Computer Systems

Chapter 1. Introduction

Spring 2016

Guo, Xunhua

清华经管学院
Tsinghua SEM

Information

- Instructor: GUO Xunhua (郭迅华)
- Office: Room 435, Weilun Building
- E-mail: guoxh@tsinghua.edu.cn
- Office Phone: 6279-2738
- Office Hours: By appointment

- TA: WANG Cong (王聪)
- E-mail: dusong00@126.com
- Office Phone: 8610-62792254

Discussion Board

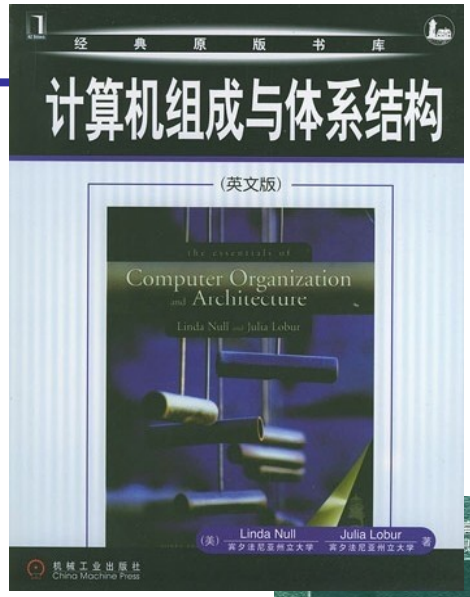
- URL: http://learning.sem.tsinghua.edu.cn
- Course Number: 30511043
- Login Account: s20165100
- Password: ta0399

Course Description

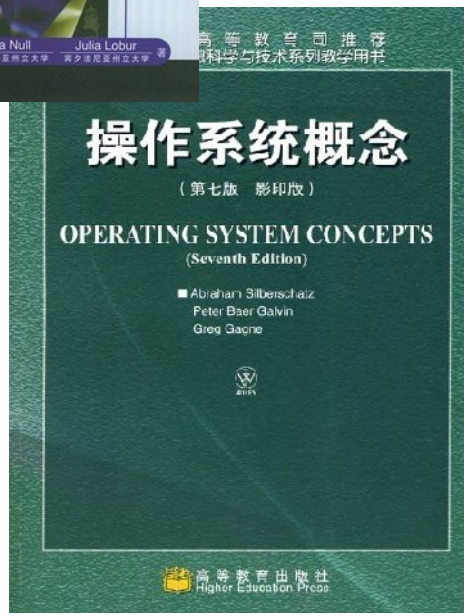
- Hardware and software technology background
  - For systems developers and managers
  - To understand the computer architecture for effective use in a business environment
- Part I: Hardware (Computer Architecture)
  - computing architecture, memory structure, storage and other peripheral devices
- Part II: Operating Systems (Computer Systems Software)
  - main-stream operating systems, major functional modules of modern operating systems
- Prerequisites: Programming Language

Textbooks

- Null, L. and Lobur, J. *The Essentials of Computer Organization and Architecture*, Beijing: China Machine Press. 2004.



- Silberschatz, A., Galvin, P., and Gagne, G. *Operating System Concepts (7th Edition)*. Beijing: Higher Education Press. 2007.



Reference books

- Ramachandran, U. and Leahy, W. D. Jr. *Computer Systems: An Integrated Approach to Architecture and Operating Systems*, Beijing: China Machine Press. 2010. (“计算机系统：集成方法”)
- Tanenbaum, A. S. *Modern Operating Systems (3rd Edition)*, Beijing: China Machine Press. 2009. (“现代操作系统”)

Grading

- Assignments: 20%
- Course project: 20%
- Class participation: 10%
- Final exam: 50%

Why study technologies?

- “Computing is not about computers anymore. It is about living. . . .
- We have seen computers move out of giant air-conditioned rooms into closets, then onto desktops, and now into our laps and pockets. But this is not the end. . . .
- Like a force of nature, the digital age cannot be denied or stopped. . . .
- The information superhighway may be mostly hype today, but it is an understatement about tomorrow. It will exist beyond people’s wildest predictions. . . .
- We are not waiting on any invention. It is here. It is now. It is almost genetic in its nature, in that each generation will become more digital than the preceding one.”

  —*Nicholas Negroponte, professor of media technology at MIT*

Why study technologies?

- To understand the impacts of IT
  - To understand the impacts on the economy, the society, and industries
  - To be more insightful towards changes, trends, and opportunities
- To improve work skills
  - To use IT more effectively
  - To communicate with IT professionals better
- To learn from the wisdom of technologies
  - e.g.: layered structures, platforms
  - e.g.: structured thinking, object-oriented

What are we going to learn?

- What are inside a computer …
- … and how they are organized.

What are important in this course?

- What are important?
  - Concepts
  - Structures
  - Design principles
- What are not required?
  - Implementation details
  - Technical specifications
  - Technical development

Introduction

- Computer systems overview
- Historical development
- System hierarchy
- The von Neumann Model

Computer Systems Overview: What is a computer?

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What kinds of computers are being used?

- PC / Microcomputer
  - Desktop
  - Laptop
  - Tablet
  - Netbook
  - Workstation
  - Server
- Mini computer
- Mainframe
- Supercomuter
- PDA and palmtop computer
- Mobile phone
- Microprocessors everywhere

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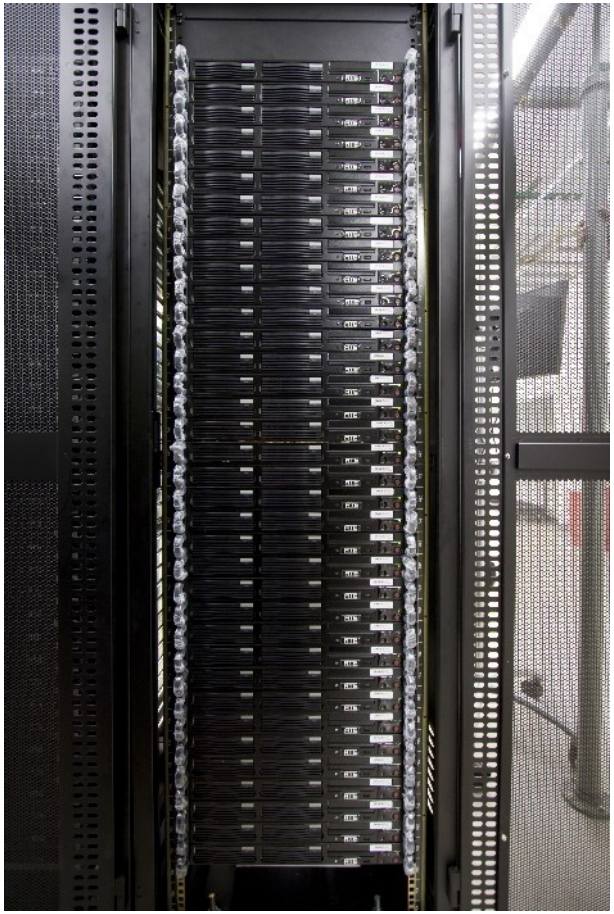
A Data Center

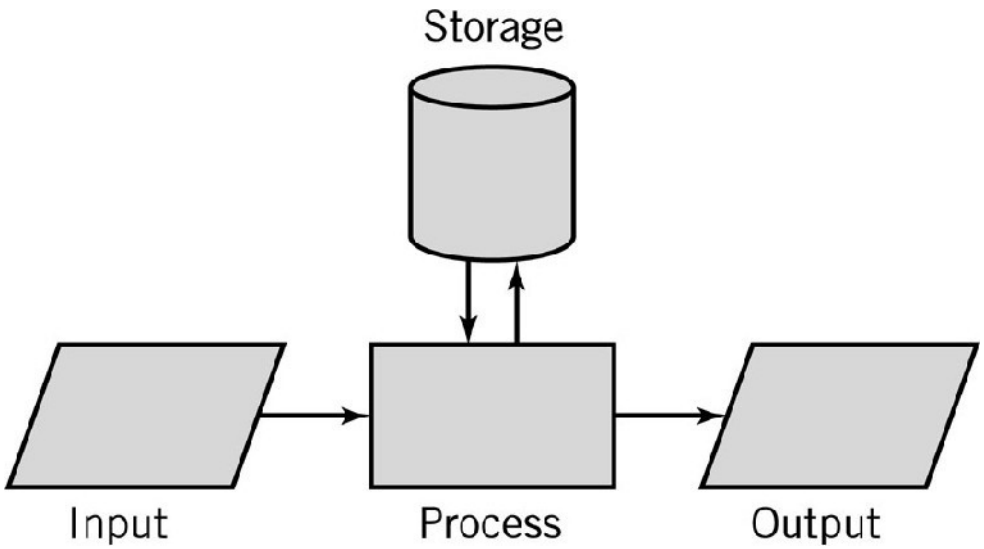


OLPC

Wearable computers

After all, what is a computer?

Input-Process-Output Model (IPO)

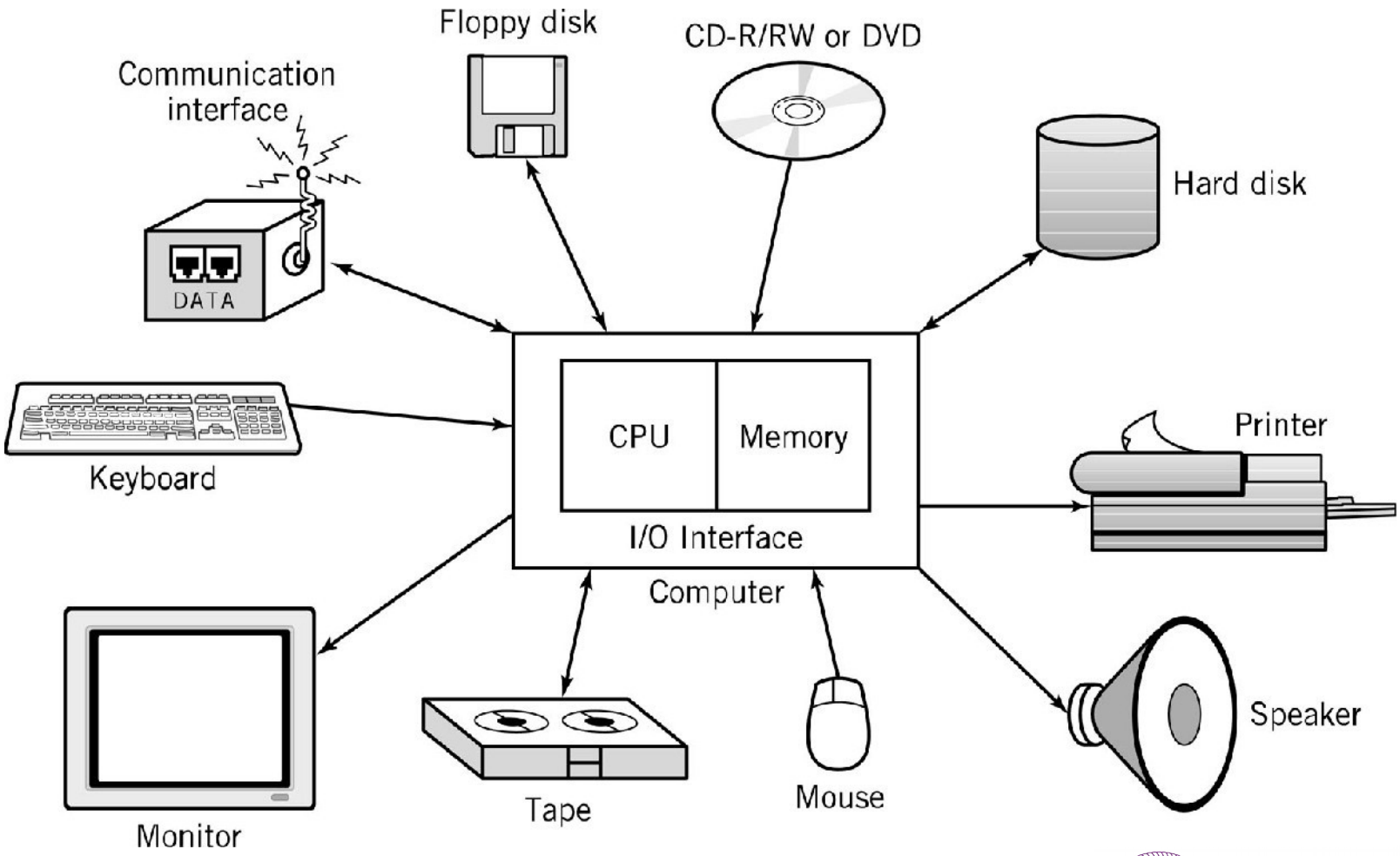


- Input: keyboard, mouse, scanner, ...
- Processing: CPU (中央处理器) executes the computer program
- Output: monitor, printer, ...
- Storage: memory, hard drive, optical media, ...

