Chapter 7:
The Memories

Introduction

- With a flip-flop, storing information on a single bit is possible.
- With a register, it is possible to store information on n bits.
- If we want to memorize information of significant size, we need to use the memory.

Hardware architecture of a machine (architecture of Von Neumann)

- The Von Neumann architecture consists of:

  - A central memory,

  - From a central unit (CU) or CPU (Central Processing Unit or processor).

- This architecture is the foundation of the computer architecture.

Central Unit(CU)

- The central unit (also called the processor) is responsible **for executing programs.**

- The CPU comprises an arithmetic and logic unit (ALU) and a control unit.

- The arithmetic and logic unit performs the processor's essential operation (addition, subtraction, multiplication, ...) at each clock cycle.
- The control unit manages memory operations (read/write) and the operations to be performed by the ALU according to the instructions currently being executed.

- The CPU must have a workspace, called the **main memory**, to perform operations on data and execute programs.

2. What is a memory?

A memory is a device capable of:

- Record information,
- Store it (memorize it)
- and Retrieve it (it is possible to read or recover it later).

Example of memories:

- Central memory
- A hard drive
- A floppy disk
- A flash drive

Memory can be in the processor (registers), internal (central memory), or external (secondary memory).

3. Characteristics of memories: The capacity of a memory

The capacity (size) of a memory is the number (quantity) of pieces of information that can be recorded (memorized) in that memory.

The capacity can be expressed in:

- **Bit:** a bit is the essential element for representing information.

- **Byte:** 1 Byte = 8 bits

- Kilobyte (KB): 1 Kilobyte (KB) = 1024 bytes = 2^{10} bytes

- Megabyte (MB): 1 Megabyte (MB) = 1024 KB = 2^{20} bytes

- Gigabyte (GB): Gigabyte (GB) = 1024 MB = 2^{30} bytes

- Terabyte (To): 1 Terabyte (To) = 1024 Go = 2^{40} octets

Memory Characteristics: Volatility

If a memory loses its content (the information) when the power supply is cut off, it is said **to be volatile**.

If a memory does not lose (retain) its content when the power supply is cut off, it is considered non-volatile (permanent or stable memory).

Characteristics of memories: Mode of access to information (reading/writing)

- On a memory, we can perform the operations of:
- **Reading:** retrieving / returning information from memory.
- **Writing**: recording new information or modifying existing information in memory.

- Some memories offer both **reading/writing** modes, called **volatile memories**.

- Some memories offer only the possibility of reading (they cannot be modified in content) and are called read-only memories.

Characteristics of memories: Access time

It is the time required to perform a **reading or writing** operation.

For example, for the **reading operation**, the access time is the time that separates the request for reading from the availability of the information.

