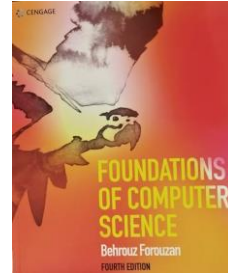


# Chapter 5

## Computer Organization

### 計算機組織



5.1 Source: Foundations of Computer Science © Cengage Learning

#### Objectives 學習目標

After studying this chapter, students should be able to:

- List the three subsystems of a computer. 電腦三個子系統
- Describe the role of the **central processing unit** (CPU).
- Describe the **fetch-decode-execute phases** of a cycle. 提取、解碼、執行
- Describe the **main memory** and its **addressing space**. 主記憶體及其位址空間
- Define the input/output subsystem. 輸入輸出子系統
- Understand the interconnection of subsystems.
- Describe different methods of **input/output addressing**. 輸入輸出定址模式
- Distinguish the **two major trends** in the design of computers.
- Understand how computer throughput can be improved using **pipelining** 管線處理 and parallel processing.

5.2

## The arithmetic logic unit (ALU)

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

**Logic operations:** NOT, AND, OR, and XOR.

**Shift operations:** logic shift operations and arithmetic shift operations

**Arithmetic operations:** arithmetic operations on integers and reals.

5.3

## Data word 資料字元

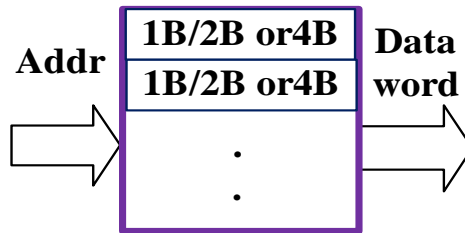
A word can be a group of 8 bits, 16 bits, 32 bits or 64 bits (and growing). If the word is **8 bits**, it is referred to as a **byte**. The term “byte” is so common in computer science that sometimes a **16-bit** word is referred to as a **2-byte word**, or a **32-bit word** is referred to as a **4-byte word**.

## Address space 位址空間

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位址空間為有多少唯一識別記憶體儲存位置. 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**.

5.4

## Memory Address and Space 記憶體位址與容量



Memory (SRAM or DRAM)

1. Given #Addr=32 and each word=2B,  
**Mem space =  $2^{32} * 2B = 8GB$**
2. Given Mem space=32GB and each  
word=4B  
 **$32GB / 4B = 8G = 2^{33}$  #Addr = 33**

5.5

## Memory types 記憶體型態

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

### Random access memory (RAM) 隨機存取記憶體

- Static靜態 RAM (SRAM)
- Dynamic動態 RAM (DRAM) – e.g., **DDR SDRAM**  
(Double Data Rate Synchronous Dynamic Random Access Memory)
- NAND-based Flash快閃 RAM**

### Read-only memory (ROM) 僅能讀取記憶體

- Programmable可程式化 ROM (PROM). 僅能燒錄一次
- Erasable可用紫外線擦拭的PROM (EPROM).
- Electrically erasable可用電子式擦拭的PROM (**EEPROM**).

5.6

## Cache memory 快取記憶體

**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.

**80-20 rule: Most of computers spend 80% of their time accessing only 20% of the data. In other words, cache holds 20% of the data to make access faster at least 80% of the time.**

5.7

## 輸入/輸出子系統

The **input/output (I/O) subsystem** in a computer **is the collection of devices**. 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**分兩大類:

**Non-storage devices** 非儲存裝置

**Storage devices** 儲存裝置

5.8

## SSD – Solid State Disk 固態硬碟

- ❑ A **solid-state drive (SSD)** uses **NAND-based flash memory**, which **retains data without power**.
- ❑ A **SSD** is also called an **electronic disk 電子硬碟**, though it contains no actual “disk” of any kind, nor motors to “drive” the disks **非馬達驅動碟片**.
- ❑ SSD technology uses electronic interfaces compatible with traditional input/output (I/O) **hard disk drives (HDDs)**, thus permitting simple replacement in common applications, like **SATA Express**.
- ❑ SSDs are **expensive per unit of storage** than HDDs, but will gradually decrease down.

5.9

## USB controller to connect I/O devices

**通用串列匯流排：Hot Swap、Plug and Play 熱插拔**

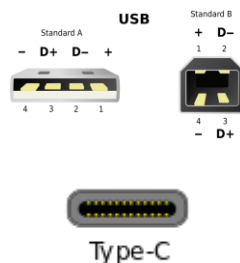
**USB 1.1 (in 1996): 12Mbps / 63 devices**

**USB 2.0 (High speed) (in 2000): 480Mbps / 127 devices**

**USB 3.0 (Super speed) (in 2008): 5Gbps**

**USB 3.1 (Super speed) (in 2013): 10Gbps Type-C**

**USB 3.2 (Super speed) (in 2017): 2GB/s Type-C, Two 10Gbps**



5.10

## Addressing input/output devices I/O裝置的定址法

The CPU usually uses the same bus to read data from or write data to main memory and I/O device. The only difference is the instruction. If the instruction refers to a word in main memory, data transfer is between main memory and the CPU. If the instruction identifies an I/O device, data transfer is between the I/O device and the CPU. 指令要能識別資料讀取或寫入為CPU與記憶體之間或CPU與I/O裝置之間，因此要能區分為記憶體位址與I/O裝置位址

There are two methods for handling the addressing of I/O devices: isolated I/O 隔離式I/O裝置位址 and memory-mapped I/O 記憶體對映I/O裝置位址.

5.11

## Pipelining 管線處理

Modern computers use a technique called **pipelining** to improve the throughput 通過率 (the total number of instructions performed in each period of time 每個時間周期執行多少指令). The idea is that if the control unit can do two or three of these phases simultaneously, the next instruction can start before the previous one is finished.

5.12

## *Review Questions*

- What are the differences between **SRAM** and **PROM**?
- What are the differences between **isolated** and **memory-mapped I/O addressing modes**?
- What are the differences among **programmed I/O**, **interrupt-driven I/O**, and **DMA I/O**?
- What are the differences between **CSIC** and **RSIC**?
- Explain the function for each terminologies of **cache memory**, **pipelining**, and **SSD**.
- Explain the mean of **data bus** and **address bus** in a computer.
- A computer has **16GB** of memory and each word is four bytes, how many bits are needed to address any single word in memory?