Tomorrow's Technology and You

8th Edition

Chapter 2

Hardware Basics: Inside the Box

Objectives

- ✓ Explain how computers store and manipulate information.
- ✓ Describe the basic organization of a computer.
- ✓ Discuss the functions and interactions of computer's internal components.
- ✓ Explain the need for different types of memory and storage devices.




What Computers Do

Basic Functions of a Computer

- ✓ Receive input: Accept data from the outside world
- ✓ Process data: Perform arithmetic or logical operations on data
- ✓ Produce output: Communicate data to the outside world
- ✓ Store data: Move and store data in long-term memory (a.k.a. storage)




Basic Components of a Computer

- Input devices
  - Keyboards and pointing devices (mouse)
- Output devices
  - Display or video monitor
  - Printer
  - Speakers
- Central Processing Unit (CPU)




Basic Components of a Computer

- Memory and storage devices
  - Primary storage: RAM (Random Access Memory) (volatile)
  - Secondary storage: Storage devices that serve as long-term repositories for data:
    - Hard disk drives
    - Recordable CD and DVD drives
    - Tape drives
    - Flash memory (non-volatile)
      - USB flash memory




Basic Components of a Computer

- Memory and storage devices
  - Read-only storage:
    - ROM (Read-Only Memory)
    - Non-Recordable CD-ROM and DVD-ROM




- **Information**
  - Interpretation of data
  - Anything that can be communicated, whether it has value or not

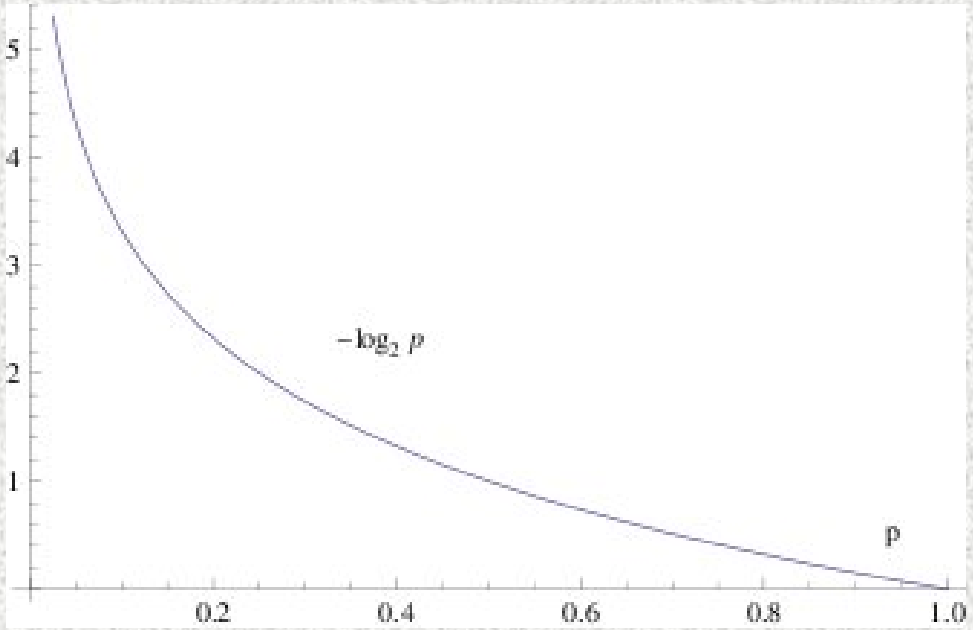
Information comes from:

  - Data
  - Words, numbers, pictures
  - Sound, movies, etc.

- **FALSE: In computer terminology the terms data and information are more or less interchangeable.**

Measure of information

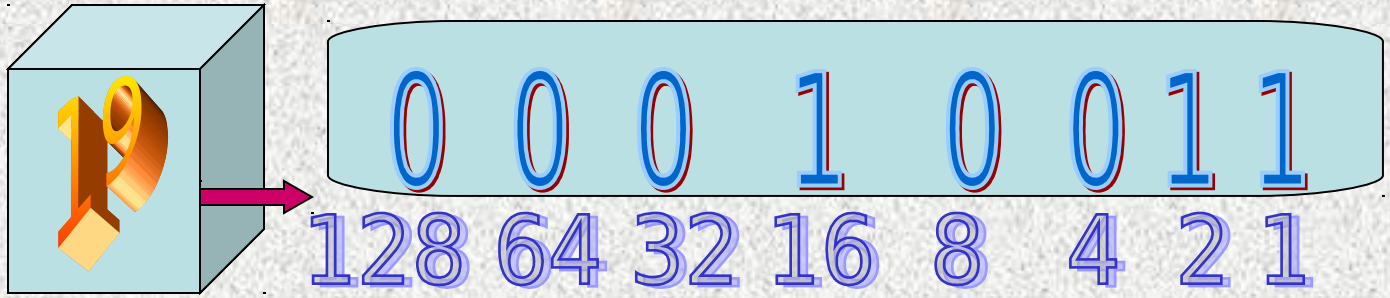
- p - probability that the information is true
- $-\log_2 p$ - the measure of information



