



IT111 - Introduction to Information Technology

Bachelor of Science in Information Technology

LECTURE 6 COMPUTER ORGANIZATION

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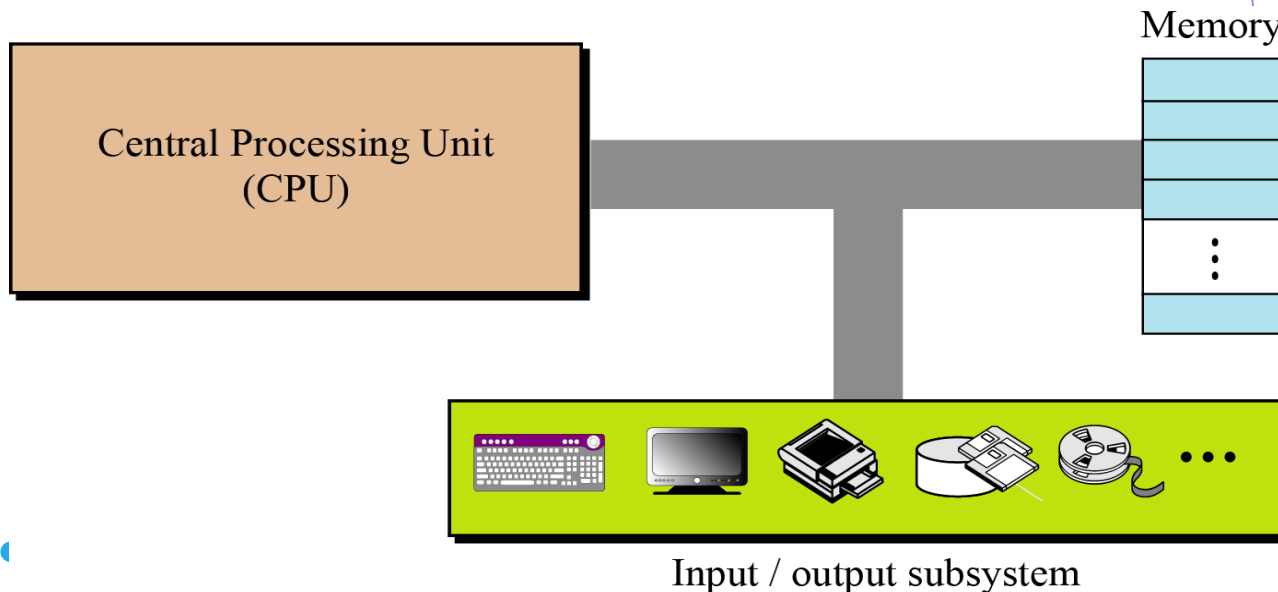
After studying this chapter, the student should be able to:

- ☐ List the three subsystems of a computer.
- ☐ Describe the role of the central processing unit (CPU).
- ☐ Describe the main memory and its addressing space.
- ☐ Define the input/output subsystem.
- ☐ Understand the interconnection of subsystems.

5-1 INTRODUCTION

We can divide the parts that make up a computer into three broad categories or subsystem: **the central processing unit (CPU), the main memory, and the input/output subsystem.**

Figure 5.1 Computer hardware (subsystems)

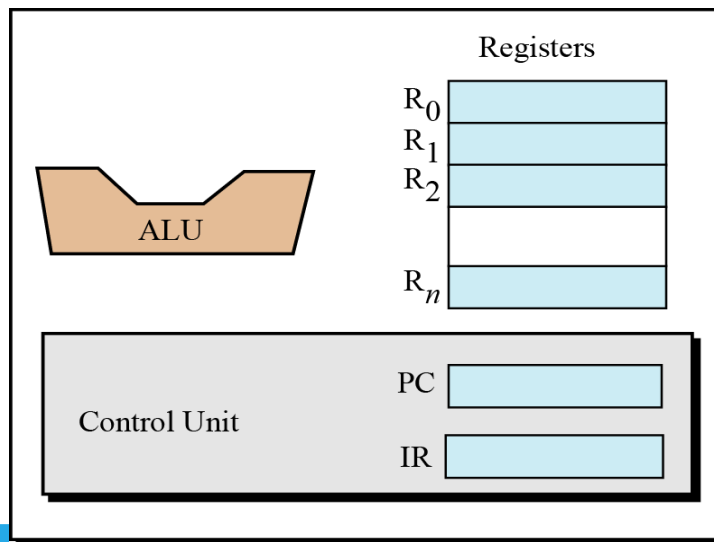


5-2 CENTRAL PROCESSING UNIT

The **central processing unit (CPU)** performs operations on data. In most architectures it has three parts:

- An arithmetic logic unit (ALU)
- A control unit
- A set of registers, fast storage locations.

Figure 5.2 Central processing unit (CPU)



Central Processing Unit (CPU)

5.2.1 The arithmetic logic unit (ALU)

The **arithmetic logic unit (ALU)** performs logic, shift, and arithmetic operations on data.

Logic operations

We discussed several logic operations, such as NOT, AND, OR, and XOR, in Chapter 4.

These operations treat the input data as bit patterns and the result of the operation is also a bit pattern.

