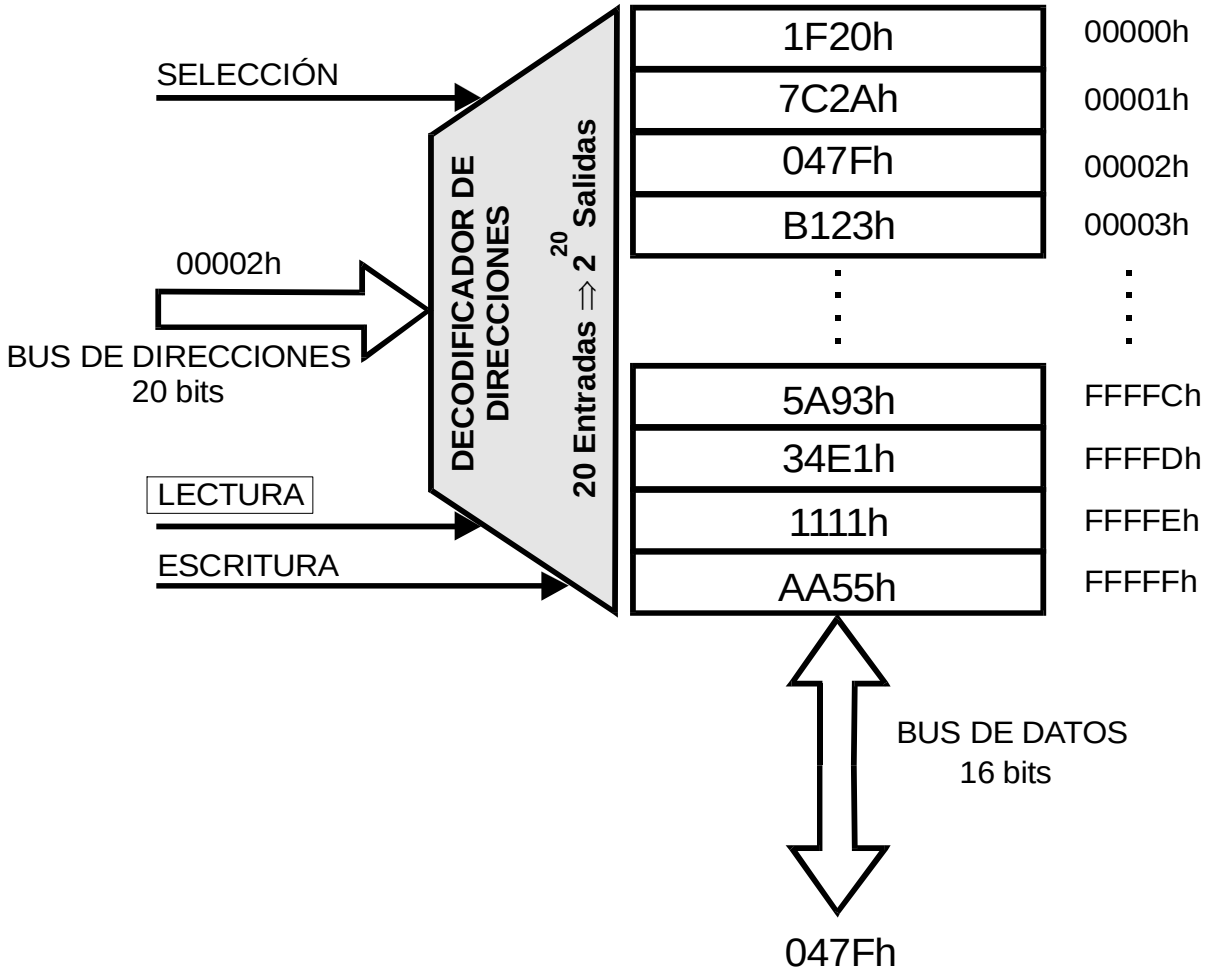
- SRAM – Static RAM
- DRAM - Dynamic RAM
  - SDRAM - Synchronous Dynamic RAM

**ROM** *Read Only Memory* **(non-volatile,** only **read)**

- PROM - *Programmable ROM* –
- EPROM - *Erasable PROM*
- EEPROM - *Electrically EPROM* –

