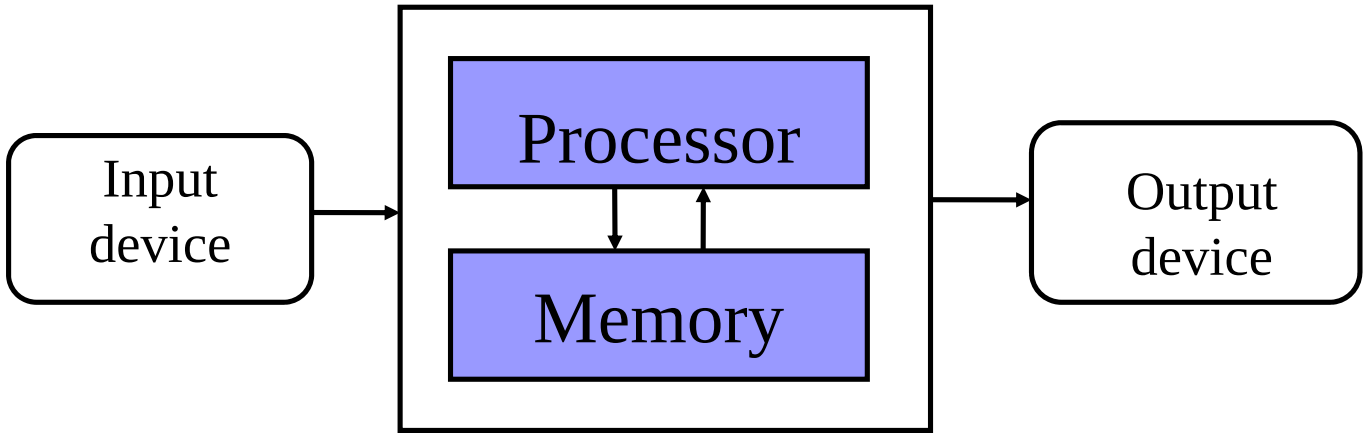
Computer Systems
Lecture 19

Overview

- Data storage
- Main memory
- Words, bytes and bits
- RAM
- ROM
- Memory hierarchy
- Mass storage
- Storage requirements for digital audio & video

The von Neumann Model (reminder)



- **Input device** is for transmitting information from a user into the computer's memory.
- **Output device** enables a user to see the results of a program.

Data storage - overview

- Main memory.
- Mass storage.
- Memory hierarchy.
- Coding of information.

Data storage

- Storage is the capacity of a device to hold and retain data.
- Two main types of storage in a computer:
  - Main memory.
  - Mass storage.

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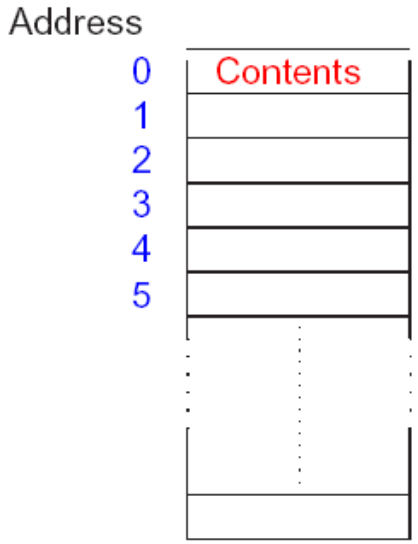
Main memory

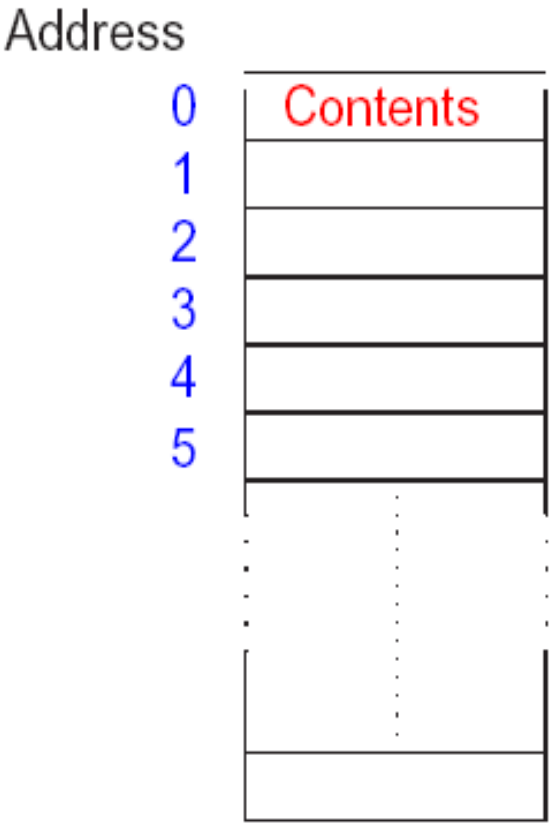
- It refers to *physical memory* that is internal to the computer.
- The computer can manipulate only data that is inside the main memory.
- The amount of main memory in a computer is crucial because:
  - It determines how many programs can be executed at one time.
  - How much space can be allocated to a program.