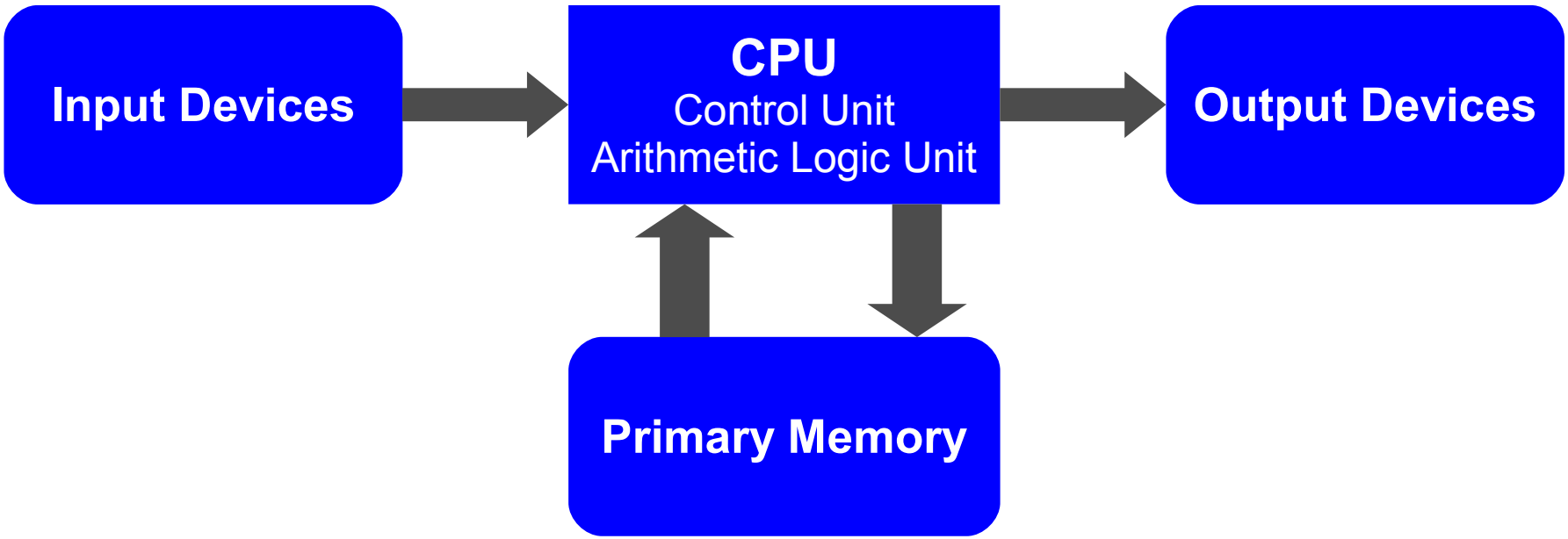
Computer Hardware Systems

- All computer systems, no matter how complex, consists of the following:
  - At least one CPU
  - Memory to hold programs and data
  - I/O devices
  - Long-term storage