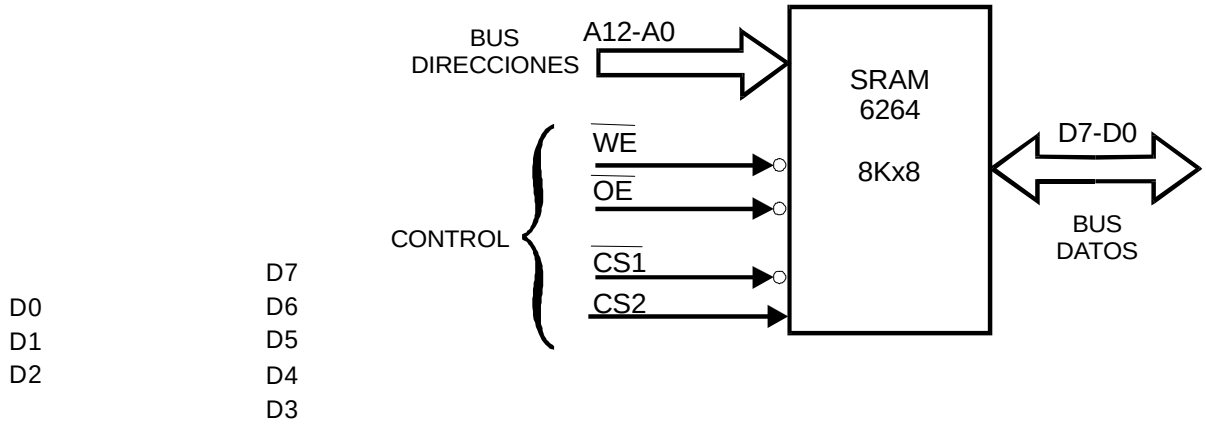
**FLASH** – **(non-volatile,** only **read/write).** Pen drives, cameras**….**

# Principal Memory: structure (I)



# Principal Memory: structure (II)

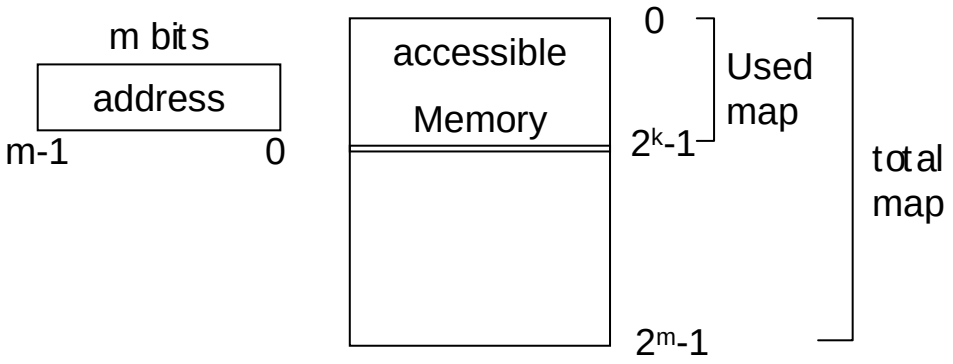
Example: static RAM 8Kx8



# Memory map (I)

## Memory map

- Organization and structure of the addressable space in a computer
- It is determined by the quantity of addresses and the size of the content of each address (word size)
  - Size of address bus, *m*, determines number of addresses, $2^m$
  - Size of data bus, *n,* generally equals the size of the content of each address (word)

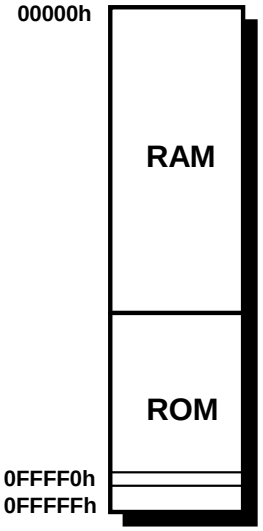



## Memory map amplification

- Generally a processor is not equipped with all the memory it can address.