A Bit About Bits

- Computer's data are digital
  - Bit, or binary digit
    - The unit of information
    - Can have one of two values: 1 or 0
    - Sequences of bits can represent data (numbers, codes) or instructions
  - Byte: a sequence of 8 bits

- All numbers can be represented using bits
  - Each number is a sum of its positional values (each being a power of 2).
  - 19 is represented as 00010011.
- Binary arithmetic



Bits as Numbers

- Binary number system
  - Binary numbers use digits 0 and 1 (bits) only.
  - Decimal numbers are automatically converted into binary numbers and vice versa.
  - Binary number processing in a computer is usually hidden from the user.




Bits as Codes

- ASCII code
  - The most widely used code
  - An abbreviation of American Standard Code for Information Interchange
  - Typically supports up to 256 characters
- Unicode
  - Supports 65,000 unique characters




Bits as Instructions in Programs

- Programs are stored as sequences of bits.
  - Program instructions are represented in binary notation through the use of codes.

http://richardbowles.tripod.com/durham/comparch/arch1.htm

http://focus.ti.com/vf/docs/blockdiagram.tsp?family=vf&blockDiagramId=6044

http://www.vaughns-1-pagers.com/computer/pc-block-diagram.htm

http://www.hitequest.com/Kiss/computer_arch.htm




Bits, Bytes, and Buzzwords

Bit-related terminology

- Byte = 8 bits
- Kilobyte (KB) ≈ 1 Thousand Bytes
- Megabytes (MB) ≈ 1 Million Bytes
- Gigabytes (GB) ≈ 1 Billion Bytes
- Terabytes (TB) ≈ 1 Trillion Bytes




Bits, Bytes, and Buzzwords

Bit-related terminology

- Kilo (K) $\approx 10^3$
- Mega (M) $\approx 10^6$
- Giga (G) $\approx 10^9$
- Tera (T) $\approx 10^{12}$
- Peta (P) $\approx 10^{15}$




Bits, Bytes, and Buzzwords

Bit-related terminology (for binary arithmetics only)

- Kilo (K) = 2^{10} = 1,024
- Mega (M) = 2^{20} = 1,048,576
- Giga (G) = 2^{30} = 1,073,741,824
- Tera (T) = 2^{40} = 1,099,511,627,776
- Peta (P) = 2^{50} = 1,125,899,906,842,624

Bits, Bytes, and Buzzwords

Bit-related terminology (for binary arithmetic only)

- milli (m) = 2^{-10} = 1/1,024 » 10^{-3} (one-thousandth)
- micro (μ) = 2^{-20} = 1/1,048,576 ≈ 10^{-6} (one-millionth)
- nano (n) = 2^{-30} = 1/1,073,741,824 ≈ 10^{-9} (one-billionth)
- pico (p) = 2^{-40} = 1/1,099,511,627,776 ≈ 10^{-12} (one-trillionth)

"Green" Computing

The manufacture and use of hardware and software can have an impact on the environment.

- ✓"Green" equipment (e.g., Energy Star – but beware of absurdities).
- ✓Solar batteries
- ✓Energy-saving features.

Tips:

- ✓Turn off the computer when you're away.
- ✓Screen Savers don't save energy.
- ✓Print only once.
- ✓Recycle waste products.

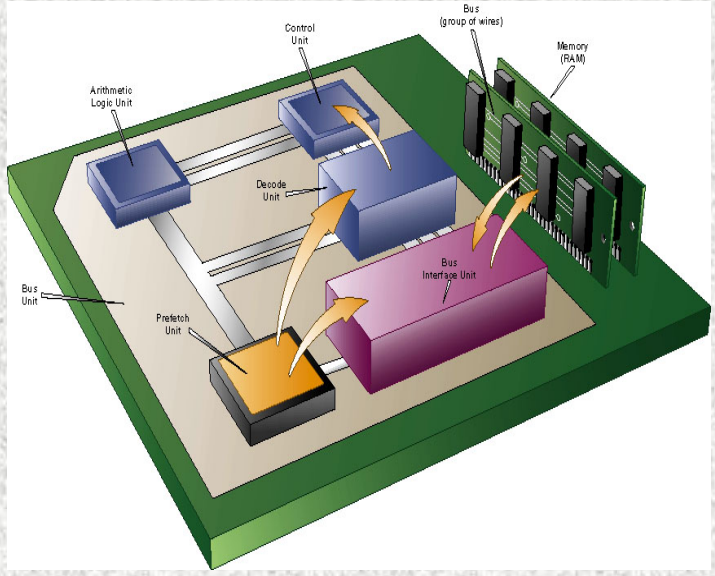
The Computer's Core: The CPU and Memory

The CPU: The Real Computer

- CPU (microprocessor)
  - Interprets and executes the instructions in each program
  - Performs arithmetic and logical operations on data