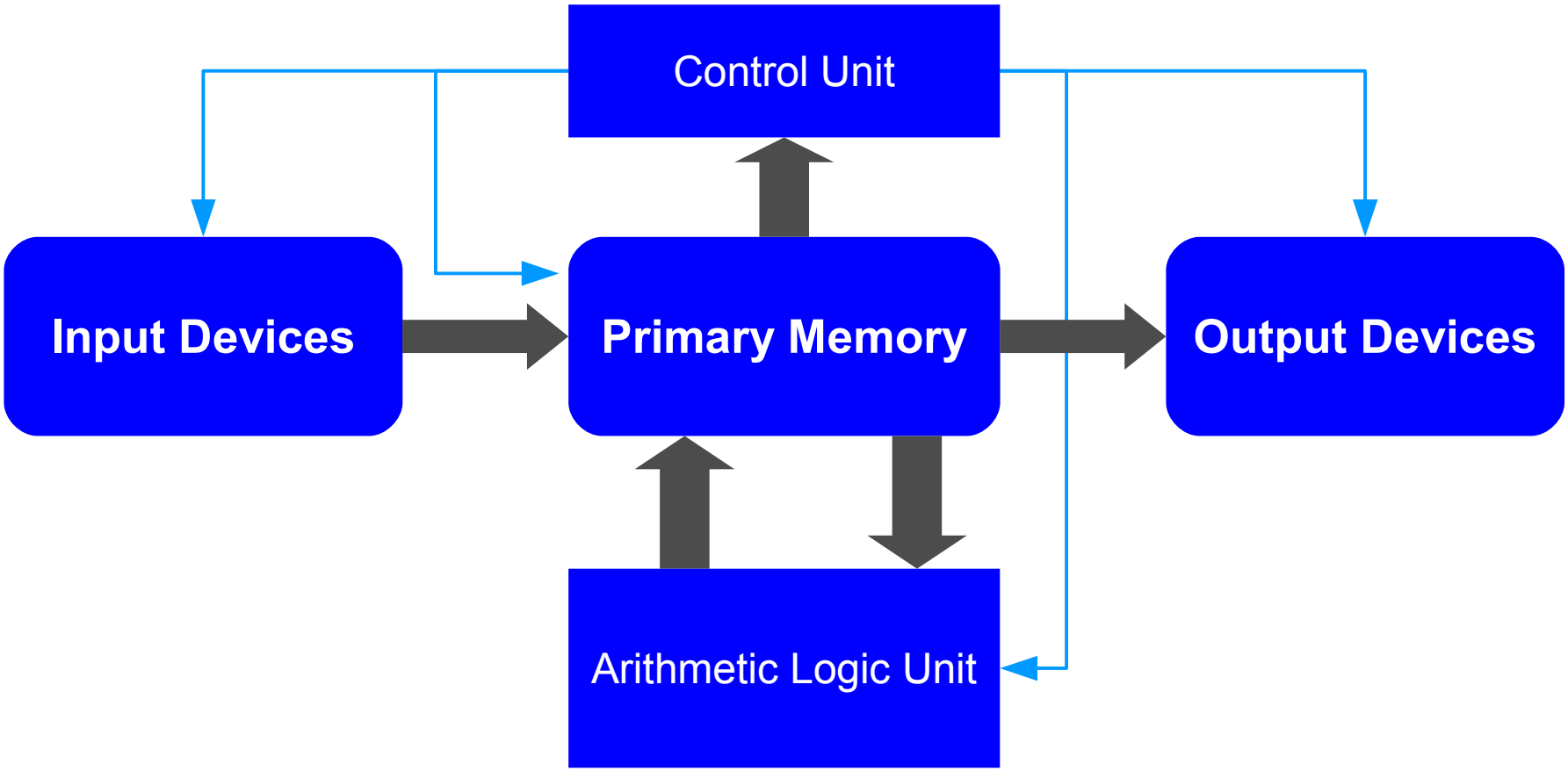
Typical Personal Computer Hardware



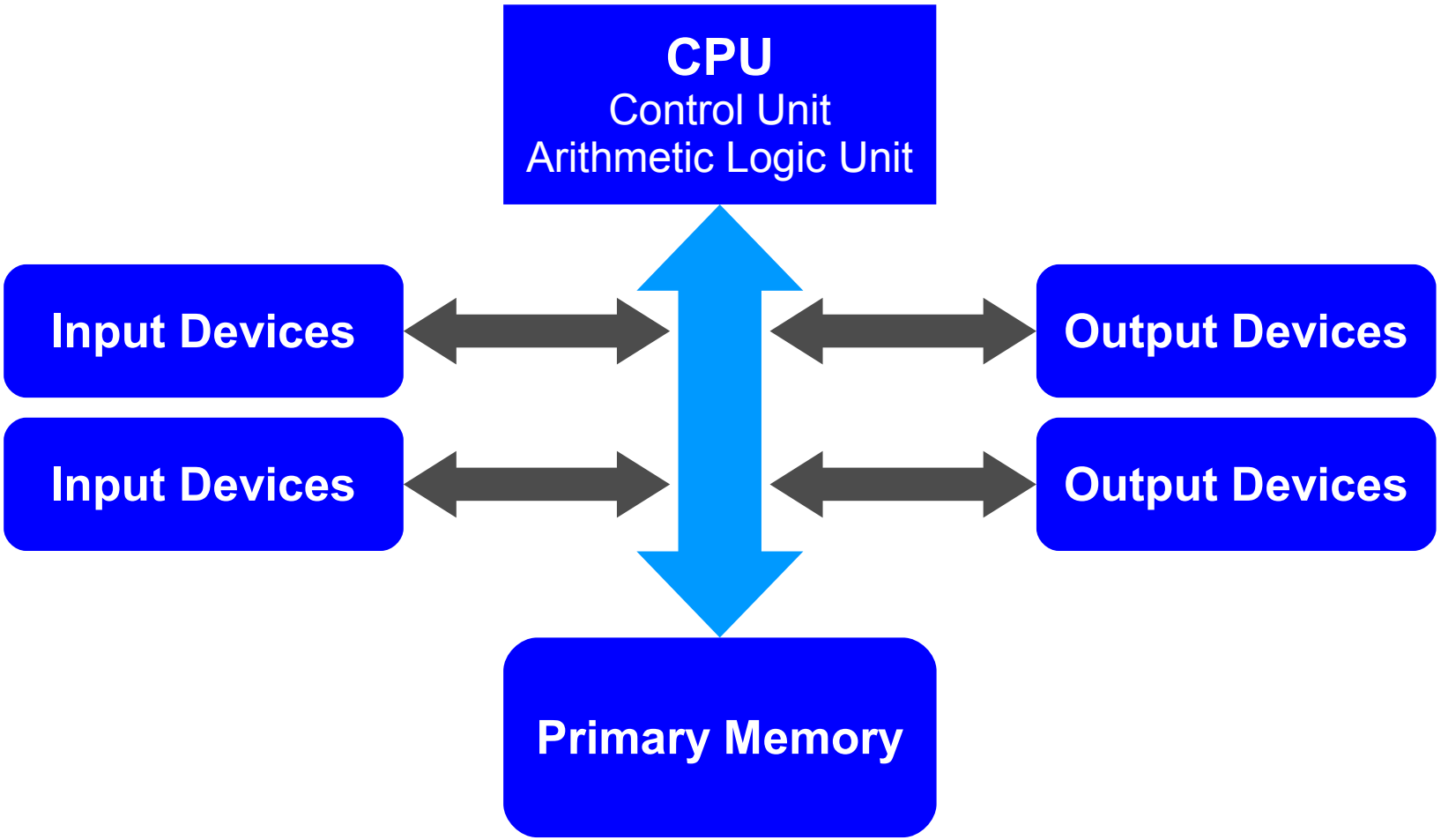
Hardware Architecture: CPU Centric



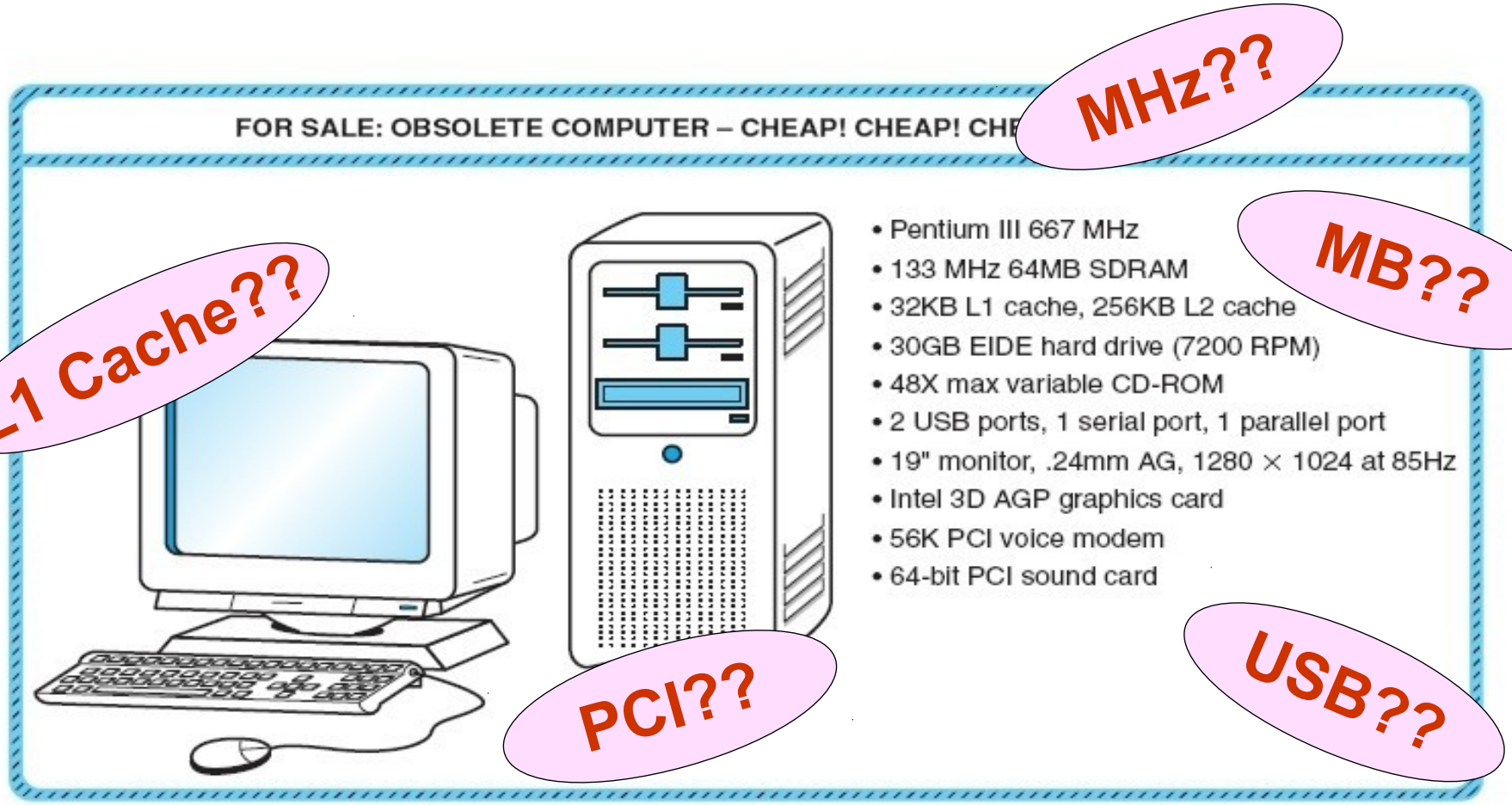
Hardware Architecture: Storage Centric



Hardware Architecture: Bus (总线)-based



An Example System



Common prefixes

Kilo- (K)	(1 thousand = $10^3 \approx 2^{10}$)	Milli- (m)	(1 thousandth = $10^{-3} \approx 2^{-10}$)
Mega- (M)	(1 million = $10^6 \approx 2^{20}$)	Micro- (μ)	(1 millionth = $10^{-6} \approx 2^{-20}$)
Giga- (G)	(1 billion = $10^9 \approx 2^{30}$)	Nano- (n)	(1 billionth = $10^{-9} \approx 2^{-30}$)
Tera- (T)	(1 trillion = $10^{12} \approx 2^{40}$)	Pico- (p)	(1 trillionth = $10^{-12} \approx 2^{-40}$)
Peta- (P)	(1 quadrillion = $10^{15} \approx 2^{50}$)	Femto- (f)	(1 quadrillionth = $10^{-15} \approx 2^{-50}$)

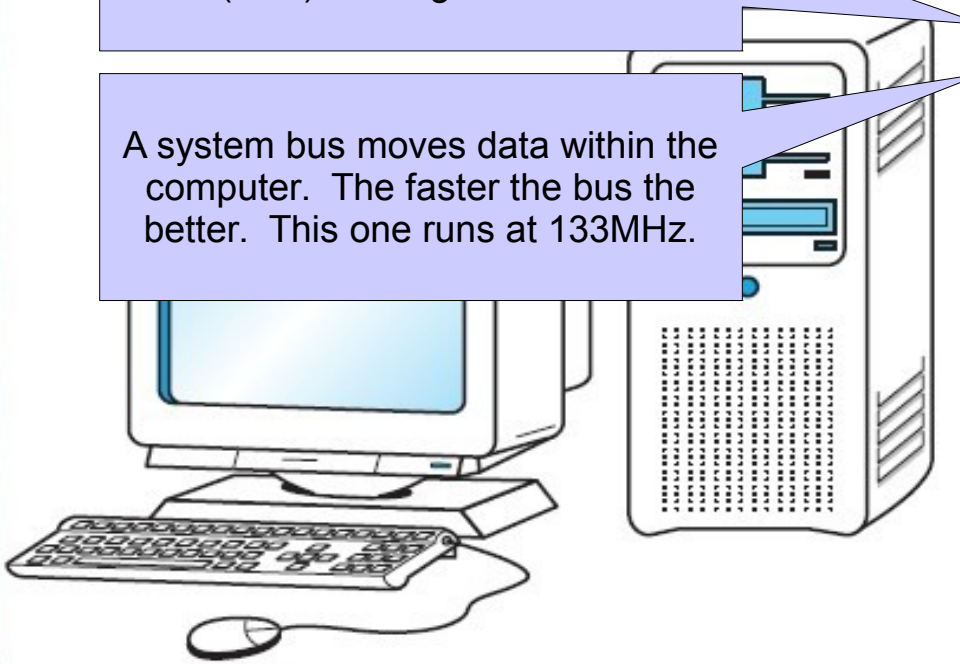
Speed and Capacity

- Hertz = clock cycles per second (frequency)
  - 1MHz = 1,000,000Hz
  - Processor speeds are measured in MHz or GHz.
- Byte = a unit of storage
  - 1KB = 2^{10} = 1024 Bytes
  - 1MB = 2^{20} = 1,048,576 Bytes
  - Main memory (RAM) is measured in MB
  - Disk storage is measured in GB for small systems, TB for large systems.

CPU and Memory

The microprocessor is the “brain” of the system. It executes program instructions. This one is a Pentium III (Intel) running at 667 MHz.

A system bus moves data within the computer. The faster the bus the better. This one runs at 133MHz.



ER – CHEAP! CHEAP! CHEAP!

- Pentium III 667 MHz
- 133 MHz 64MB SDRAM
- 32KB L1 cache, 256KB L2 cache
- 30GB EIDE hard drive (7200 RPM)
- 48X max variable CD-ROM
- 2 USB ports, 1 serial port, 1 parallel port
- 19" monitor, .24mm AG, 1280 × 1024 at 85Hz
- Intel 3D AGP graphics card
- 56K PCI voice modem
- 64-bit PCI sound card

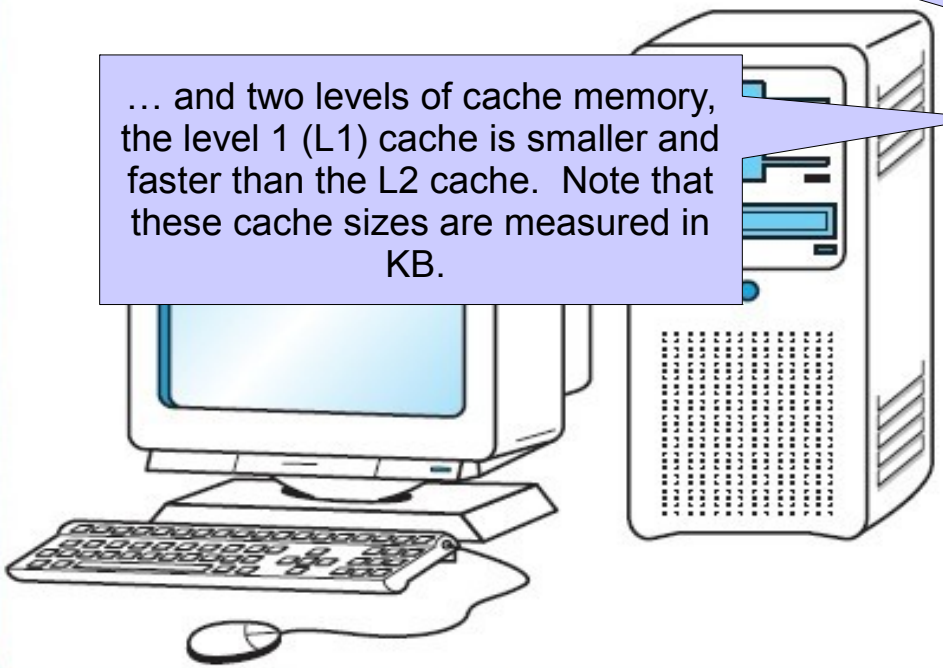
Something about Memory

- Computers with large main memory capacity can
  - run larger programs
  - with greater speed than computers having small memories
- RAM (Random Access Memory，随机存储器)
  - memory contents can be accessed directly if you know its location.
- Cache (高速缓存)
  - a type of temporary memory that can be accessed faster than RAM

Memory and Cache

This system has 64MB of synchronous dynamic RAM (SDRAM) . .

… and two levels of cache memory, the level 1 (L1) cache is smaller and faster than the L2 cache. Note that these cache sizes are measured in KB.



R – CHEAP! CHEAP! CHEAP!

