Computer Organization and Architecture

1 Introduction

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Computer is Everywhere

Change or not?

Review: What is Computer?

Review: What is Computer?

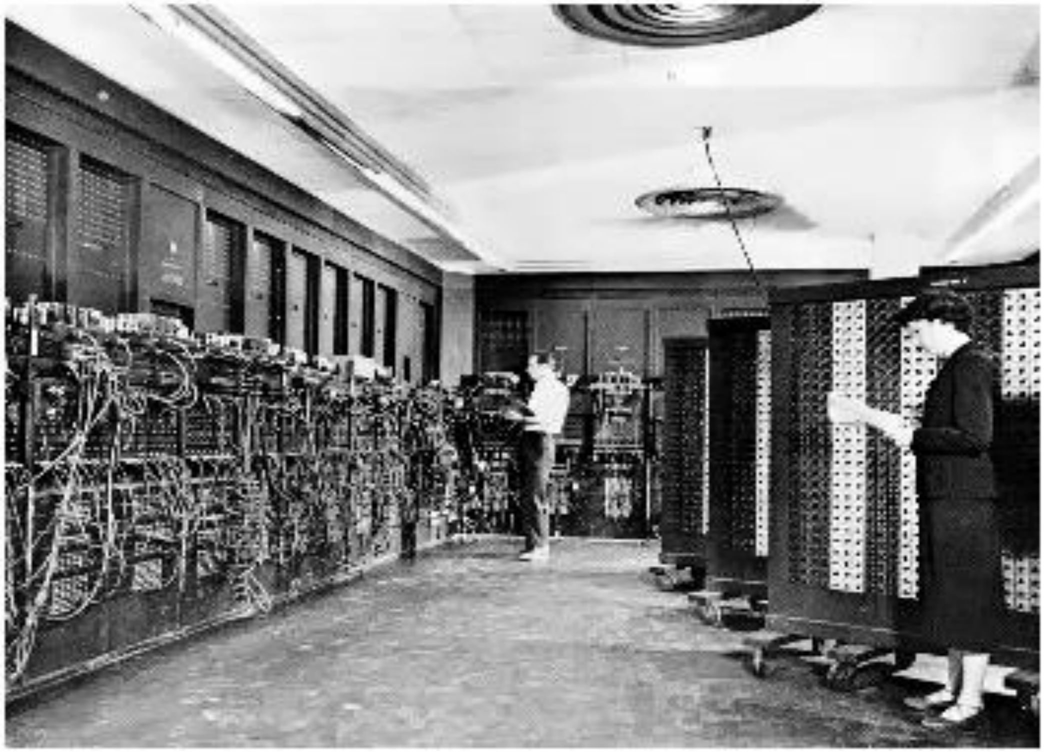
- 计算机是指“通用电子数字计算机（general-purpose electronic digital computer）”
  - 通用：不是一种专用设备
    - 所有计算机在给予足够时间和容量存储器的条件下，都可以完成同样的计算
    - 当希望完成新的计算时，不需要对计算机重新设计
  - 电子（非机械）：采用电子元器件
  - 数字（非模拟）：信息采用数字化的形式表示
- 计算机系统
  - 硬件：处理器、存储器、外部设备
  - 软件：程序，文档

Architecture and Organization

- **Architecture** (visible to programmer)
  - Its attributes have a direct impact on the logical execution of a program
  - Instruction set, the number of bits to represent data types, …
    - E.g.: Is there a multiply instruction?
- **Organization** (opaque/encapsulated to programmer)
  - The operational units and their interconnections
  - Control signals, memory technology, …
    - E.g.: Implement multiply by a hardware unit or repeated addition?