5.2.1 The arithmetic logic unit (ALU)

Shift operations

We discussed two groups of shift operations on data in Chapter 4: logical shift operations and arithmetic shift operations. Logical shift operations are used to shift bit patterns to the left or right, while arithmetic operations are applied to integers. Their main purpose is to divide or multiply integers by two.

Arithmetic operation

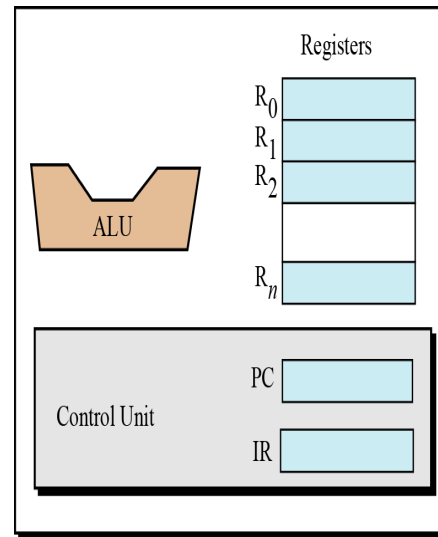
We discussed some arithmetic operations on integers and reals on Chapter 4. We mentioned that some operations can be implemented more efficiently in hardware.

5.2.2 Registers

Registers are fast stand-alone storage locations that hold data temporarily. Multiple registers are needed to facilitate the operation of the CPU. Some of these registers are shown in Figure 5.2.

Figure 5.2 Central processing unit (CPU)

- ☐ *Data registers*
- ☐ *Instruction register*
- ☐ *Program counter*

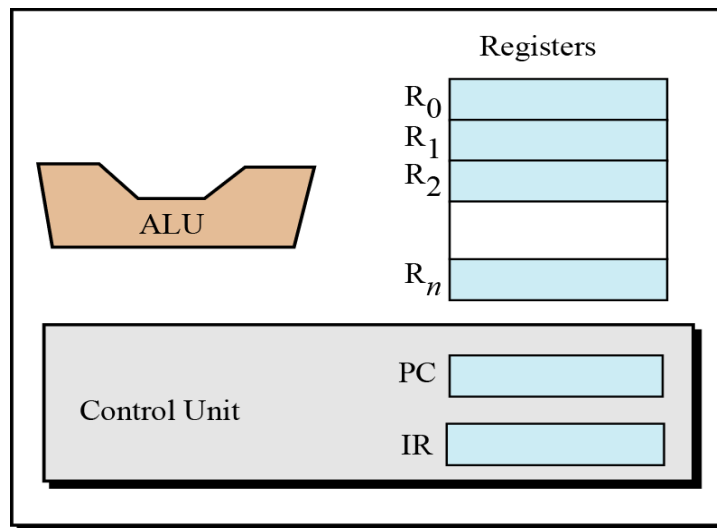


Central Processing Unit (CPU)

5.2.3 The control unit

The third part of any CPU is the control unit. The control unit controls the operation of each subsystem. Controlling is achieved through signals sent from the control unit to other subsystems.

Figure 5.2 Central processing unit (CPU)



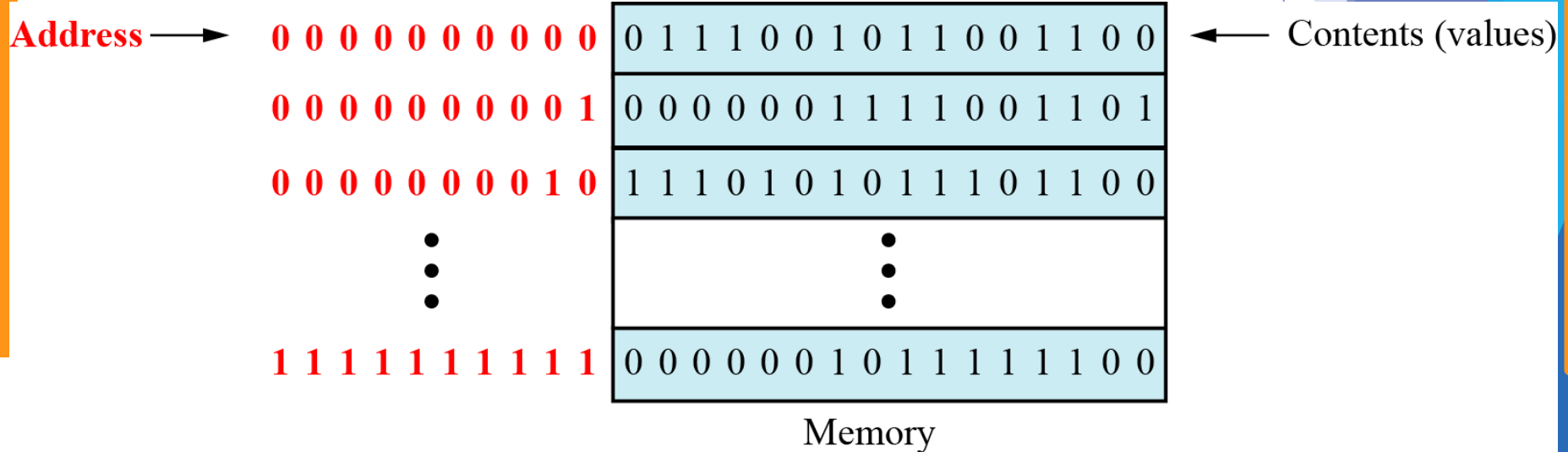
Central Processing Unit (CPU)