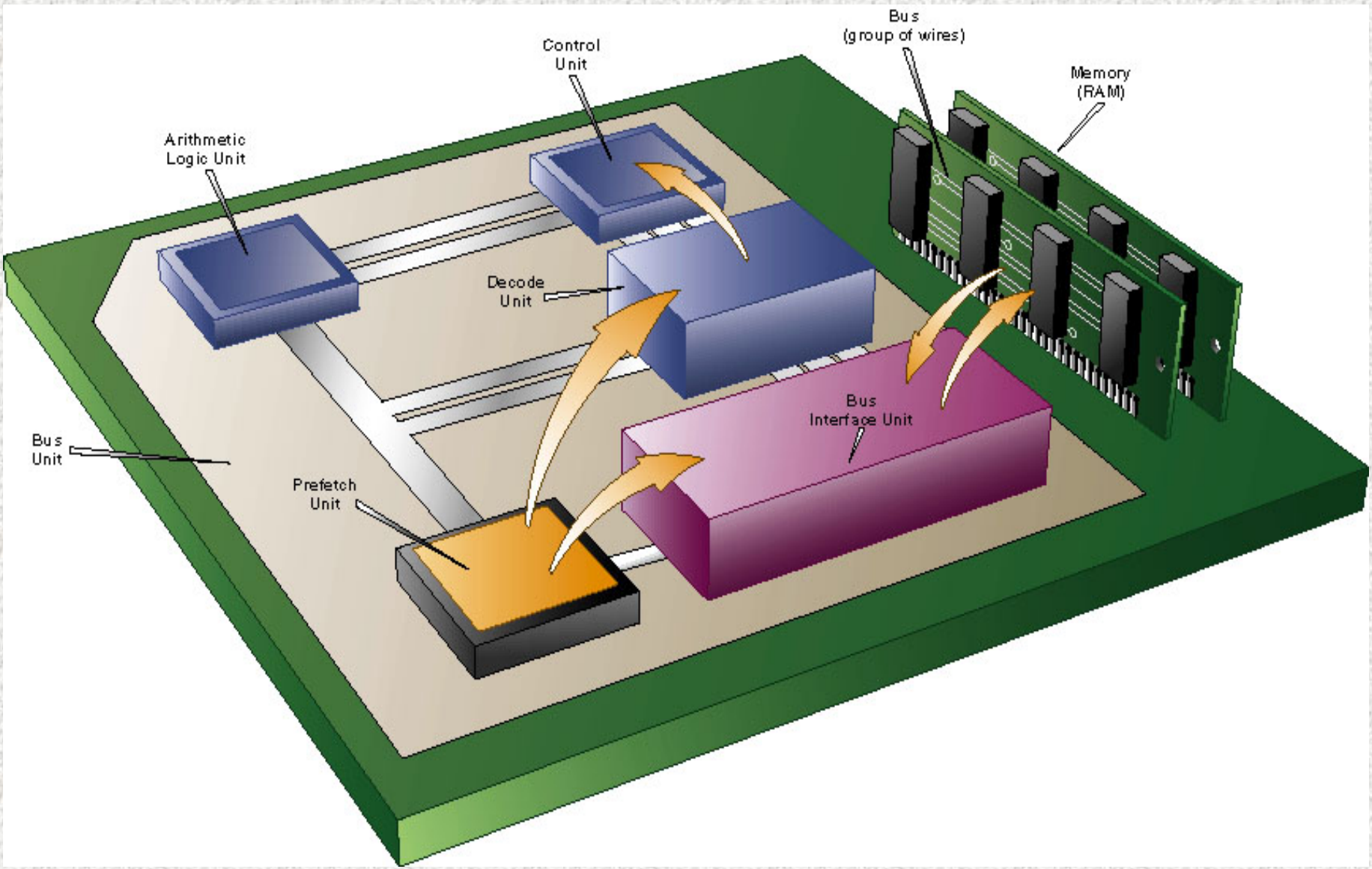



CPU



- ✓ Prefetch unit
- ✓ Decoding unit
- ✓ Arithmetic-logic unit (ALU)
- ✓ Control unit
- ✓ Cache
- ✓ Bus interface unit
- ✓ (Network interface unit)
- ✓ Registers