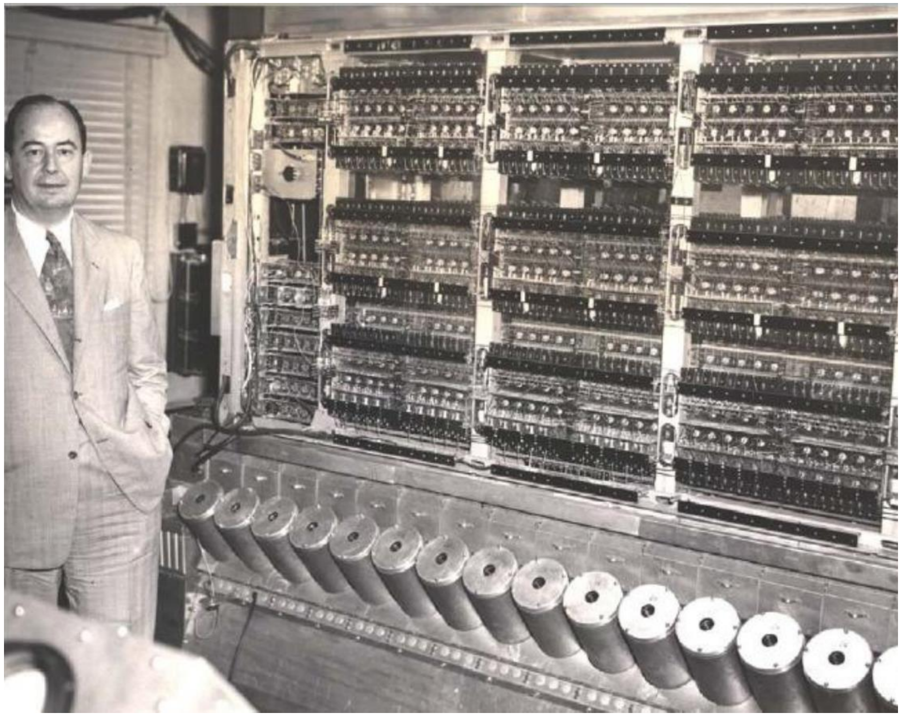
A Brief History of Computers

- First generation: Vacuum tubes (1946-1957)
    - ENIAC (1946-1955): decimal, manually programming



A Brief History of Computers

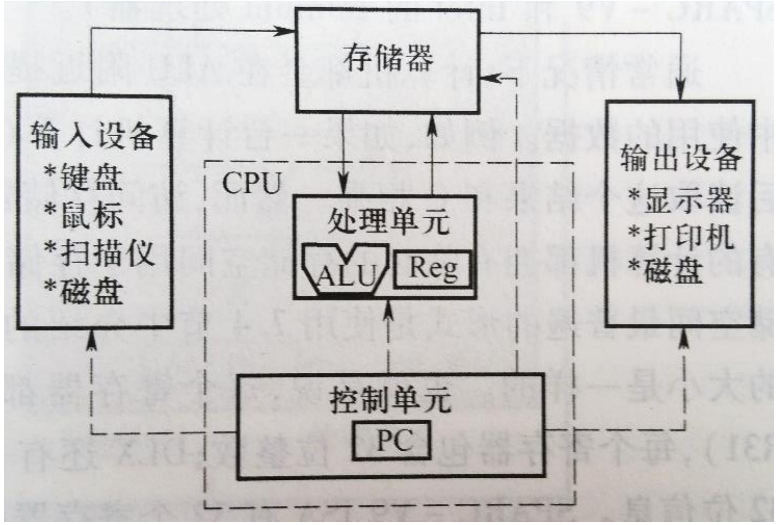
- First generation: Vacuum tubes (1946-1957)
  - IAS (1946-1952*): binary, stored program



Review: von Neumann Machine

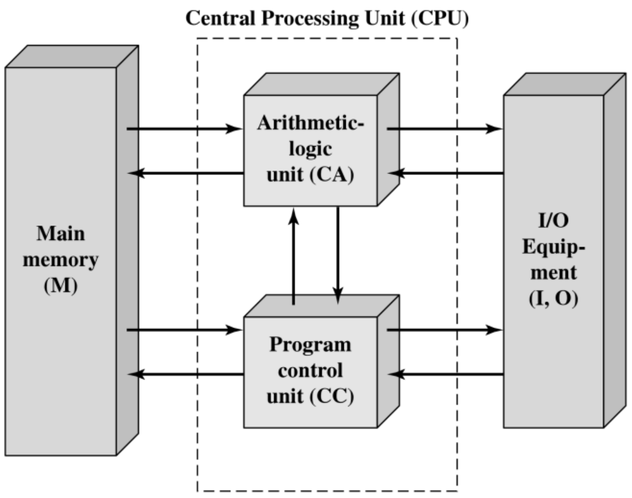
Review: von Neumann Machine

- 组成部分
  - 存储器：地址和存储的内容
  - 处理单元：执行信息的实际处理
  - 控制单元：指挥信息的处理
  - 输入设备：将信息送入计算机中
  - 输出设备：将处理结果以某种形式显示在计算机外