Main memory, RAM

- A CPU may execute only instructions loaded in the main memory.
  - RAM: Random Access Memory.
  - The name is to set it apart from serial tape storage with which you cannot access data stored in the second or following blocks without going through the first block of data.



RAM



- The memory can be seen as a set of numbered storage elements, called ***words***, each of which contains some information.
- Each word is numbered with its ***address***.
- Any word of memory can be accessed “without touching” the preceding words (Random Access).
- **Access time** is the same for all the stored items.

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Words, Bytes and Bits

- A word may be visualised as a set of more elementary storage elements (memory cells), called **bits**, arranged in a row.
- The number of bits in a word may vary between different computers; 32 bits in a word is common.
- A standard unit of 8 bits called a **byte**.

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Bytes, Kilobytes, Megabytes, etc

- 1 Byte (B) = 8 bits.
- 1 Kilobyte (KB) = 2^{10} bytes = 1024 bytes.
- 1 Megabyte (MB) = 2^{10} KB = 1024 KB.
- 1 Gigabyte (GB)= 2^{10} MB = 1024 MB.
- 1 Terabyte (TB) = 2^{10} GB = 1024 GB.

Exercise. Compute how many bytes in one Megabyte and in one Gigabyte.

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Typical sizes

- Typical RAM module has 512 MB / 1 GB of memory.

- Common size of floppy disk is 1.44 MB.
- Common size of CD is 650 MB.
- Common size of memory disc is 1+ GB.
- Common size of DVD is 4.7 GB.
- Typical hard drive has the size of 120–200-300 GB.

Compare:

- Everything written by William Shakespeare can be stored in 8 MB.
- Human genome contains about 0.8 GB of data.

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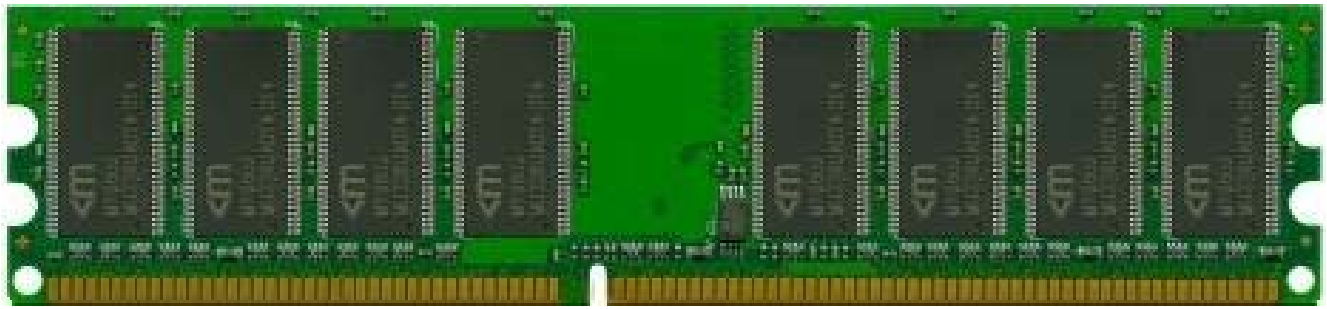
Memory module



Back to RAM

- There are two basic types of RAM:
  - Dynamic RAM (DRAM).
    - Cheaper, but slower.
    - Implemented via capacitors.
    - DRAM needs to be ***refreshed.***
  - Static RAM (SRAM).
    - Faster, but more expensive.
    - Implemented via flip-flops.
    - No need for refreshing.
- Both types of RAM are **volatile**.
  - They lose their contents when the power is turned off.

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Refreshing DRAM

- Real capacitors leak charge.
- Stored data eventually fades.

- To retain data, capacitor charge has to be refreshed periodically.