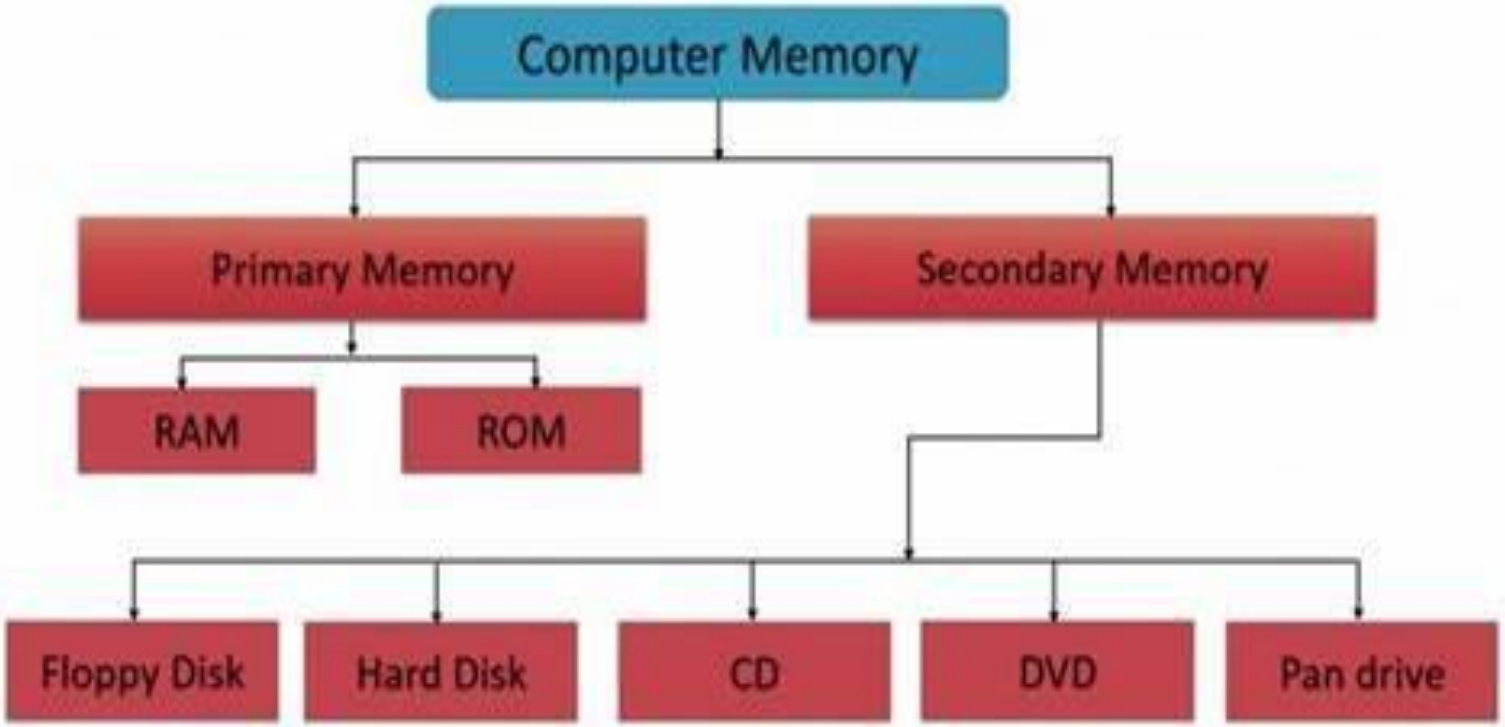
Access time is an important criterion for determining the performance of memory and a machine.

4. Classification of computer memories

Memories can be classified into three categories according to the technology used:

- Semiconductor memory (main memory, ROM, PROM,...): very fast but small in size.
- Magnetic memory (hard drive, floppy disk,...): slower but stores a very large volume of information.
- Optical memory (DVD, CDROM,..)

Computer memory types



5. Central memory
RAM : Random Acces memory

What is central memory?

- Central memory (CM) represents the computer's workspace.
- It is the main organ used by the processor for storing information.
- In a machine (computer/calculator), a program must be loaded (copied) into the main memory to be executed.
- The access time to the main memory and its capacity are two elements that affect the execution time of a program (machine performance).

5.1. Characteristics of central memory

- The central memory is made of **semiconductors**.
- The central memory is volatile: **reading and writing** access.
- The Central memory is also known as **Random Access Memory** (RAM), meaning that the access time to information is independent of its location in memory.
- **Central memory is volatile**: maintaining its content requires a continuous power supply.
- The access time to a central memory is average but faster than magnetic memories.
- The capacity of a central memory is limited, but there is always a possibility of expansion.
- The central memory uses buses (address and data buses) to communicate with other computer components.