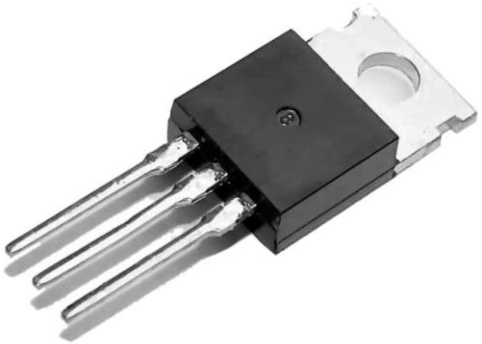
A Brief History of Computers

- First generation: Vacuum tubes (1946-1957)
  - IAS (1946-1952*): **the von Neumann machine**
    - Idea: main memory stores programs and data
    - Prototype of all subsequent computers
      - Central Arithmetical (CA)
      - Central Control (CC)
      - Memory (M)
      - Input (I) / Output (O)



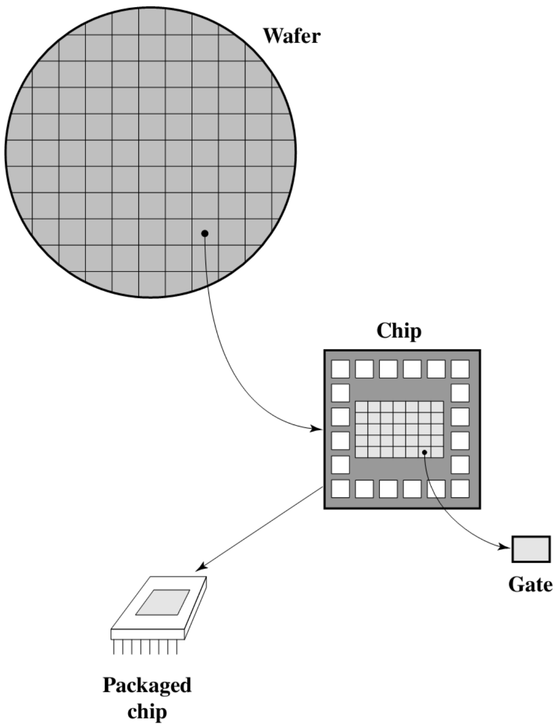
A Brief History of Computers (cont.)

- Second generation: Transistors (1958-1964)
  - NCR and RCA, IBM 7000: transistors are smaller, cheaper, and dissipate less heat; they also can be used as same as vacuum tubes
  - Introduction of more complex arithmetic and logic units and control units, the use of high-level programming languages and the provision of system software.



A Brief History of Computers (cont.)

- Third to *N* generation: Integrated circuits (1965-now)
  - Idea:
    - fabricate an entire circuit in a piece of silicon rather than assemble discrete components made from separate pieces of silicon
    - These transistors can be connected with a process of metallization to for circuits
  - Scale:
    - small ➔ large ➔ very large ➔ ultra large ...

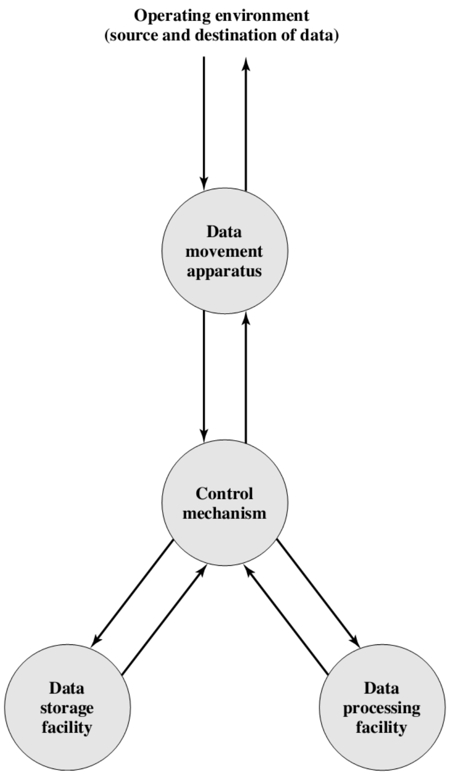


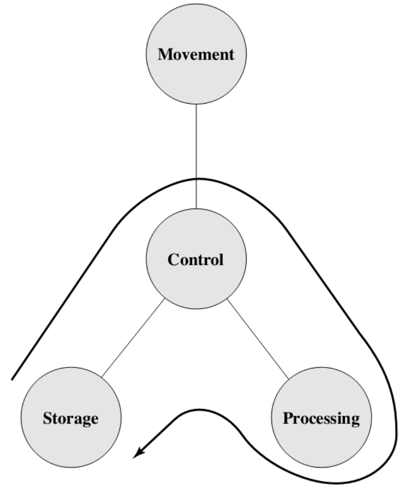
A Brief History of Computers (cont.)