5-3 MAIN MEMORY

Main memory is the second major subsystem in a computer (Figure 5.3). It consists of a collection of storage locations, each with a unique identifier, called an **address**. Data is transferred to and from memory in groups of bits called **words**. A word can be a group of 8 bits, 16 bits, 32 bits, or 64 bits (and growing). If the word is 8 bits, it is referred to as a **byte**. The term “byte” is so common in computer science that sometimes a 16-bit word is referred to as a 2-byte word, or a 32-bit word is referred to as a 4-byte word.



Figure 5.3 Main memory



5.3.1 Address space

To access a word in memory requires an identifier. Although programmers use a name to identify a word (or a collection of words), at the hardware level each word is identified by an address. The total number of uniquely identifiable locations in memory is called the **address space**. For example, a memory with 64 kilobytes and a word size of 1 byte has an address space that ranges from 0 to 65,535.

Table 5.1 Memory units

<i>Unit</i>	<i>Exact Number of Bytes</i>	<i>Approximation</i>
kilobyte	2^{10} (1024) bytes	10^3 bytes
megabyte	2^{20} (1,048,576) bytes	10^6 bytes
gigabyte	2^{30} (1,073,741,824) bytes	10^9 bytes
terabyte	2^{40} bytes	10^{12} bytes

Memory addresses are defined using unsigned binary integers.

Example 5.1

A computer has 32 MB (megabytes) of memory. How many bits are needed to address any single byte in memory?

Solution

The memory address space is 32 MB, or 2^{25} ($2^5 \times 2^{20}$). This means that we need $\log_2 2^{25}$, or **25 bits**, to address each byte.

Example 5.2

A computer has 128 MB of memory. Each word in this computer is eight bytes. How many bits are needed to address any single word in memory?

Solution

The memory address space is 128 MB, which means 2^{27} . However, each word is eight (2^3) bytes, which means that we have 2^{24} words. This means that we need $\log_2 2^{24}$, or **24 bits**, to address each word.

5.3.2 Memory types

Two main types of memory exist: **RAM** and **ROM**.

Random access memory (RAM)

- ☐ Static RAM (SRAM)
- ☐ Dynamic RAM (DRAM)

Read-only memory (ROM)

- ☐ Programmable read-only memory (PROM).
- ☐ Erasable programmable read-only memory (EPROM).
- ☐ Electrically erasable programmable read-only memory (EEPROM).



Two main types of memory exist: RAM and ROM.

Two main types of memory exist: **RAM** and **ROM**.

Random access memory (RAM) "Volatile"

Characteristics: Read and write, volatile

- ❑ Static RAM (SRAM): use flip-flop gates, hold state (0 or 1), no need to refresh memory locations, fast, expensive.
- ❑ Dynamic RAM (DRAM): use capacitors (electrical devices that stores energy), needs to be refreshed periodically, slow, inexpensive.

Memory Types: continue

Read-only memory (ROM) "non-volatile"

Characteristics: Read only, nonvolatile

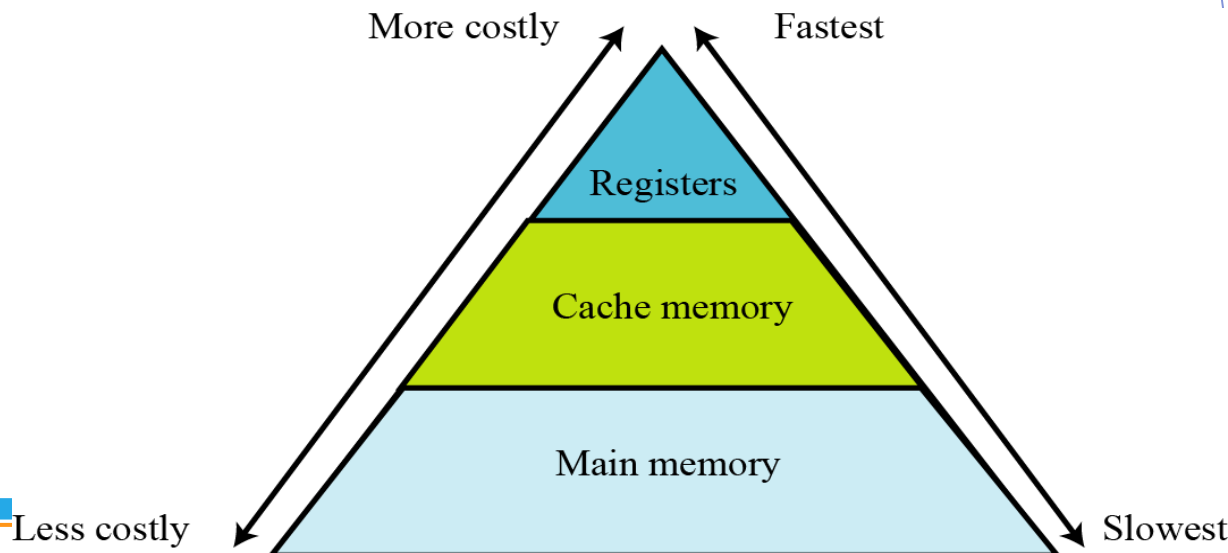
- ❑ Programmable read-only memory (PROM): shipped blank, user store programs on it with special equipments, then act as ROM
- ❑ Erasable programmable read-only memory (EPROM): programmed by user, erased with special device applying ultraviolet light, requires physical removal and reinstallation.
- ❑ Electrically erasable programmable read-only memory (EEPROM): programmed and erased using electronic impulses without removing.