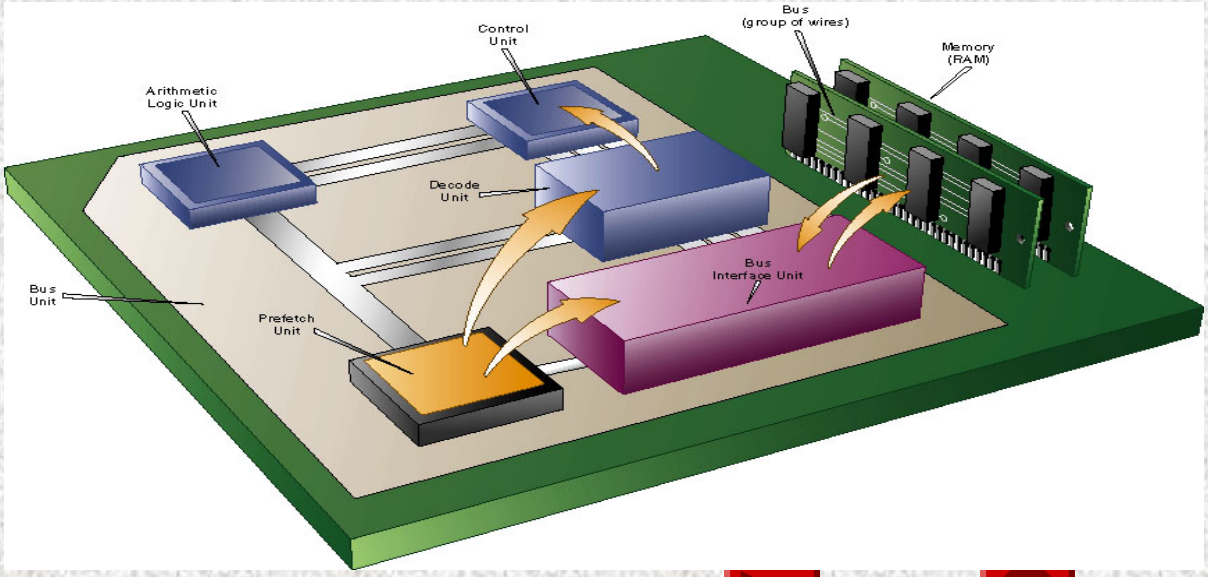
CPU



CPU cycles

- ✓ Fetch instruction
- ✓ Decode
- ✓ Fetch operands (arguments) *
- ✓ Execute
- ✓ Writeback *

* if registers are not used



CPU

- Instructions and arguments may be fetched from RAM or from cache (fast, small memory on the chip)
- Arguments may also be kept in registers from where they are available without fetching.
- The results are typically stored in registers, but can also be stored in (written back to) RAM.
- Pipeline allows for simultaneous execution of up to 5 instructions - each in different cycle.