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ROM Chips

- Read-only memory (ROM)
- Software stored inside also known as firmware
- Helps boot up the system
- BIOS
  - Basic Input Output System

Why store bootstrap software & BIOS in ROMs?

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Other Forms of Memory

- Cache memory (“cash”)
  - quick access memory, internal or external to the processor
  - bridge between the processor and RAM
  - including ***simultaneous read/write***
- Video memory
  - VRAM (“vee-ram”)

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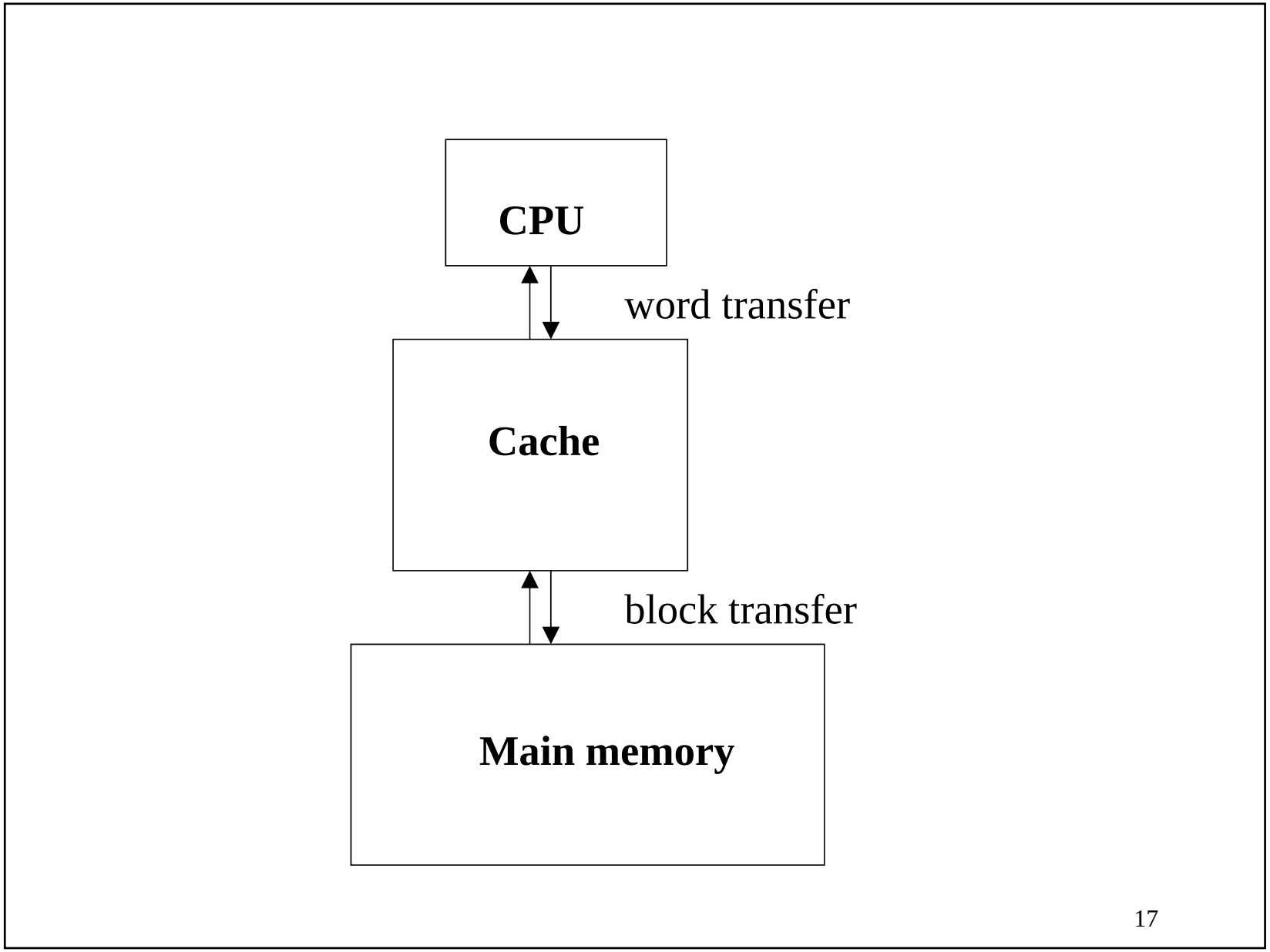
CPU
word transfer
Cache
block transfer
Main memory
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Mass storage

- It refers to various techniques and devices for storing a large amount of data.
- Unlike main memory, mass storage devices retain data even when the computer is turned off.