5.2. Main memory types

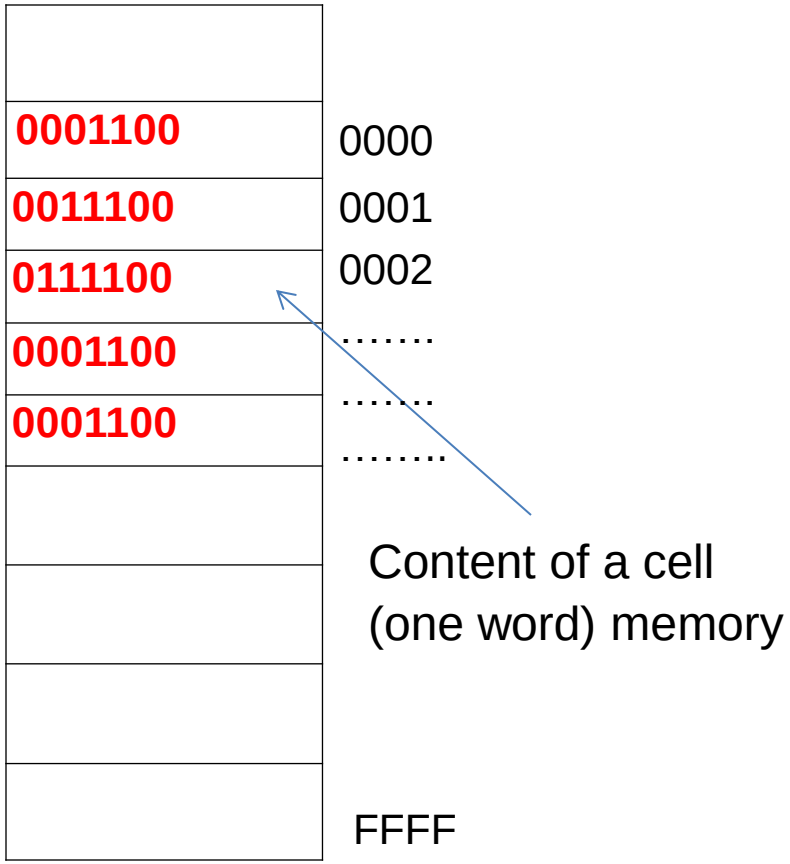
There are two main families of central memories: static (SRAM) and dynamic (DRAM).

1. Static memories are based on **D-type flip-flops**. They have a low integration rate but a fast access time (used for cache memories).

2. Dynamic memories based on capacitors have a very high integration rate. They are simpler than static memories but have a longer access time.

5.3. Logical view of the main memory

- ✓ Central memory can be seen as a large vector (array) of words or bytes.
- ✓ A memory word stores information on n bits.
- ✓ A memory word contains several memory cells.
- ✓ A memory cell stores a single bit.
- ✓ Each word has its address.
- ✓ An address is a unique number that allows access to a memory word.
- ✓ Addresses are sequential (consecutive).
- ✓ The size of the address (the number of bits) depends on the memory capacity.



5.4. Physical structure of a central memory

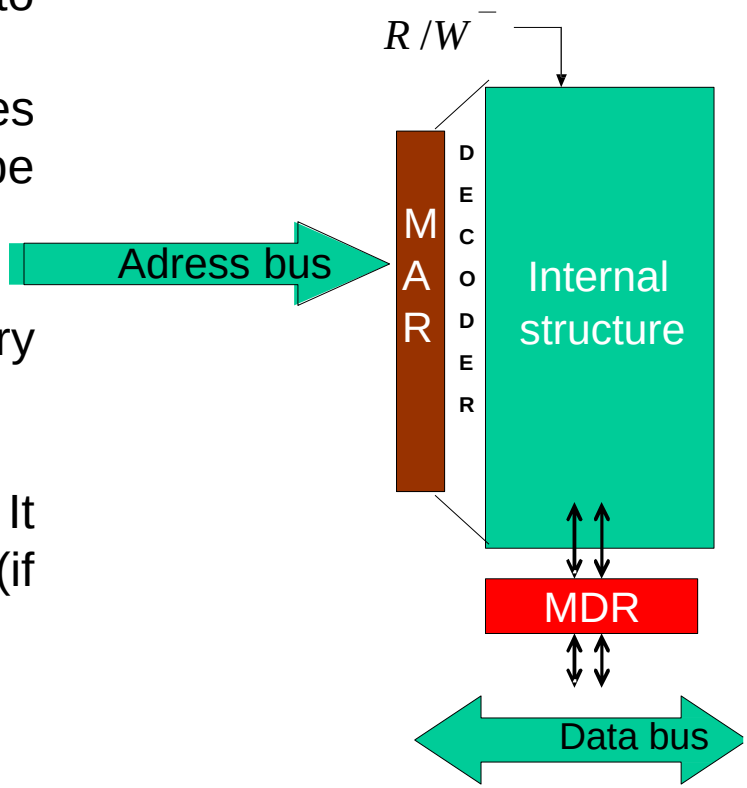
- **MAR (Memory Address Register):** This register stores the address of the word to be read or written.
- **MDR (Memory Data Register)** stores information read from memory or to be written to memory.

- **Decoder:** allows selecting a memory word.

- **R/W:** This is the read/write command. It allows reading from or writing to memory (if R/W=1, then read; otherwise, write).