5.3.3 Memory hierarchy

Computer users need a lot of memory, especially memory that is very fast and inexpensive. This demand is not always possible to satisfy—very fast memory is usually not cheap. A compromise needs to be made. The solution is **hierarchical** levels of memory.

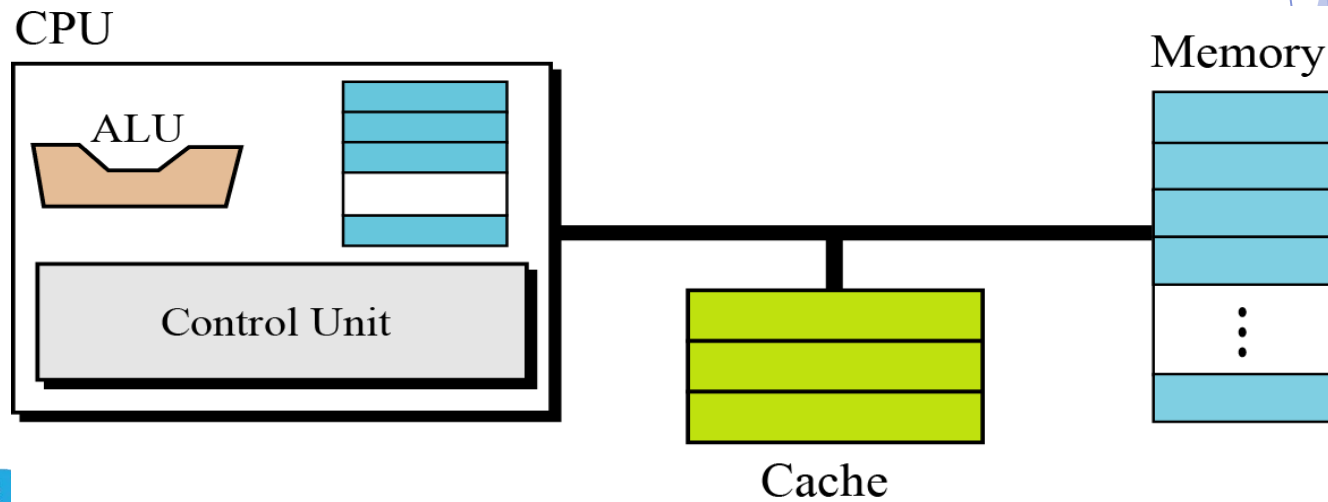
Figure 5.4 Memory hierarchy



5.3.4 Cache memory

Cache memory is faster than main memory but slower than the CPU and its registers. Cache memory, which is normally small in size, is placed between the CPU and main memory (Figure 5.5).

Figure 5.5 Cache memory



5-4 INPUT/OUTPUT SUBSYSTEM

The third major subsystem in a computer is the collection of devices referred to as the input/output (I/O) subsystem. This subsystem allows a computer to communicate with the outside world, and to store programs and data even when the power is off. Input/output devices can be divided into two broad categories: **non-storage** and **storage** devices.

5.4.1 Non-storage devices

Non-storage devices allow the CPU/memory to communicate with the outside world, but they cannot store information.