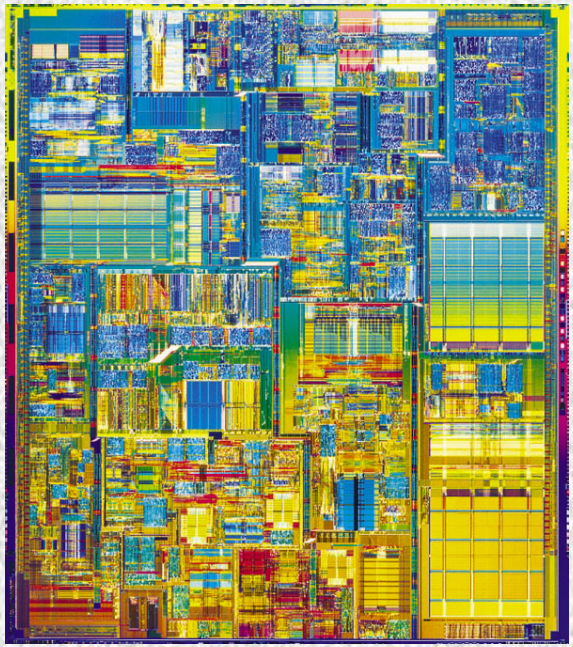



CPU

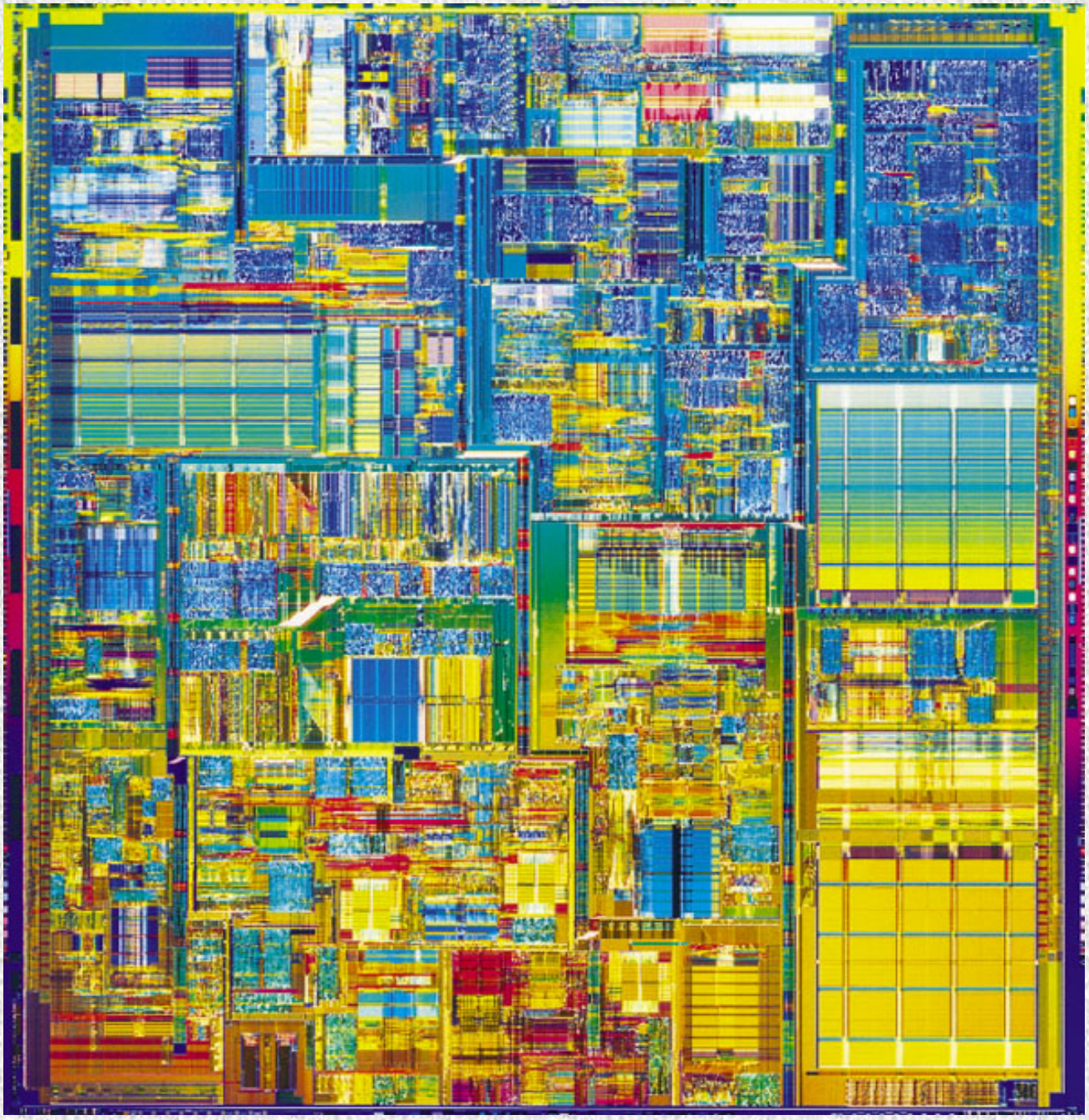
- Typical instructions:
- http://www.jegerlehner.ch/intel/opcode.html




- CPU (microprocessor)
  - Communicates with and supervises all other components of the computer system
  - Is an extraordinarily complex system of electronic circuits



✓CPU



- CPU is housed along with other chips and electronic components on the **motherboard**

- http://www.gup20.com/images/motherboard.jpg

http://focus.ti.com/vf/docs/blockdiagram.tsp?family=vf&blockDiagramId=6044

http://www.vaughns-1-pagers.com/computer/pc-block-diagram.htm

http://www.hitequest.com/Kiss/computer_arch.htm




Compatibility

- All software is not necessarily compatible with every CPU.
  - Software written for the RISC processors used in mobile and low-end computers won't run on Intel processors used in laptops.
    - System Programs written for Linux can't run on Windows.
  - CPUs in the same family (like Intel) are generally designed to be **backward compatible.**
    - Newer processors can process all of the instructions handled by (most recent) earlier models.

Compatibility

- That was a few years ago …
- Today:
  - Windows, Mac OS, and Linux can be installed on PCs and Macintosh computers.
  - One can have any two of the above and decide which one to run at the time of booting.




Performance

- Time-consuming applications require faster machines to produce results on time.
- A computer hardware's overall performance is determined by:
  - Its microprocessor's internal **clock speed**
    - Measured in units called gigahertz (GHz) for billions of clock cycles per second
  - The **architecture** and **word size** of the processor
    - Most PCs and Macintoshes use 64-bit processors.
    - Some embedded and special-purpose computers still use 16-bit and 32-bit processors.