- **Moore's law** (Gordon Moore, 1965)
  - The number of transistors that could be put on a single chip is doubling every year (1965-1969) / 18 months (1970-now)
  - Consequence
    - The cost of computer logic and memory circuitry has dramatically fallen for the cost of a single chip is unchanged
    - Smaller size leads to flexibility and probability
    - Increased operating speed for shortened electrical path length
    - Reduction in dependency on power and cooling
    - The interconnections on the integrated circuit are more reliable than solder connections and few interchip connections

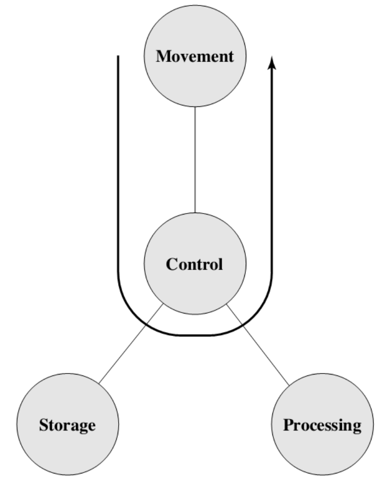
A Brief History of Computers (cont.)

- Constant function

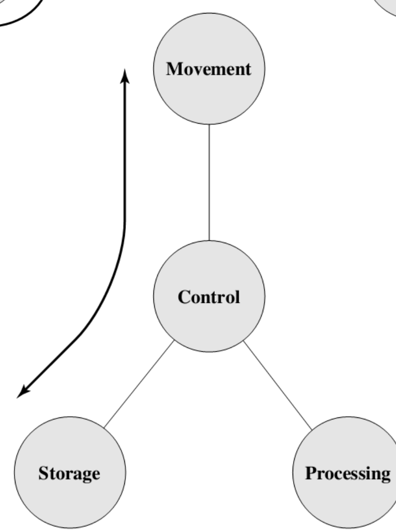




Data processing



Data movement



Data storage

A Brief History of Computers (cont.)

- Performance improvements

Generation	Approximate Dates	Technology	Typical Speed (operations per second)
1	1946–1957	Vacuum tube	40,000
2	1958–1964	Transistor	200,000
3	1965–1971	Small and medium scale integration	1,000,000
4	1972–1977	Large scale integration	10,000,000
5	1978–1991	Very large scale integration	100,000,000
6	1991–	Ultra large scale integration	1,000,000,000

Computer Performance

- One of key parameters of computer
  - Performance, cost, size, security, reliability, power consumption, …
- Sample performance evaluation criteria
  - CPU: speed
  - Memory: capacity, speed
  - I/O: speed, capacity

The main goal / driver is the increase of CPU speed

CPU Performance

- System clock
  - Clock rate / clock speed (HZ): fundamental rate in cycles per second at which a computer performs its most basic operations
  - Clock cycle / clock tick: a single electronic pulse of a CPU
  - Cycle time (s): the time between pulses
    - Sometimes **“clock cycle”**

CPU Performance (cont.)

- Instruction execution
  - A processor is driven by a clock with a constant frequency f or, equivalently, a constant cycle time t.
  - Let CPI_i be the number of cycles required for instruction type i, and I_i be the number of executed instructions of type i for a given program.
  - The overall can be calculated as follows:

$$CPI = \frac{\sum_{i=1}^{n}(CPI_i \times I_i)}{I_c}, \;\; I_c = \sum_{i=1}^{n} I_i$$

  - Process time to execute a given program:

$$T = I_c \times CPI \times t$$

$$T = I_c \times [\boxed{p} + (m \times k)] \times t$$

Transfer data between processor and memory

[刁子恒, 131250084]

CPU Performance (cont.)

- Million Instructions Per Second (MIPS)

$$MIPS = \frac{I_c}{T \times 10^6} = \frac{f}{CPI \times 10^6}$$

- Million Floating Point Operations Per Second (MFLOPS)

$$MFLOPS = \frac{N_{floating-point\ op}}{T \times 10^6}$$

CPU Performance (cont.)

- Benchmarks
  - Measure the performance of systems using a set of benchmark programs
  - Averaging results:
    - Arithmetic mean: $R_A = \frac{1}{m}\sum_{i=1}^{m} R_i$
    - Harmonic mean: $R_H = \frac{m}{\sum_{i=1}^{m}\frac{1}{R_i}}$

Summary

- Concepts
  - organization, architecture
- Computer history
  - The von Neumann machine, Moore’s law
- Possible computer operations
- Computer performance
  - CPU performance evaluation

Thank You

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