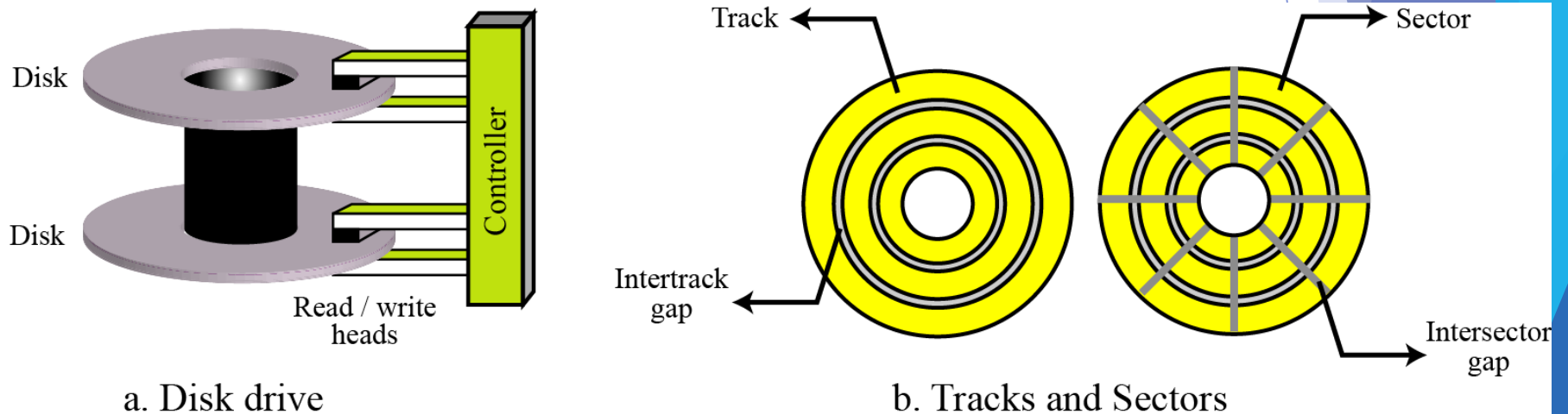
- ☐ Keyboard and monitor
- ☐ Printer

5.4.2 Storage devices

Storage devices, although classified as I/O devices, can store large amounts of information to be retrieved at a later time. They are cheaper than main memory, and their contents are nonvolatile—that is, not erased when the power is turned off. They are sometimes referred to as auxiliary storage devices. We can categorize them as either **magnetic** or **optical**.

Magnetic storage devices

Figure 5.6 A magnetic disk



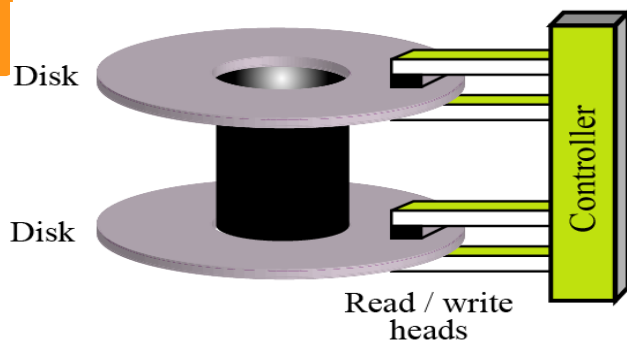
Magnetic Storage devices

Use magnetization to store bits of data. If a location is magnetized, it represents 1, if not magnetized, it represents 0.

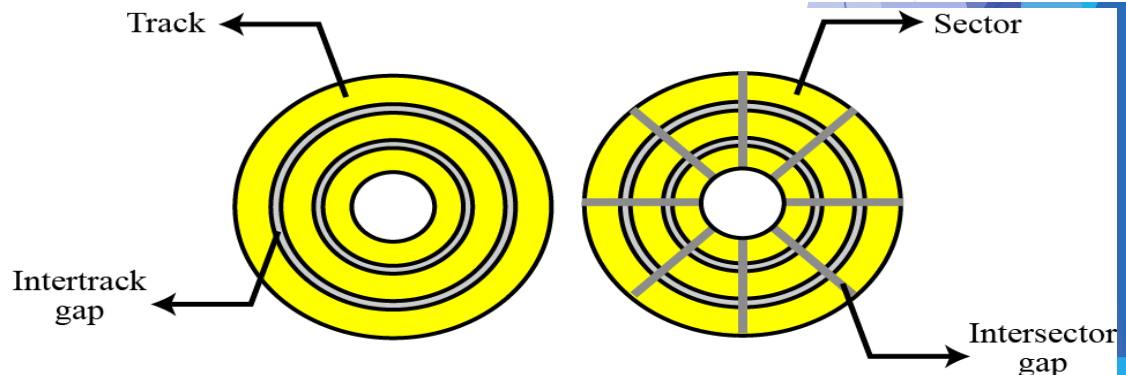
Magnetic disks

Consists of one or more disks stacked on top of each other. The disks are coated with a thin magnetic film. Information is stored on and retrieved from the surface of the disk using read/write head for each magnetized surface of the disk.

Surface Organization, Data Access (random access),
Performance (rotational speed, seek time, transfer time)



a. Disk drive



b. Tracks and Sectors

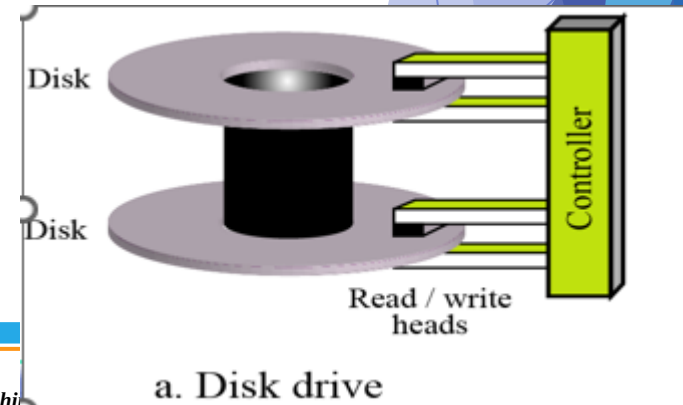
Magnetic Storage devices

Data access. A magnetic disk is considered a random access device. In a random access device, a data item can be accessed randomly without the need to access all other data items located before it. However, the smallest storage area that can be accessed at one time is a sector. A block of data can be stored in one or more sectors and retrieved without the need to retrieve the rest of the information on the disk.