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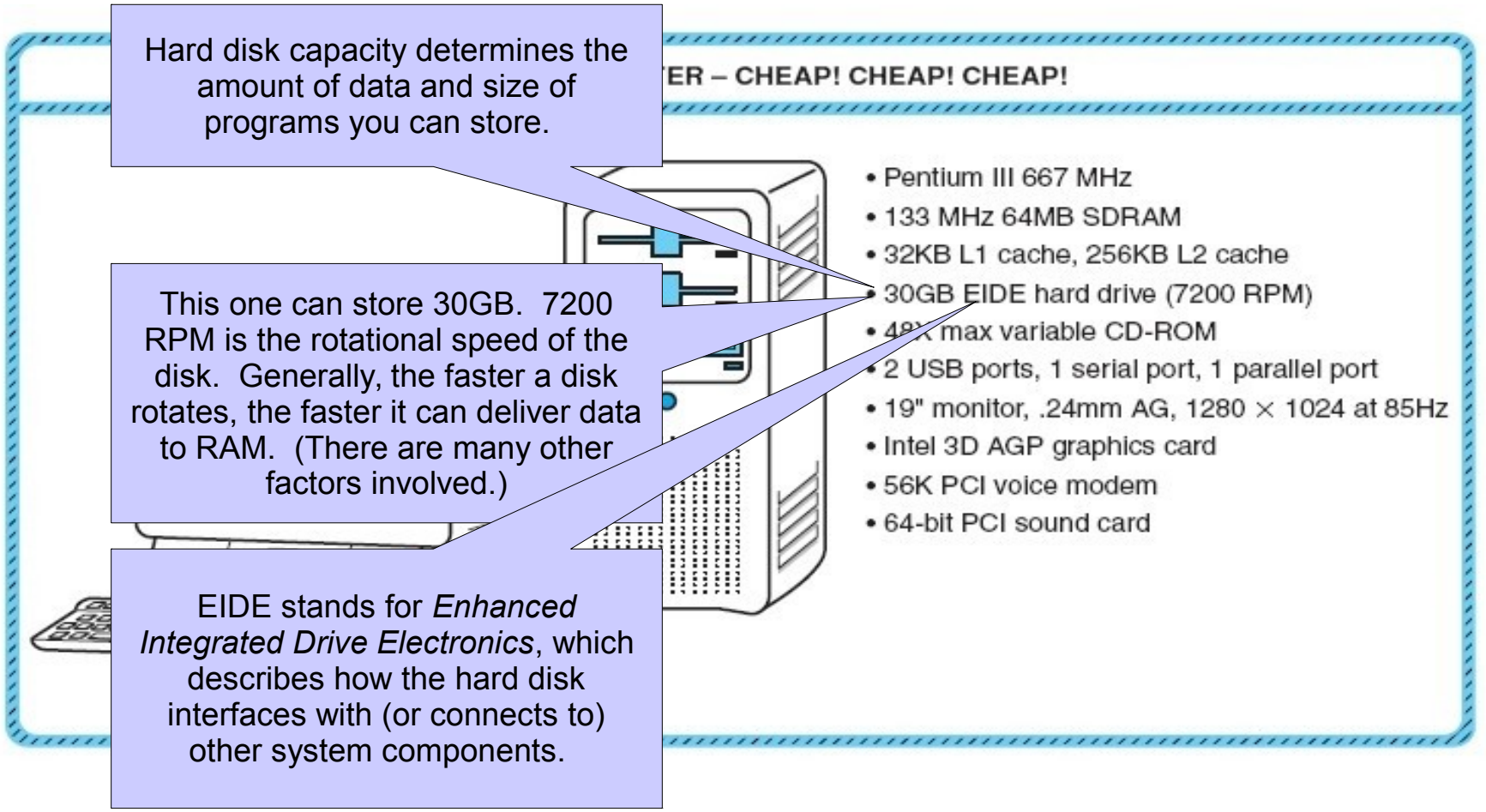
Hard Disk

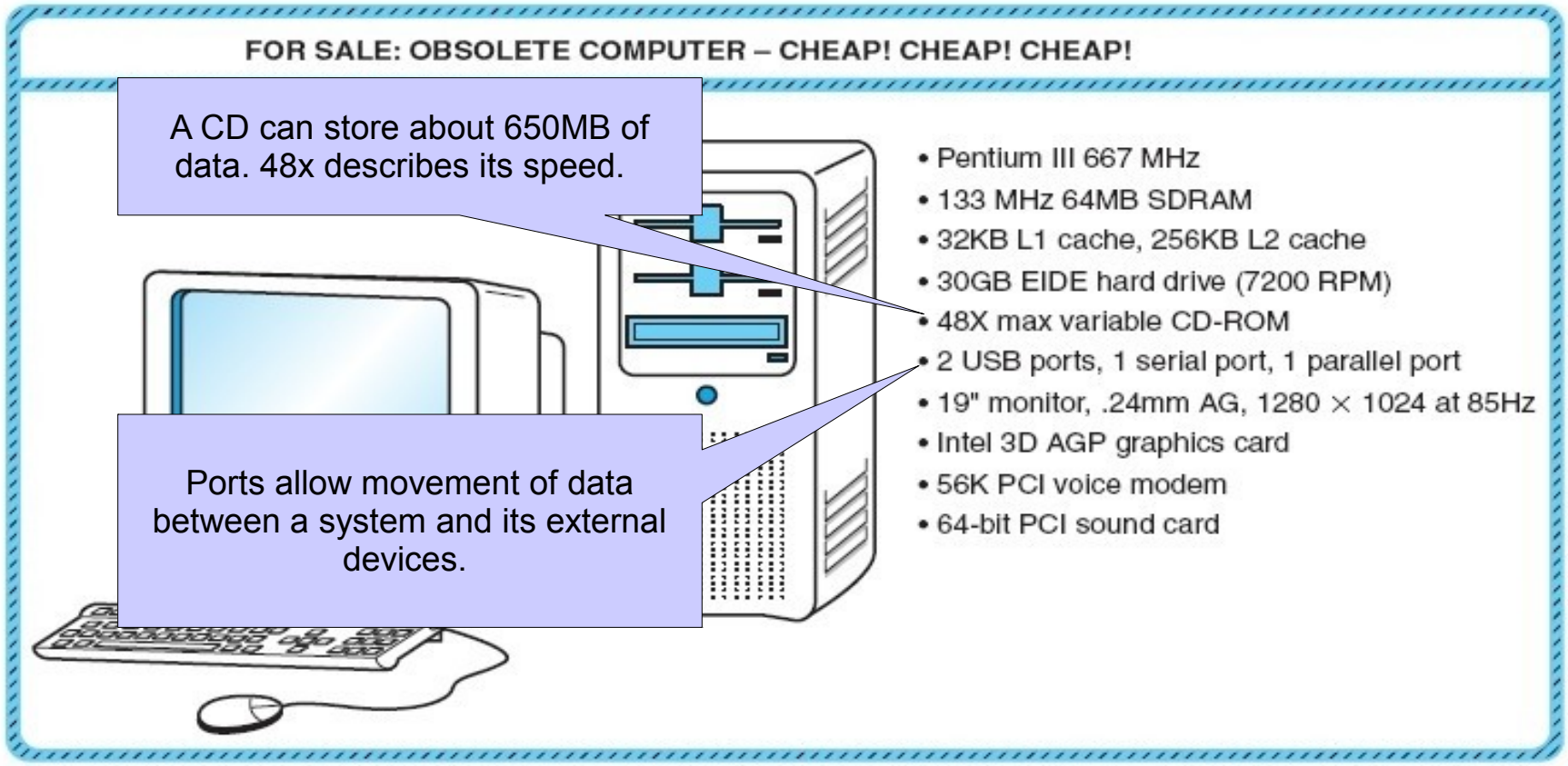


Hard disk capacity determines the amount of data and size of programs you can store.

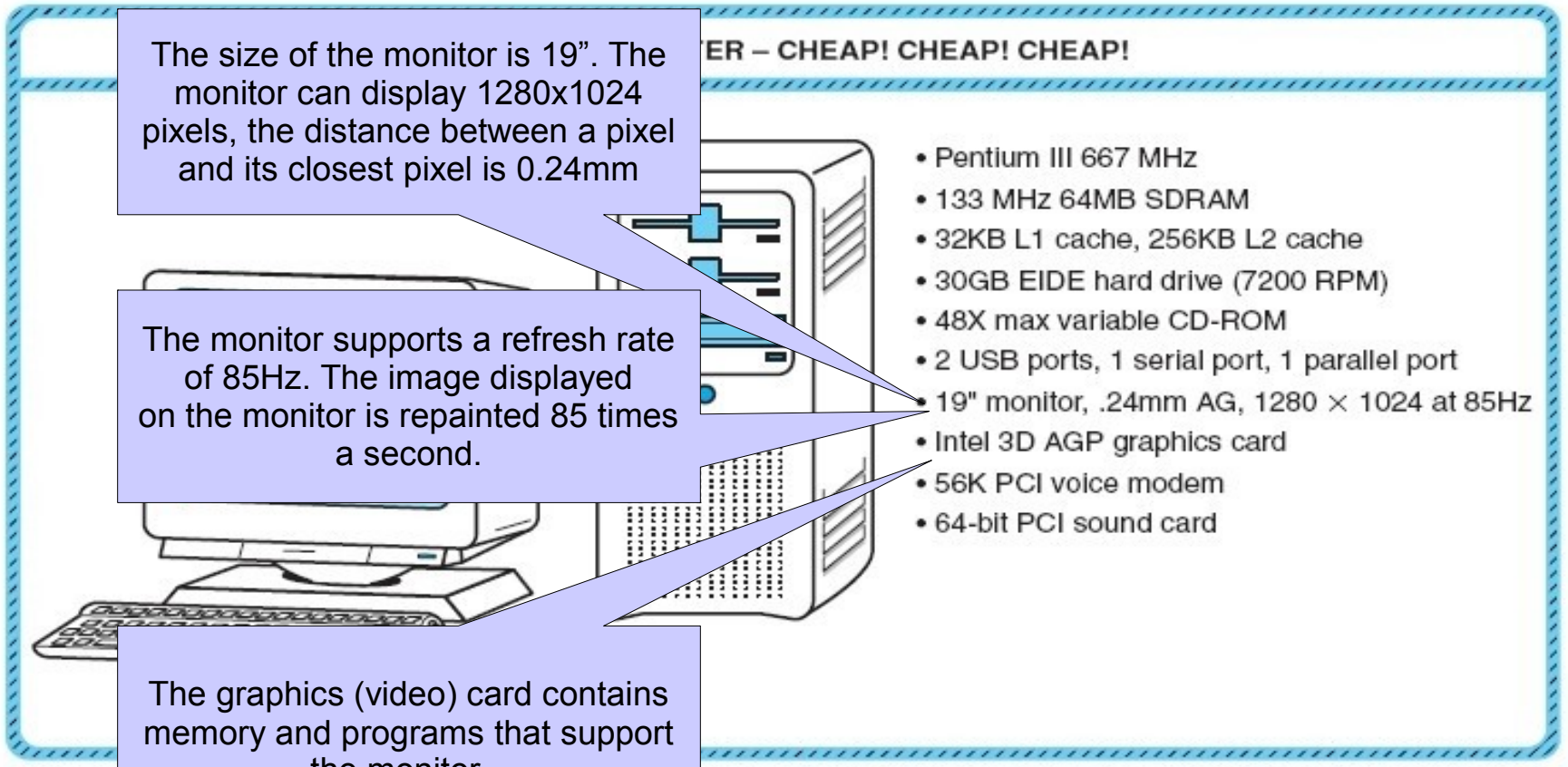
This one can store 30GB. 7200 RPM is the rotational speed of the disk. Generally, the faster a disk rotates, the faster it can deliver data to RAM. (There are many other factors involved.)

EIDE stands for *Enhanced Integrated Drive Electronics*, which describes how the hard disk interfaces with (or connects to) other system components.