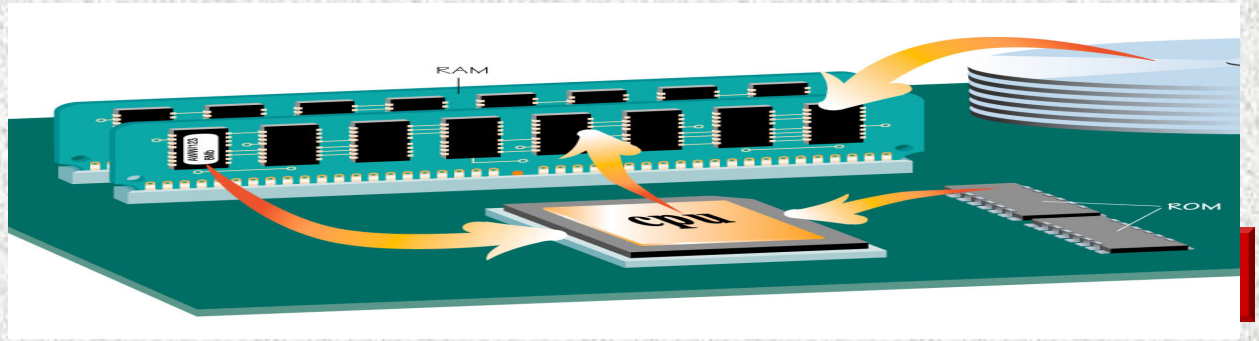



- Techniques for speeding up computer hardware's performance:
  - Pipelining (scalar processors)
  - Multicore processors
  - Parallel processing (supercomputers)
  - Server clusters