Magnetic Storage devices

Performance. The performance of a disk depends on several factors, the most important being the rotational speed, the seek time, and the transfer time.

- The **rotational speed** defines how fast the disk is spinning.
- The **seek time** defines the time to move the read/write head to the desired track where the data is stored.
- The **transfer time** defines the time to move data from the disk to the CPU/memory.



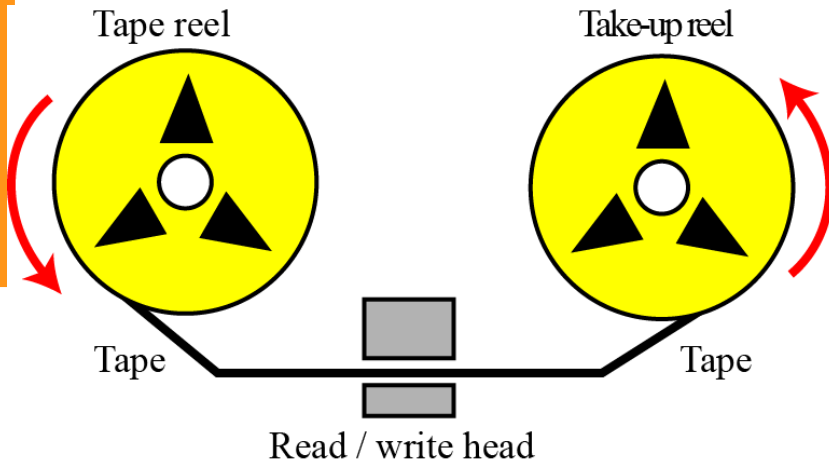




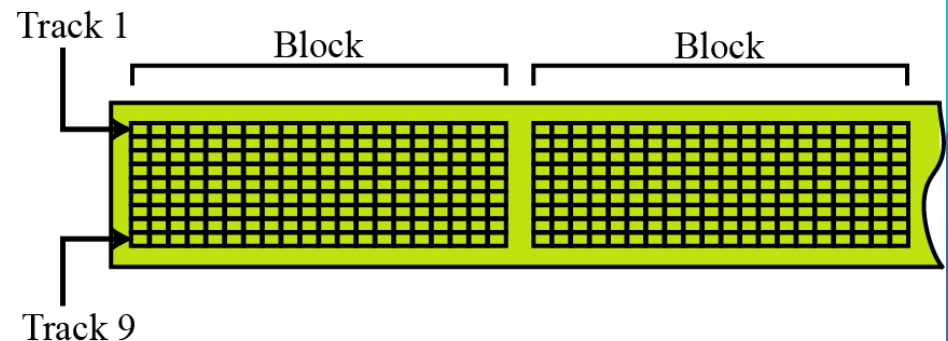
Magnetic tapes

- Comes in various sizes.
- One common type is half inch plastic tape coated with a thick magnetic film.
- The tape is mounted on the two reels and uses a read/write head that reads or writes information when the tape is passed through it.

Surface Organization, Data Access (sequential access),
Performance (slower but cheaper, used for backups)



a. Tape drive

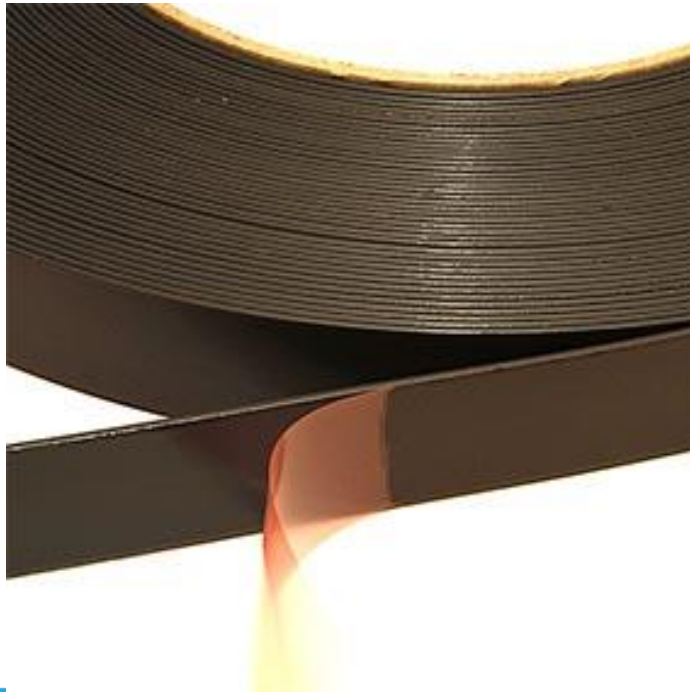


b. Surface organization

❑❑ **Surface organization.** The width of the tape is divided into nine tracks, each location on a track storing 1 bit of information. Nine vertical locations can store 8 bits of information related to a byte plus a bit for error detection.

❑❑ **Data access.** A magnetic tape is considered a sequential access device. Although the surface may be divided into blocks, there is no addressing mechanism to access each block. To retrieve a specific block on the tape, we need to pass through all the previous blocks.