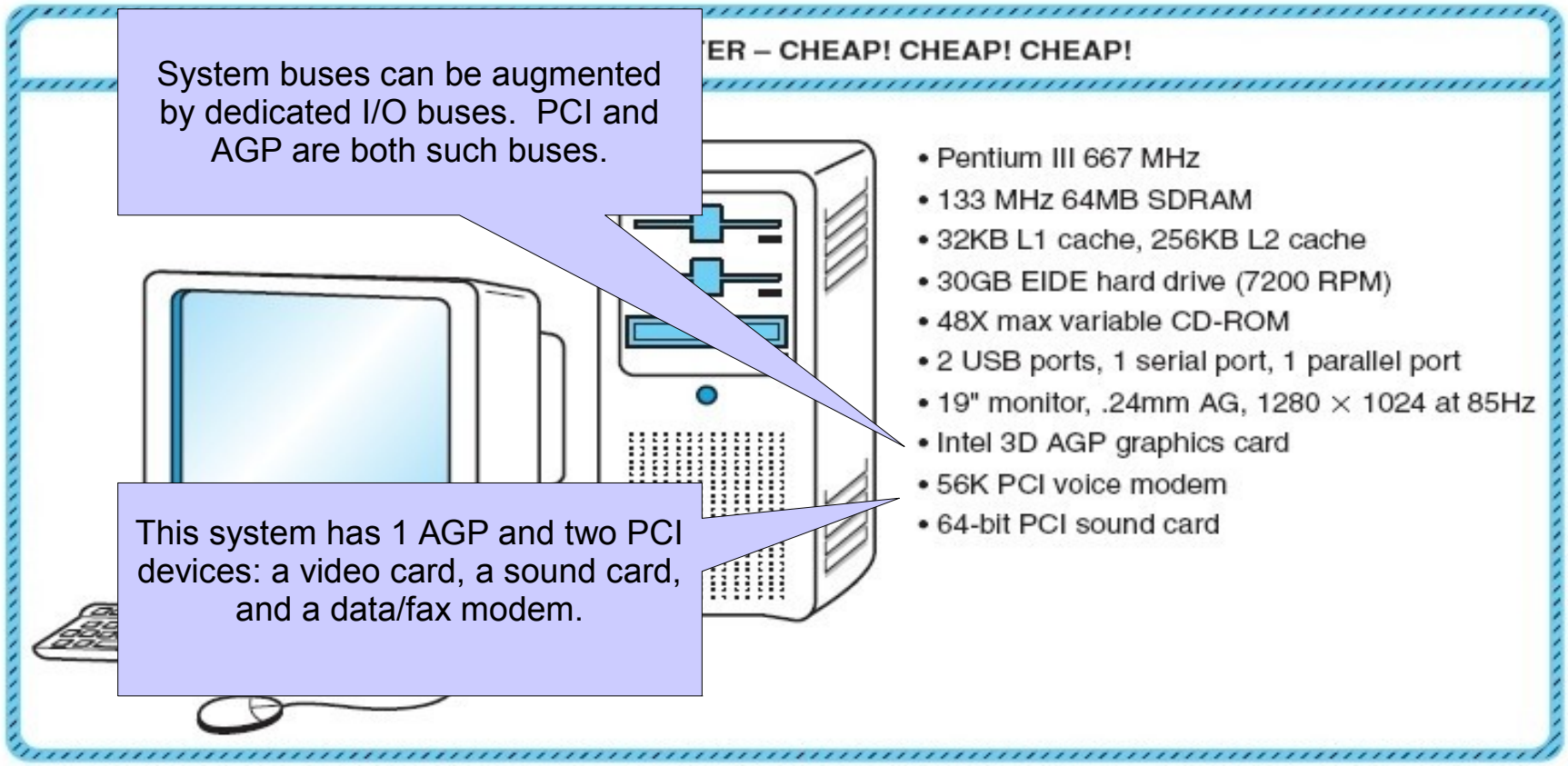
CD-ROM, Ports (端口)



Graphics Card and Monitor



I/O Bus


ER – CHEAP! CHEAP! CHEAP!
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• 2 USB ports, 1 serial port, 1 parallel port
• 19" monitor, .24mm AG, 1280 × 1024 at 85Hz
• Intel 3D AGP graphics card
• 56K PCI voice modem
• 64-bit PCI sound card
System buses can be augmented by dedicated I/O buses. PCI and AGP are both such buses.
This system has 1 AGP and two PCI devices: a video card, a sound card, and a data/fax modem.

A newer system

Battery Life

Up to 7 hours with standard 6-cell battery

Weight

Starting at 4.1 lbs

Ports

Mini DP, VGA, 2 x USB 3.0 (1x always-on), 2 x USB 2.0, Combo jack, Smart Card Reader (optional)

Microphone

Dual noise-cancelling HD microphones

Speakers

Stereo speakers with Dolby® HomeTheater® v4

Processor

Intel Core i3-4000M Processor (3MB Cache, 2.40GHz)

Operating System

Windows 8 64

Display

T440p 14.0HD WWAN

Graphics

Intel HD Graphics 4600 with docking connector

Memory

4GB PC3-12800 DDR3L SDRAM 1600MHz SODIMM

Hard Drive

500GB Hard Disk Drive, 7200rpm

Optical Device

DVD Recordable 8x Max Dual Layer, Ultrabay Slim w/ SW Royalty for Windows 8

Wireless

Intel Single Band Wireless 7260BN with Bluetooth 4.0

Warranty

1 Year Depot or Carry-in

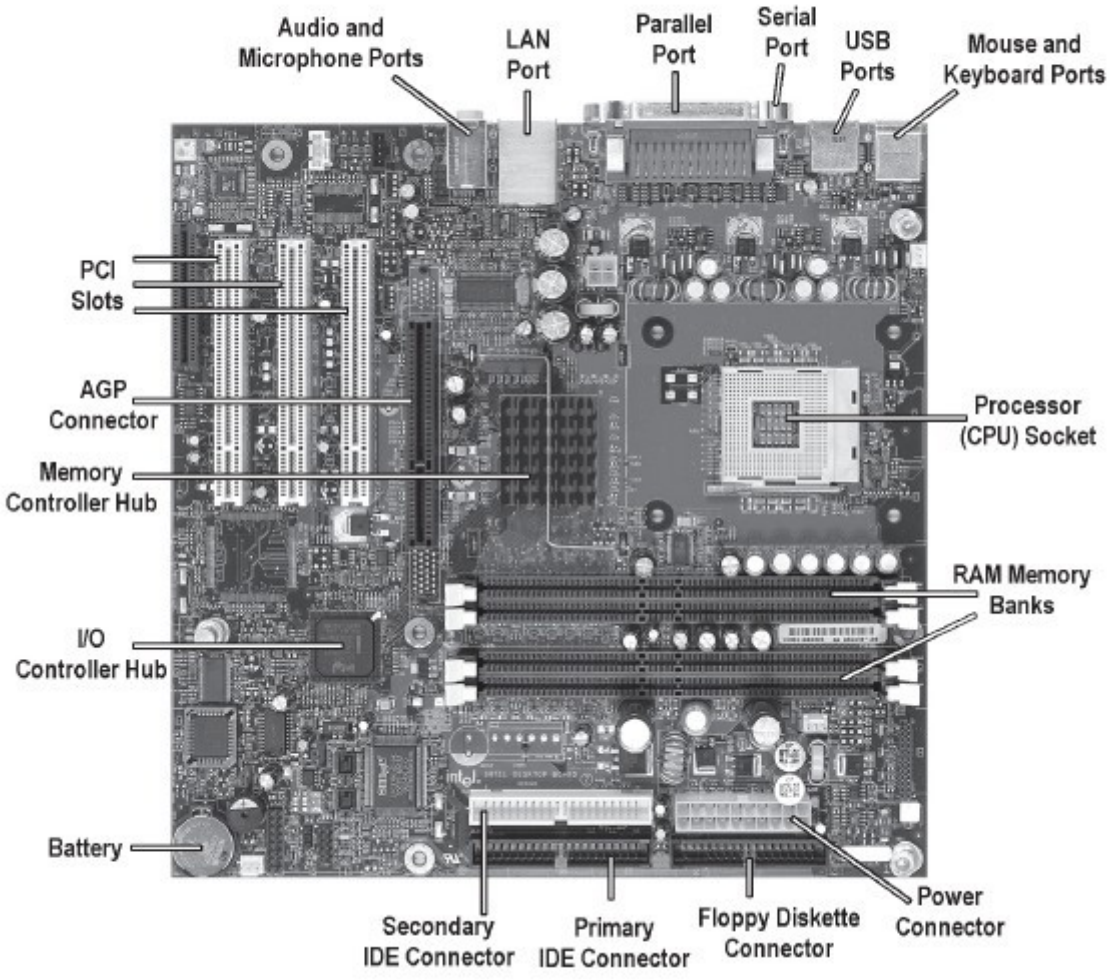
Pointing Device

Fingerprint Reader

Battery

6 Cell Li-Ion Cylindrical Battery 56.16Wh

The Mainboard – How they are put together



Questions raised

- How these components work and how they interact with software to make complete computer systems
  - What assurance do we have that computer components will operate as we expect?
  - And what assurance do we have that computer components will operate together?

Standards

- Created to ensure universal compatibility of data formats and protocols
- May be created by committee or may become a *de facto* standard through popular use
- Examples:
  - Computer languages: Java, SQL, C, JavaScript
  - Display standards: Postscript, MPEG-2, JPEG, GIF
  - Character set standards: ASCII, Unicode, EBCDIC
  - Video standards: VGA, XGA, RGB

Standard Organizations

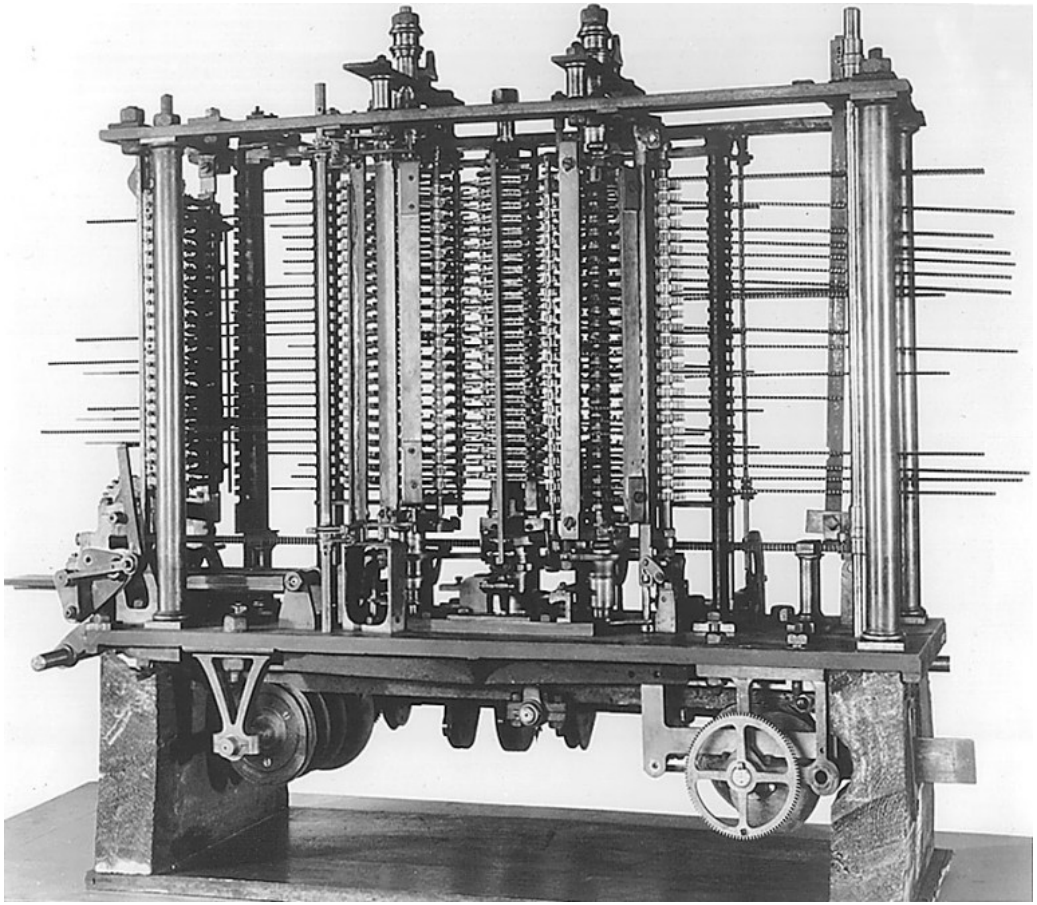
- The Institute of Electrical and Electronic Engineers (IEEE)
- The International Telecommunications Union (ITU)
- The American National Standards Institute (ANSI)
- The British Standards Institution (BSI)
- The International Organization for Standardization (ISO)
- The World Wide Web Consortium (W3C)

Historical Development

Generation Zero: Mechanical Calculating Machines (1642 - 1945)

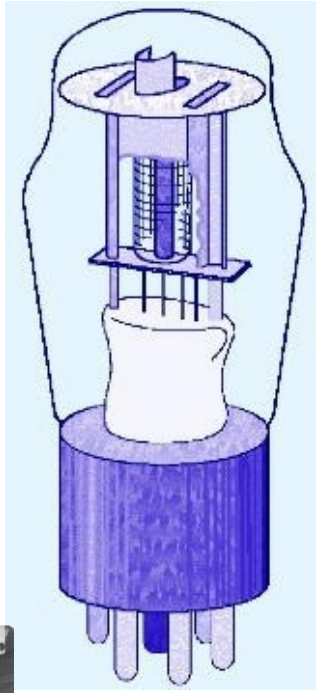
- Pascaline - Blaise Pascal (1623 - 1662).
- Difference Engine - Charles Babbage (1791 - 1871), also designed but never built the Analytical Engine.
- Punched card tabulating machines - Herman Hollerith (1860 – 1929).
- Augusta Ada Byron develops many of the fundamental concepts of programming
- George Boole invents Boolean logic.