## RAM and ROM positions

- Example: Simplified memory map of 8086 micro processor

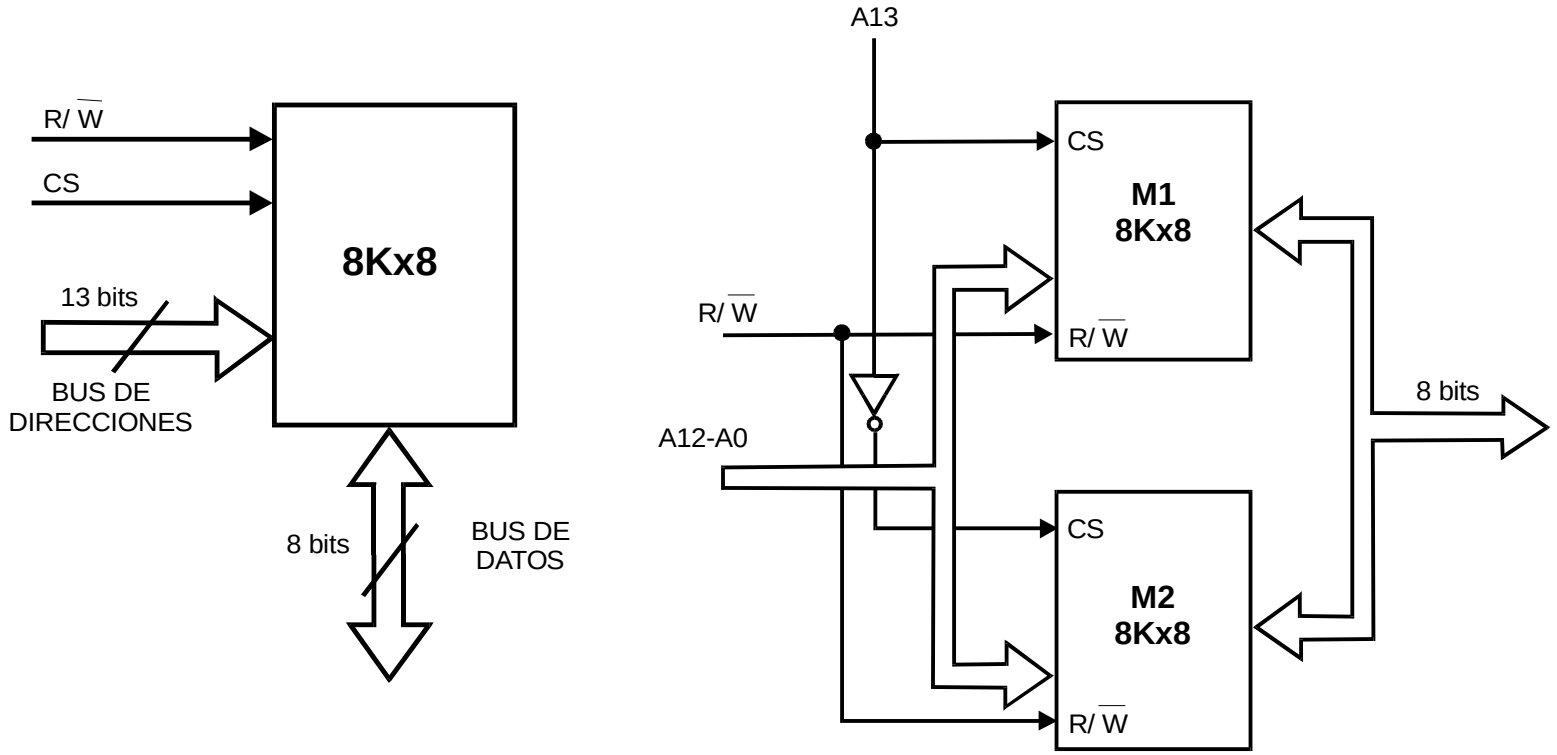


# Memory map (II)

**Example of capacity amplification (number of addresses):**

Use more memory chips to increase number of addresses – ie of accessible words

Built a 16Kx8 memory system with 8Kx8 chips



# Memory map (III)

**Example of word size amplification:**

Use more memory chips to increase the size of the content of each memory position (word size)

Built a 8Kx16 memory system with 8Kx8 chips