❑❑ **Performance.** Although magnetic tape is slower than a magnetic disk, it is cheaper. Today, people use magnetic tape to back up large amounts of data.



Optical Storage devices

Use laser light to store and retrieve data.

CD-ROMs

- Compact disc read-only memory
- Uses the same technology as the CD, the only difference is CD-ROM drive is more robust and checks for errors.

Creation: It involves three steps.

- Master disc:
 - created using a high-power infrared laser.
 - Bit patterns translated into a sequence of pits (holes) and lands (no holes). Pits represents 0 and lands represents 1.
- Mold disk is made from the master. Pits are replaced by bumps.
- Molten polycarbonate resin is injected into the mold to produce the same pits as the master disc. A very thin layer of aluminum (reflective surface) is added to the polycarbonate. On top of it a protective layer of lacquer is applied, and label is added.

Optical storage devices

Figure 5.8 Creation and use of CD-ROMs

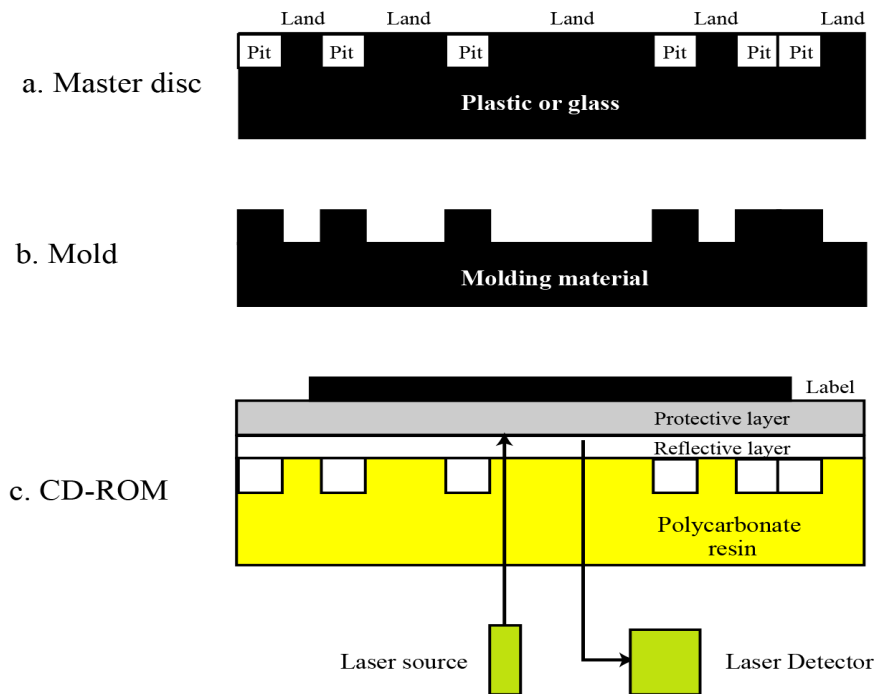


Table 5.2 CD-ROM speeds

<i>Speed</i>	<i>Data rate</i>	<i>Approximation</i>
1x	153,600 bytes per second	150 KB/s
2x	307,200 bytes per second	300 KB/s
4x	614,400 bytes per second	600 KB/s
6x	921,600 bytes per second	900 KB/s
8x	1,228,800 bytes per second	1.2 MB/s
12x	1,843,200 bytes per second	1.8 MB/s
16x	2,457,600 bytes per second	2.4 MB/s
24x	3,688,400 bytes per second	3.6 MB/s
32x	4,915,200 bytes per second	4.8 MB/s
40x	6,144,000 bytes per second	6 MB/s

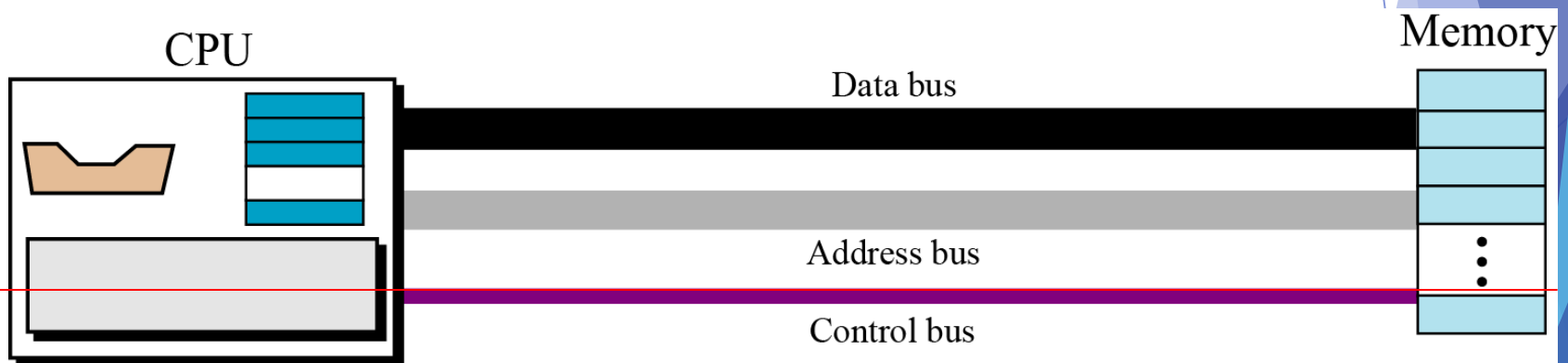
5-5 SUBSYSTEM INTERCONNECTION

The previous sections outlined the characteristics of the three subsystems (CPU, main memory, and I/O) in a stand-alone computer. In this section, we explore how these three subsystems are interconnected. The interconnection plays an important role because information needs to be exchanged between the three subsystems.