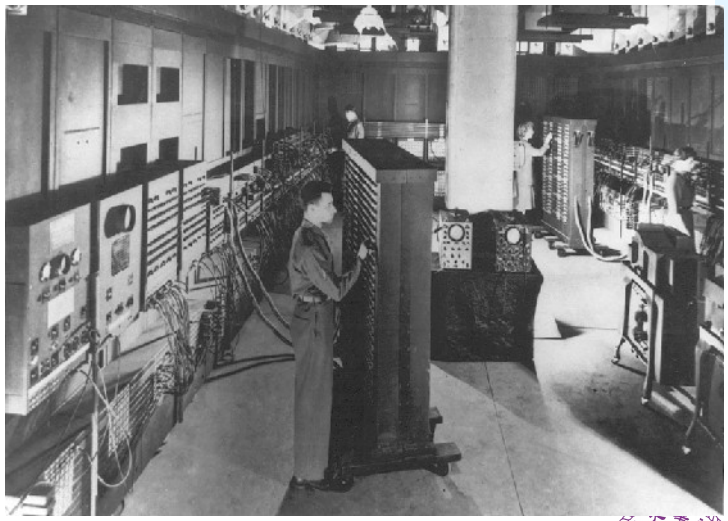
Babbage's Analytical Engine



The First Generation: Vacuum Tube (电子管) (1945 - 1953)

- Electronic Numerical Integrator and Computer (ENIAC)
  - John Mauchly and J. Presper Eckert
  - University of Pennsylvania, 1946

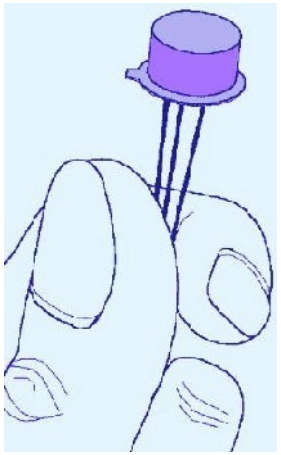




Important first generation products

- The IBM 650 first mass-produced computer. (1955)
  - It was phased out in 1969.
- Other major computer manufacturers of this period include UNIVAC, Engineering Research Associates (ERA), and Computer Research Corporation (CRC).
  - UNIVAC and ERA were bought by Remington Rand, the ancestor of the Unisys Corporation.
  - CRC was bought by the Underwood (typewriter)

The 2nd Generation: Transistorized (晶体管) (1954 - 1965)



- Products
  - IBM 7094 (scientific) and 1401 (business)
  - Digital Equipment Corporation (DEC) PDP-1
  - Univac 1100
  - Control Data Corporation 1604.
  - ……

The Third Generation: Integrated Circuit (集成电路) (1965 - 1980)

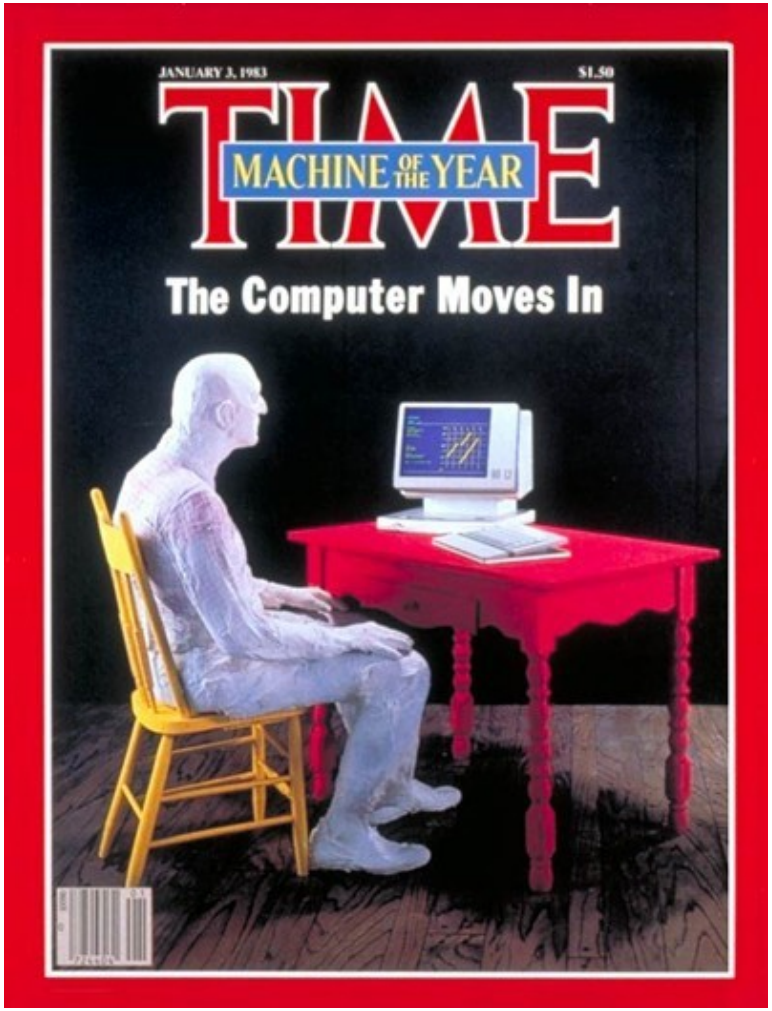
- Products
  - IBM 360
  - DEC PDP-8 and PDP-11
  - Cray-1 supercomputer
- IBM had gained overwhelming dominance in the industry
- Other manufacturers: the BUNCH
  - Burroughs, Unisys, NCR, Control Data, and Honeywell

The Fourth Generation: VLSI (大规模集成电路) (1980 - ????)

- Very large scale integrated circuits (VLSI)
  - have more than 10,000 components per chip
- Enabled the creation of microprocessors (微处理器)
  - The first was the 4-bit Intel 4004
  - Later versions, such as the 8080, 8086, and 8088 spawned the idea of “personal computing”

IBM PC: August 1981

- Open architecture
  - Intel and Microsoft

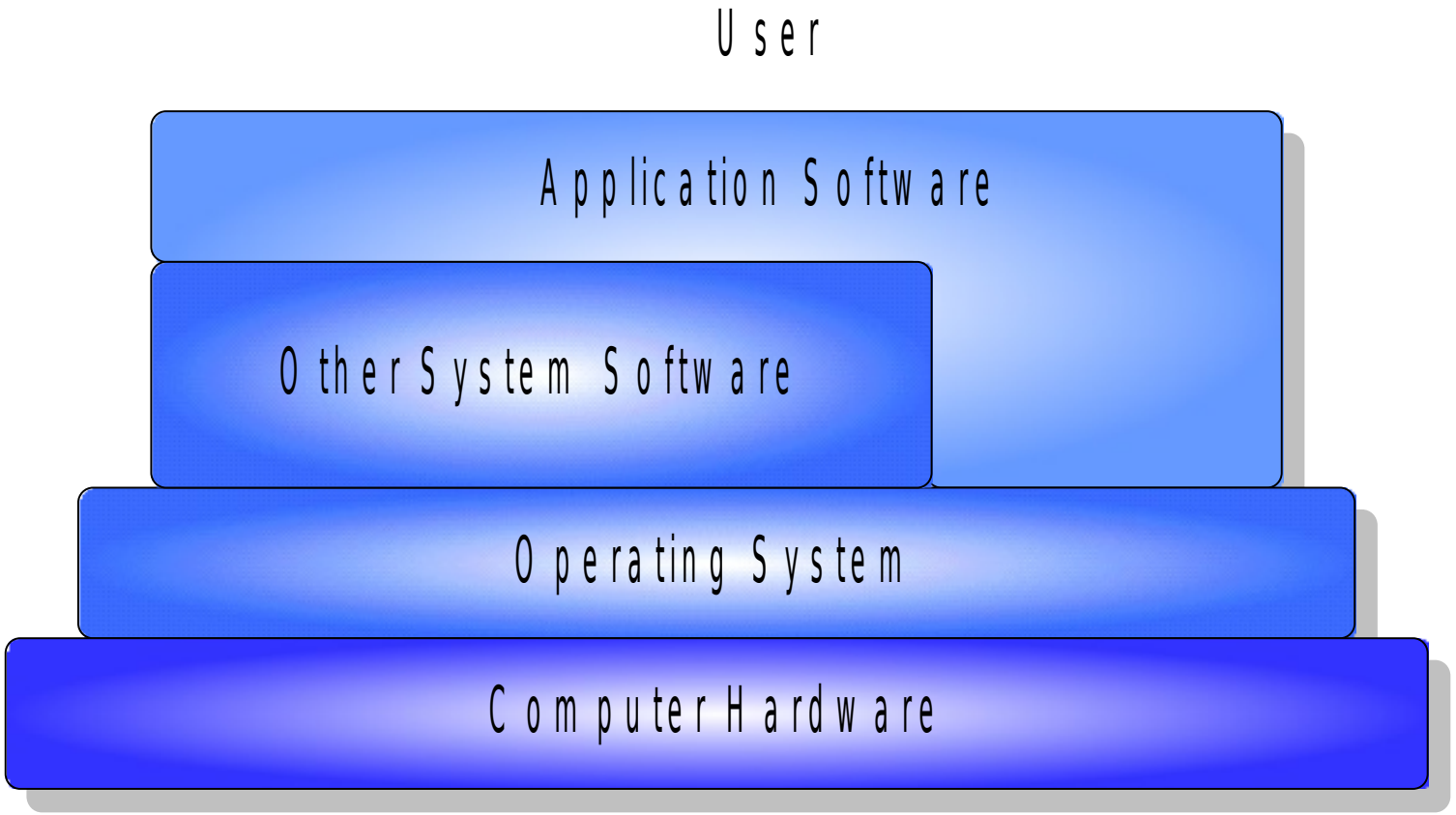


History of micro processors

- 4 bits processors
  - Intel 4004 (1971)
- 8 bits processors
  - Intel 8008 (1972), 8080 (1974)
- 16 bits processors
  - Intel 8086/8088 (1978), 80286 (1982)
- 32 bits processors
  - Intel 80386 (1985), 486 (1988), Pentium (1993), Pentium II, III, IV
- 64 bits and multi-core processors
  - Intel i3, i5, i7
- Low-voltage processors
  - ARM, Qualcomm, Nvidia

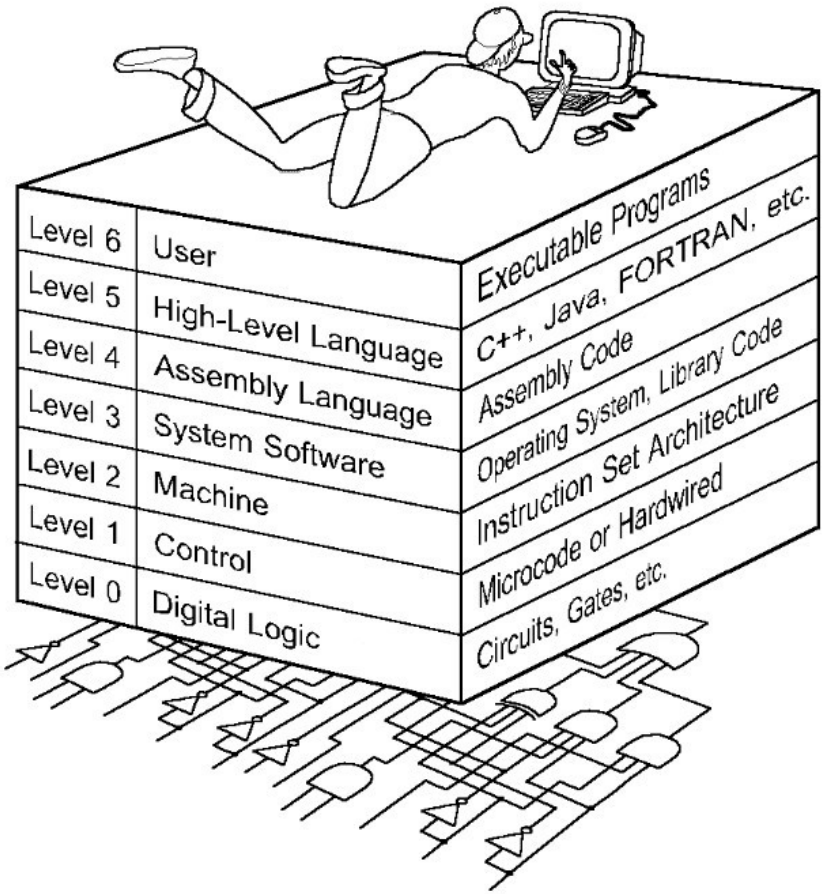
System Hierarchy

Relationship between hardware and software



Hierarchy: Layered Structure

- Each virtual machine layer is an abstraction of the level below it.
- The machines at each level execute their own particular instructions, calling upon machines at lower levels to perform tasks as required.
- Computer circuits ultimately carry out the work.