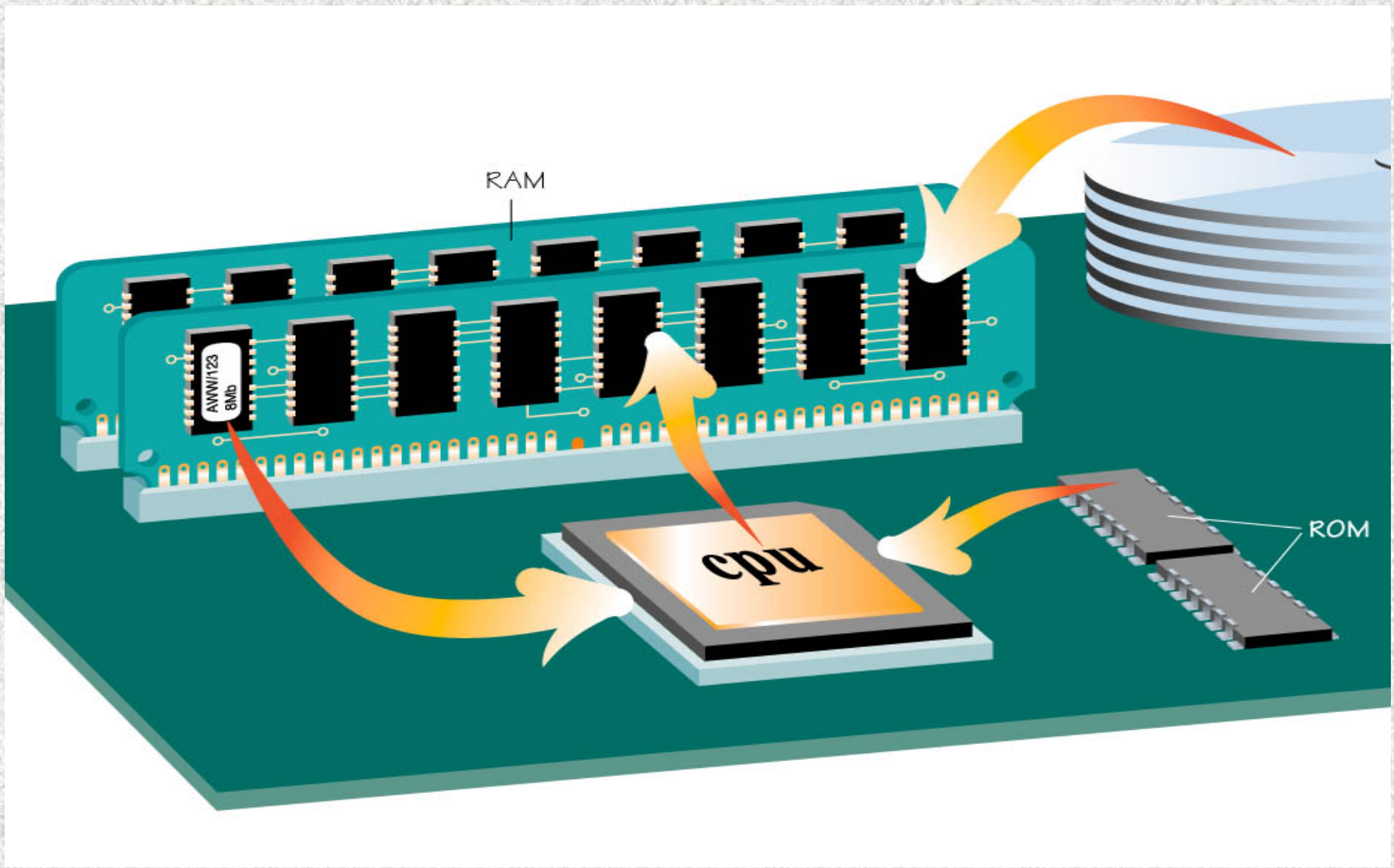



The Computer's Memory

- RAM (random access memory)
  - Used to store program instructions and data temporarily
  - Instructions and data can be stored in any locations (addresses)
  - Can quickly retrieve what's stored (in **nanoseconds**)
  - Will not retain data if power goes off (volatile)