5.5.1 Connecting CPU and memory

The CPU and memory are normally connected by three groups of connections, each called a **bus**: *data bus*, *address bus*, and *control bus* (Figure 5.12).

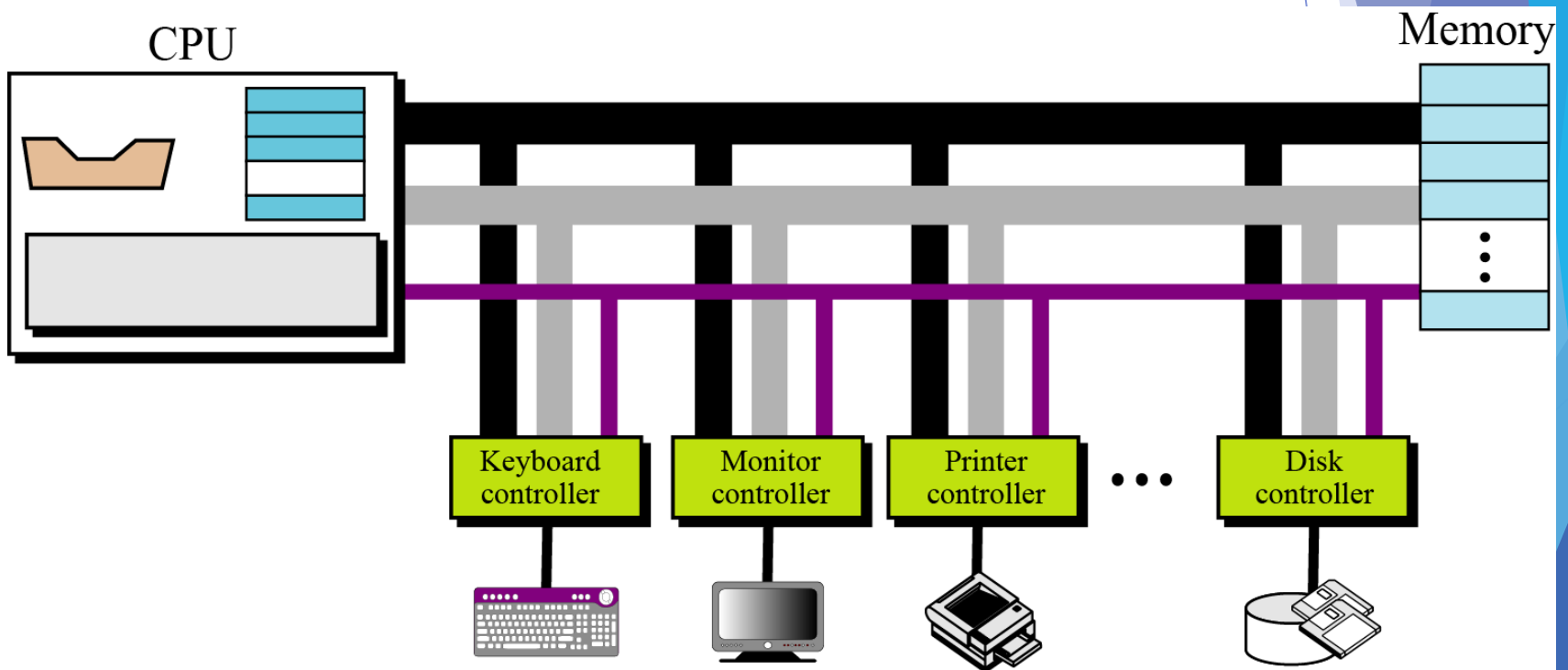
Figure 5.12 Connecting CPU and memory using three buses



5.5.2 Connecting I/O devices

I/O devices cannot be connected directly to the buses that connect the CPU and memory because the nature of I/O devices is different from the nature of CPU and memory. I/O devices are electromechanical, magnetic, or optical devices, whereas the CPU and memory are electronic devices. I/O devices also operate at a much slower speed than the CPU/memory. There is a need for some sort of intermediary to handle this difference. Input/output devices are therefore attached to the buses through input/output controllers or interfaces. There is one specific controller for each input/output device (Figure 5.13).

Figure 5.13 Connecting I/O devices to the buses



Summary

- ☐ The three subsystems of a computer.
- ☐ Describe the role of the central processing unit (CPU).
- ☐ Describe the main memory and its addressing space.
- ☐ Define the input/output subsystem.
- ☐ Understand the interconnection of subsystems

Thank You