Levels 6 & 5

- Level 6: The User Level
  - Program execution and user interface level.
  - The level with which we are most familiar.
- Level 5: High-Level Language Level (高级语言)
  - The level with which we interact when we write programs in languages such as C, Pascal, Lisp, and Java.

Level 4 & 3

- Level 4: Assembly Language Level (汇编语言)
  - Acts upon assembly language produced from Level 5, as well as instructions programmed directly at this level.
- Level 3: System Software Level
  - Controls executing processes on the system.
  - Protects system resources.
  - Assembly language instructions often pass through Level 3 without modification.

Level 2

- Level 2: Machine Level
  - Also known as the Instruction Set Architecture (ISA) Level.
  - Consists of instructions that are particular to the architecture of the machine.
  - Programs written in machine language need no compilers, interpreters, or assemblers.

Level 1

- Level 1: Control Level
  - A control unit decodes and executes instructions and moves data through the system.
  - Control units can be microprogrammed or hardwired.
  - A microprogram is a program written in a low-level language that is implemented by the hardware.
  - Hardwired control units consist of hardware that directly executes machine instructions.

Level 0

- Level 0: Digital Logic Level
  - This level is where we find digital circuits (the chips).
  - Digital circuits consist of gates and wires.
  - These components implement the mathematical logic of all other levels.

Two concepts in the textbook

- Computer organization
  - Encompasses all physical aspects of computer systems.
  - E.g., circuit design, control signals, memory types.
- Computer architecture
  - Logical aspects of system implementation as seen by the programmer.
  - E.g., instruction sets, instruction formats, data types, addressing modes.

“Organization” and “Architecture”

- There is no clear distinction between matters related to computer organization and matters relevant to computer architecture.
- Principle of Equivalence of Hardware and Software:
  - ***Anything that can be done with software can also be done with hardware, and anything that can be done with hardware can also be done with software.****

* Assuming speed is not a concern.

The von Neumann Model: How does a computer work?

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Where are the programs?

- On the ENIAC, all programming was done at the digital logic level.
- Programming the computer involved moving plugs and wires.
  - Configuring the ENIAC to solve a “simple” problem required many days labor by skilled technicians.
- A different hardware configuration was needed to solve every unique problem type.

The von Neumann Model

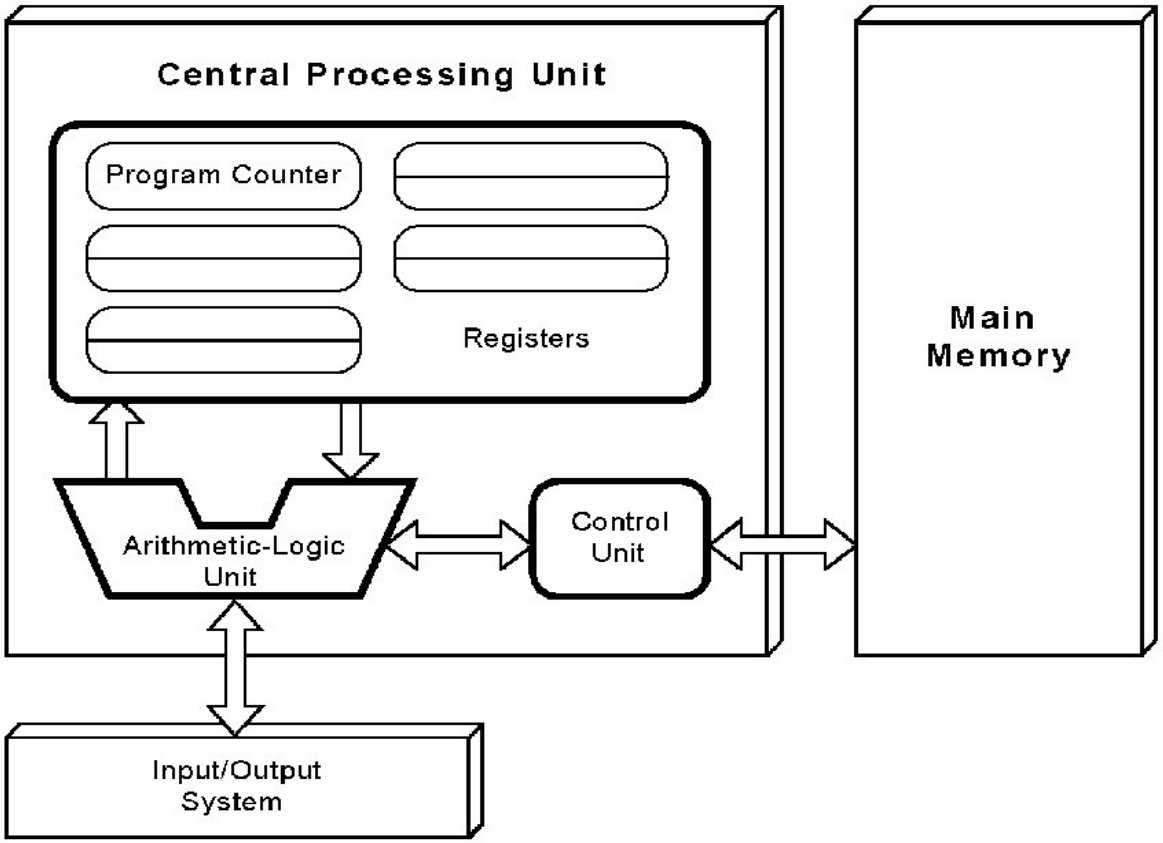
- **Stored-program computers**
  - a computer that could store instructions in memory
  - The design was conceived by John Mauchley and J. Presper Eckert, Inventors of the ENIAC
  - The idea was ascribed to John von Neumann, a mathematician

Stored-program Computers

- Three hardware parts:
  - A central processing unit (CPU)
  - A main memory system
  - An I/O system
- Providing the capacity to carry out sequential instruction processing
- A single data path between the CPU and main memory
  - The von Neumann bottleneck.

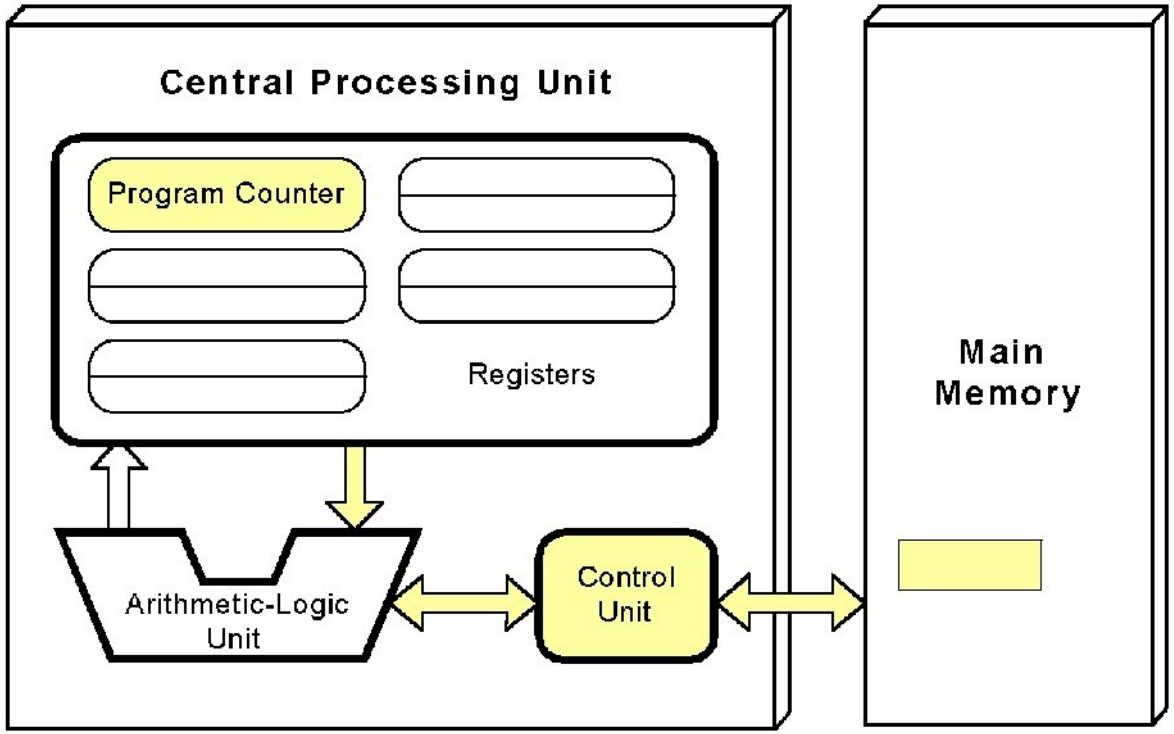
A General Depiction of a von Neumann System

- a fetch-decode-execute cycle to run programs



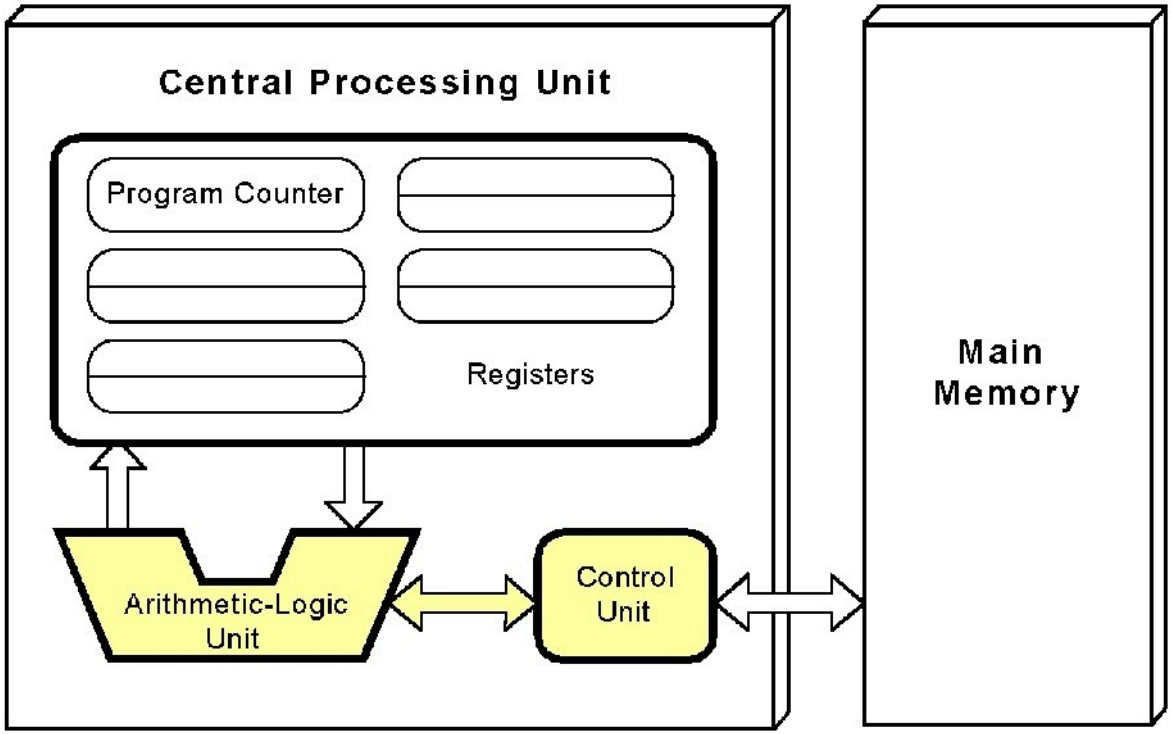
Fetch the instructions

- The control unit fetches the next instruction from memory using the program counter to determine where the instruction is located.