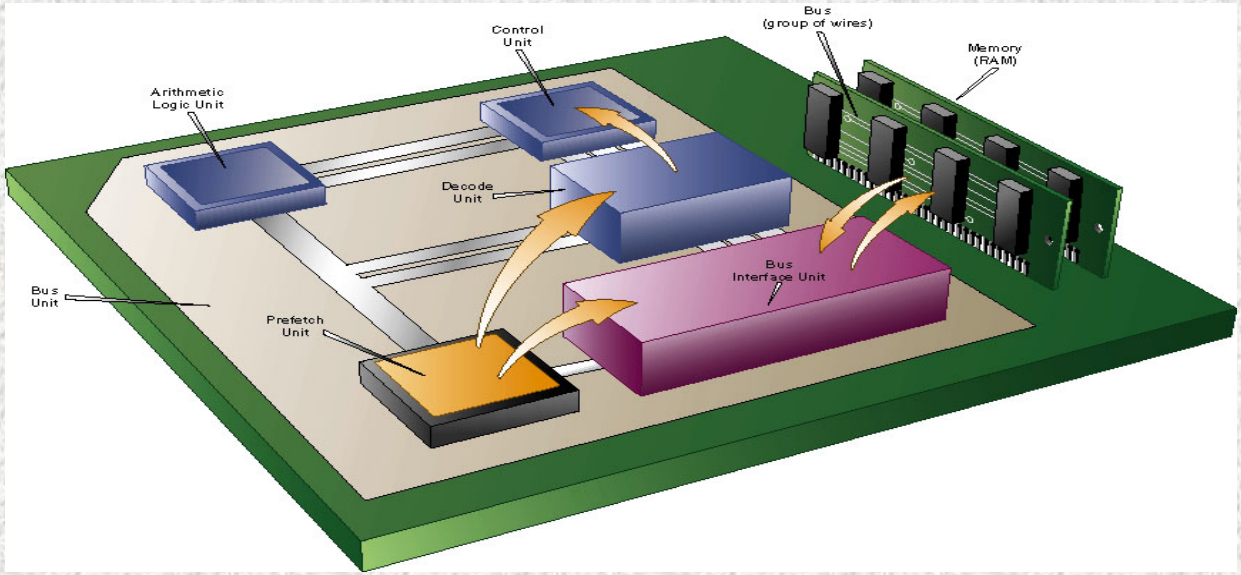
The Computer's Memory



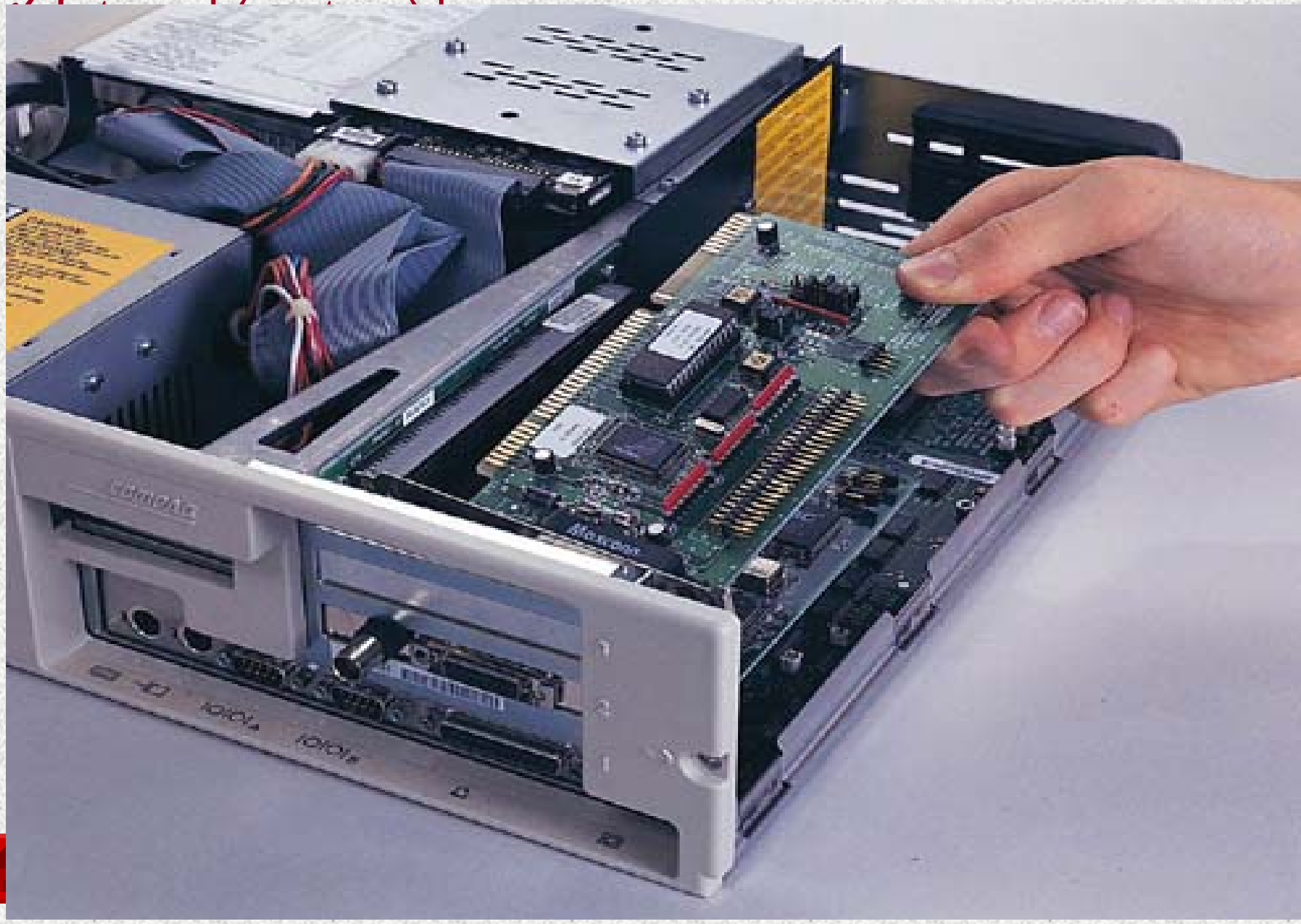
- ROM (read-only memory, permanent)
  - Data and/or instructions stored permanently on a chip
  - Contains startup instructions and permanent data
- CMOS (complementary metal oxide semiconductor)
  - Special low-energy kind of RAM
  - Stores date, time, and calendar on PC
- Flash memory (non-volatile)
  - Used for phones, pagers, portable computers, handheld computers, and PDAs, and removable memory devices (USB)

Buses, Bays, Ports, and Peripherals

- ✓ Information travels between components on the motherboard through groups of wires called **buses.**
- ✓ Each bus follows a protocol for data transfer.



- Internal (system) buses
  - Typically, 32 or 64 wires with protocols for data transfers
  - Connect to storage devices in bays
  - Connect to expansion slots
  - Connect to external buses and ports
- Slots and ports
  - Make it easy to add external devices, called **peripherals**.



Inventing the Future

- ✓ New laser etching technology called extreme ultraviolet lithography (EUVL) could reduce chip size and increase performance radically.
- ✓ Superconductors that transmit electricity **without heat** could increase computer speed a hundredfold.
- ✓ The optical computer transmits information in light waves rather than electrical pulses.

The only thing *that has consistently* ***grown faster*** *than hardware in the last 40 years is* ***human expectation****.*
—Bjarne Stroustrup, AT&T Bell Labs, designer of the C++ programming language


Lesson Summary

- ✓A computer manipulates patterns of bits—binary digits of data.
- ✓The CPU follows software instructions, reduced to strings of bits, to perform the calculations and logical manipulations that transform input data into output.
- ✓Not all CPUs are compatible with each other. MOST ARE NOT.

*The great Information Age is really **an explosion of non-information**; it is an explosion of data. To deal with the increasing **onslaught of data**, it is imperative to distinguish between the two; information is **that which leads to understanding**.*
—Richard Saul Wurman, in Information Anxiety




Lesson Summary (continued)

- The CPU uses:
  - RAM (random access memory) as a temporary storage area for instructions and data
  - ROM (read-only memory), which contains unchangeable information (e.g., startup instructions)
- The CPU and main memory are housed in silicon chips on the motherboard.