- The Address bus of size k bits.

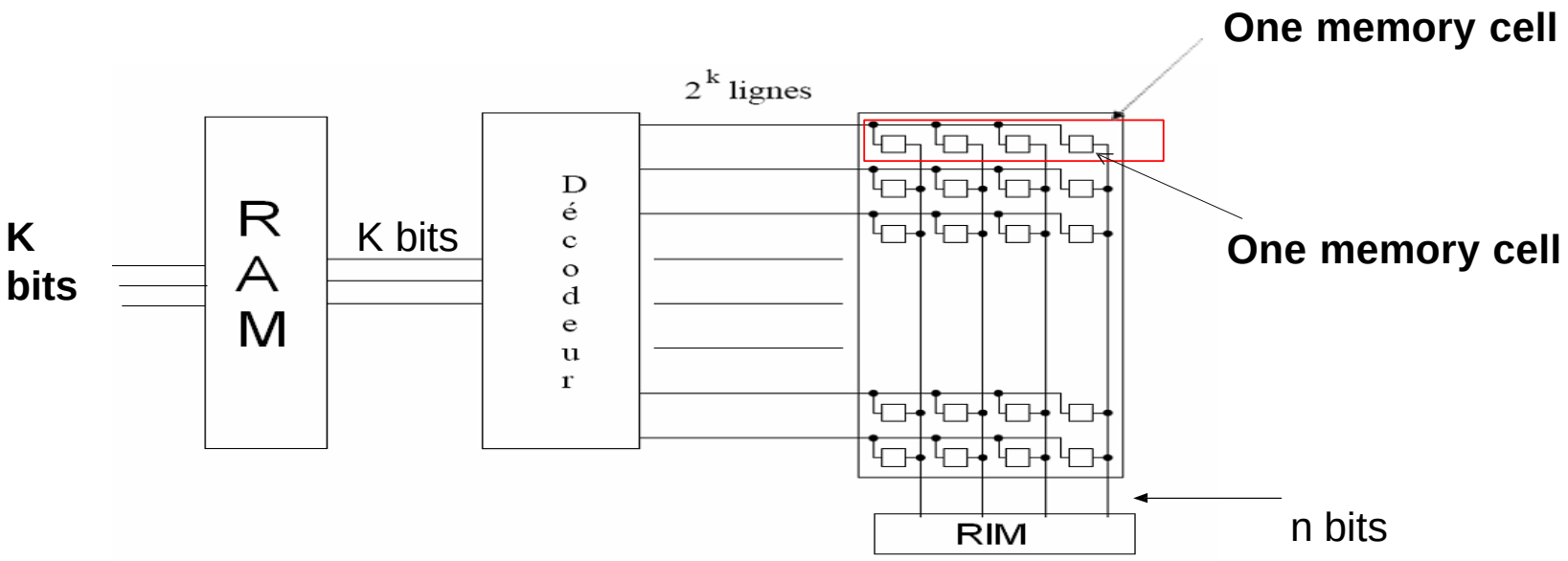
- The data bus of size n bits



5.4.1. How do you select a memory word?

When an address is loaded into the MAR register, the decoder receives the same information from the MAR.

We will have a single active output at the decoder's output, allowing us to select a single memory word.



5.4.2. How to read information?

To read information in main memory, the following operations must be performed:

- Load the address of the word to be read into the MAR register.
- Start the read command (R/W=1)
- The information is available in the MDR register after a certain period (access time).

5.4.3. How to write information?

To write information in Central memory, the following operations must be performed:

- Load the address of the word where the writing will take place into the MAR(register).
- Place the information to be written in the MDR (register).
- Launch the write command to transfer the content from the MDR to the memory.

5.4.4. How to calculate the capacity of a central memory?

- Let k be the size of the address bus (the size of the register MAR)

- Let n be the size of the data bus (the size of the MDR register or the size of a memory word)

- The main memory's capacity can be expressed in terms of the number of memory words or bits (bytes, kilobytes, etc.).

The capacity = 2k Memory words
The capacity = 2k * n Bits

Example: In memory, the address bus size K=14 and the data bus size n=4. Calculate the capacity of this memory.

C=214 = 16384 Words of 4 bits
C= 214 * 4 = 65536 Bits = 8192 Bytes = 8 KB