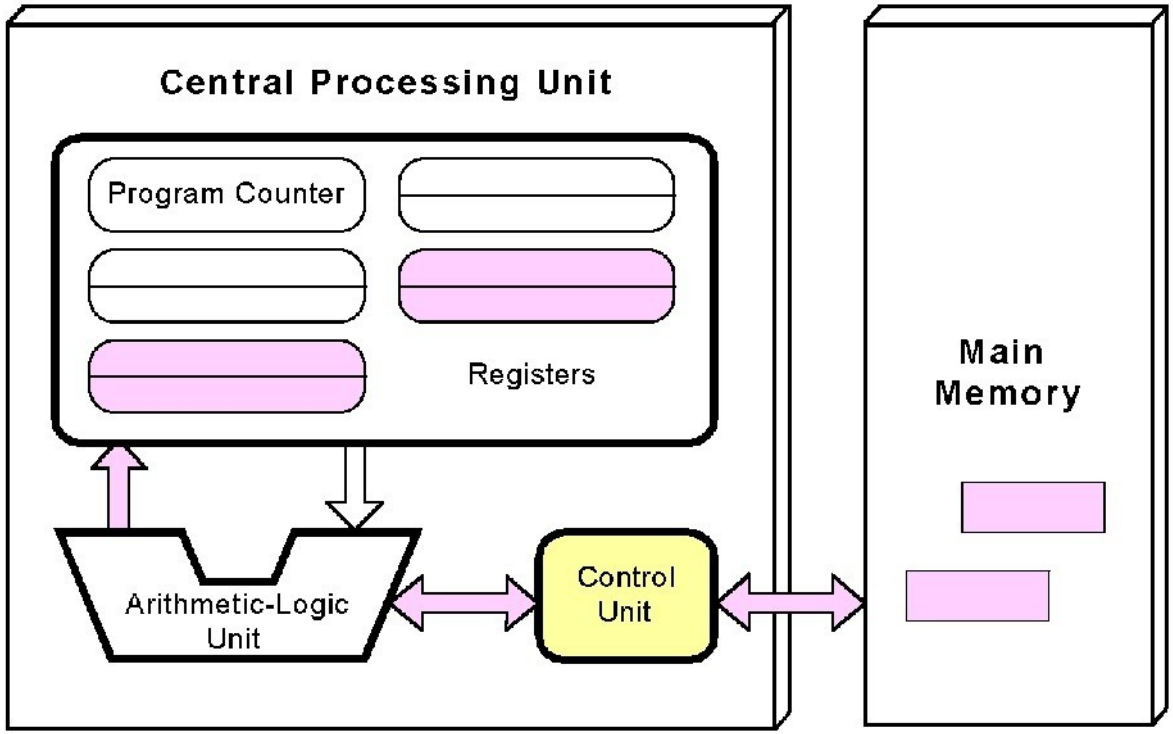
Decode

- The instruction is decoded into a language that the ALU can understand.



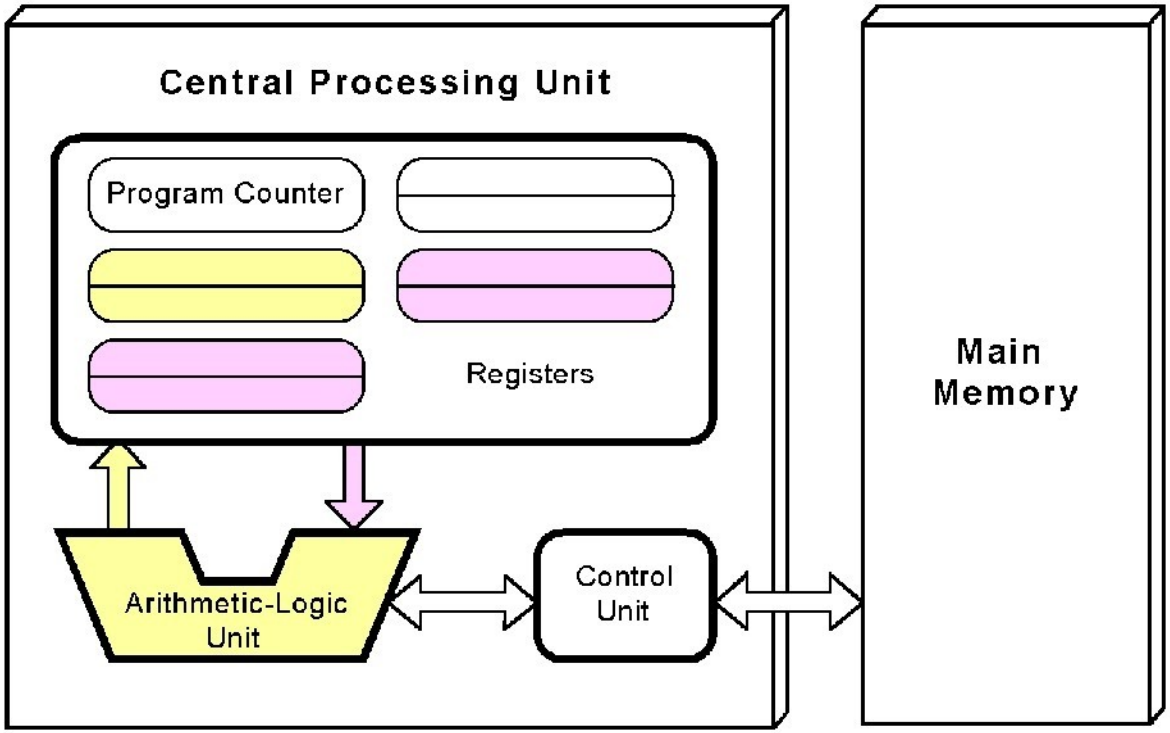
Fetch the data

- Any data operands required to execute the instruction are fetched from memory and placed into registers within the CPU



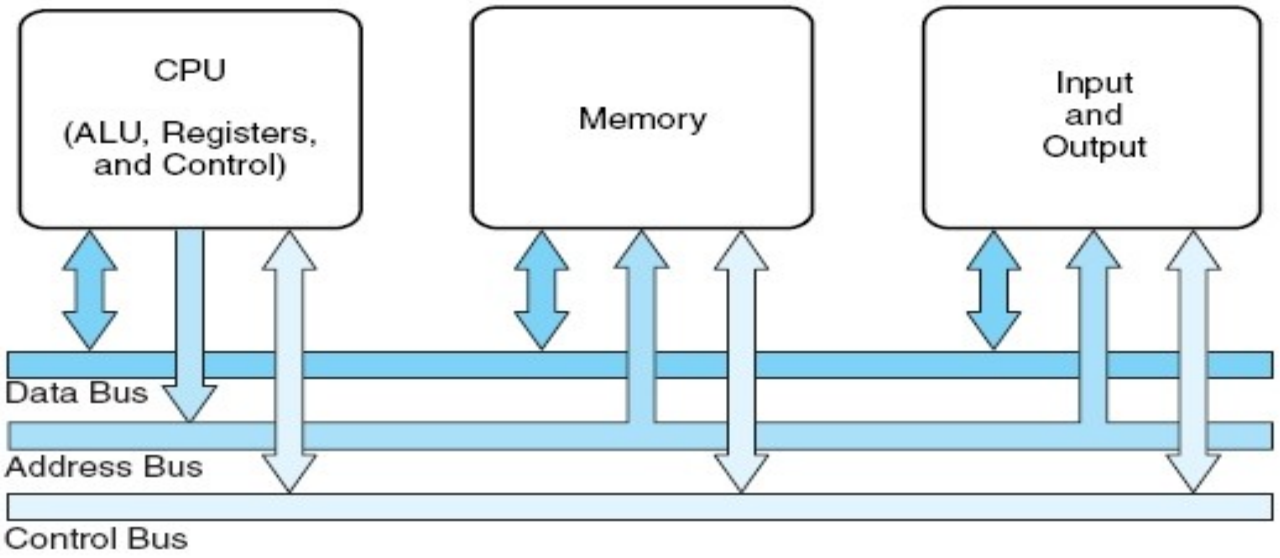
Execute

- The ALU executes the instruction and places results in registers or memory.



Improvements of von Neumann Models

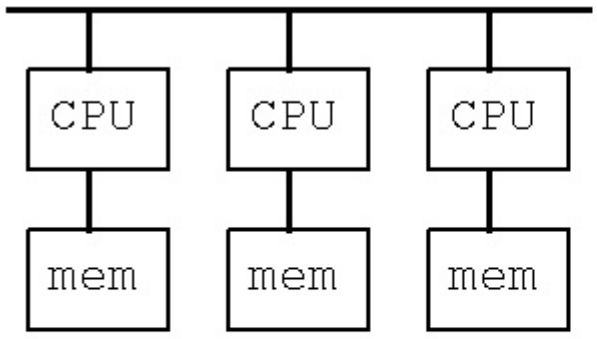
- Specialized buses



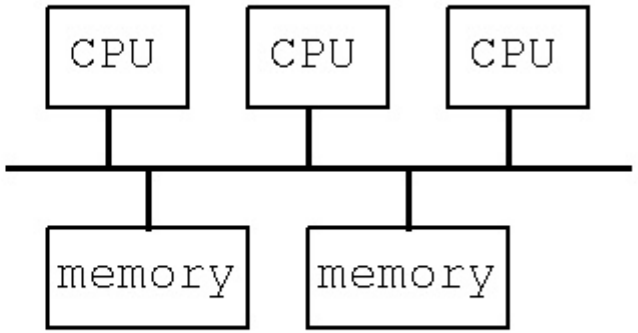
- Floating-point units
- Cache memories
- ……

Adding Processors

- Enormous improvements in computational power require departure from the classic von Neumann architecture
  - Adding processors is one approach.



Distributed Memory Multiprocessor



Shared Memory Multiprocessor

Multiprocessor

Multi-processor (多处理器)/ Parallel Processing (并行处理)

- late 1960s: high-performance computer systems with dual processors to increase computational throughput
- 1970s: supercomputer systems with 32 processors
- 1980s: Supercomputers with 1,000 processors
- 1999: IBM announced its Blue Gene system containing over 1 million processors
- 2000s: Dual Core / Multi-core microcomputers

Non-von Neumann Models

- Parallel processing is only one method of providing increased computational power
- More radical systems have reinvented the fundamental concepts of computation
  - genetic computers (基因计算机)
  - quantum computers (量子计算机)
  - dataflow systems (数据流计算机)
  - ……
- Will any of these systems provide the basis for the next generation of computers?

Review: Computer Hardware

- **What is a computer? (What is the basic structure of a computer?)**
  - **Working: Input – process – output**
  - **Conceptually layered: user – software – hardware**
  - **Program execution: von Neumann Model**
- What does it process?
  - Data: how they are represented.
- How does it process?
  - Mathematically: boolean algebra
  - Electronically: gate circuits
  - Systematically: instructions
  - Workflow: fetch – decode - execute
- How to better handle data?
  - Memory: hierarchy, cache
- How about Input and Output?
  - I/O devices: I/O control, storage devices

Exercises

- Reading
  - Textbook: Chapter 1
- Questions
  - What are the driving factors for the development of computer technology?
  - Why did IBM PC become so successful?
  - What are the benefits of the layered structure?
  - What are the advantages and disadvantages of the von Neumann model?