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Types of mass storage

- Hard disks.
- Optical disks: CD-ROM, CD-RW, DVD, etc.
- USB disks, Floppy disks.
- Etc.

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Hard Disk Drives (HDD)

- Hard disk drives are the most important types of permanent storage used in computers (esp. PCs).
- Hard disks differ from the other mass storage devices in three ways:
  - Size (usually larger).
  - Speed (usually faster).
  - Permanence (usually fixed in computer and not removable).

RAM vs. Mass Storage (HDD)

- RAM is volatile, hard disks are not.
- In general RAM is much faster than mass storage (hard disks):
  - 10 ns (10^{-8}s) vs. 10 ms (10^{-2}s) seek time.
  - It is about one million times faster.
- But it is more expensive:
  - 50 pounds for 8 GB RAM vs. 50 pounds for 1 TB hard disk
  - 1MB of RAM is about 125 times more expensive.

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Storing real-world data in digital

Analog data → digital data

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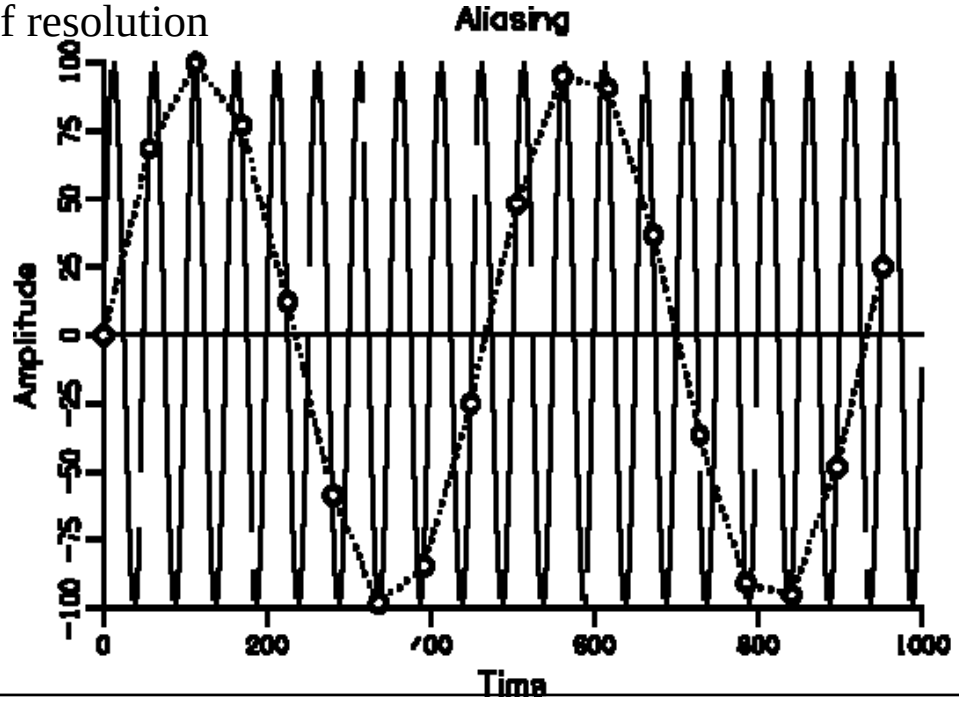
Converting Analog Signal to Digital: Sampling Rate

- The solid curve represents the analog signal at a comparatively high frequency. Circles show where samples were taken at a relatively low sampling rate. The dotted line illustrates the apparent frequency of the sampled waveform, completing about two cycles in the period that the original signal completed 20 cycles
- Issue of resolution



Storage Requirements for Digital Audio

- CD quality Audio:
- 44.1 KHz sampling rate, 16 bits/sample →
  16 bits*44.1KHz = 705,600 bps
  (1KHz = 1000Hz)

- Stereo:
- 44.1 KHz, 32 bits/sample →
  1,411,200bps

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- Q: A computer system encodes data by means of this coding scheme to represent letters, numbers, and special characters.
- a. magnetic
- b. analog
- c. binary
- d. optical.

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- Q. Which of the following is volatile?
- A. ROM B. RAM C. DVD D. Hard Disk

- Q. Which of the following has best access?
- A. register B. cache C. DVD D. RAM

Readings

- [Wil06] Section 3.6 for memory, general information.
- [Wil06] Section 12.7 for hard disk.
- [Wil06] Sections 12.8-12.10 for CDs and DVDs.

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