Introduction to Information Systems

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Information Systems

-Hardware-

- What is a Computer System?
- The Evolution of Computer Hardware
- Types of Computers
- The Microprocessor and Primary Storage
- Input/Output Devices

Learning Objectives

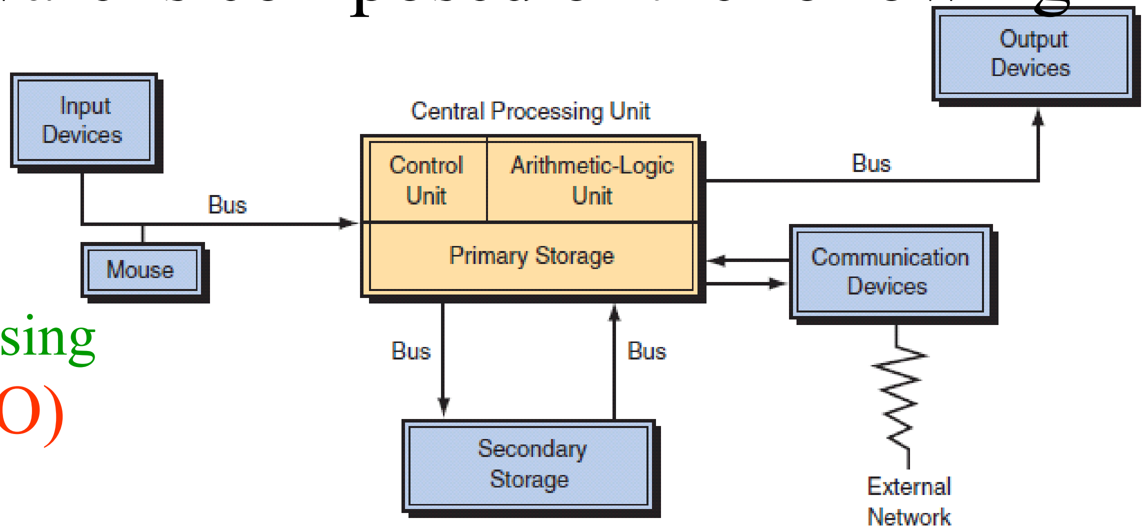
- Recognize major components of an electronic computer.
- Understand how the different components work.
- Know the functions of peripheral equipment.
- Be able to classify computers into major categories and identify their strengths and weaknesses.
- Be able to identify and evaluate key criteria when deciding what computers to purchase.

Technology dimension of information systems

- Computer hardware and software
- Data management technology
- Networking and telecommunications technology
  - Networks, the Internet, intranets and extranets, World Wide Web
- IT infrastructure:
  - provides platform that system is built on

What is a Computer System?

- Computer hardware is composed of the following components:
  - Central processing unit (CPU),
    - for data processing
  - Input/output (I/O) devices
    - for data movement,
  - Memory
    - for data storage,
  - System interconnection.
    - for control



- Each of the hardware components plays an important role in computing.

The Evolution of Computer Hardware

- Computer hardware has evolved through four stages, or generations, of technology.

- Each generation has provided increased processing power and storage capacity, while simultaneously exhibiting decreases in costs

- The generations are distinguished by different technologies that perform the processing functions.

First-generation of computers

- From 1946 to about 1956,
- used vacuum tubes to store and process information.
- Vacuum tubes consumed large amounts of power, generated much heat.
- had limited memory and processing capability.

Second-generation of computers

- From 1957–1963,
- used transistors for storing and processing information.
- Transistors consumed less power than vacuum tubes, produced less heat, and were cheaper, more stable, and more reliable.
- Second-generation computers, with increased processing and storage capabilities, began to be more widely used for scientific and business purposes.

Third-generation of computers

- 1964–1979,
- used integrated circuits for storing and processing information.
- Integrated circuits are made by printing numerous small transistors on silicon chips.
- employed software that could be used by nontechnical people, thus enlarging the computer's role in business.

Fourth-generation of computers

- Early to middle 4th-generation computers, 1980–1995,
- used very large-scale integrated (VLSI) circuits to store and process information.
- VLSI technique allows the installation of hundreds of thousands of circuits (transistors and other components) on a small chip.
- With ultra-large-scale integration (ULSI), 100 million transistors could be placed on a chip.
- These computers are inexpensive and widely used in business and everyday life.

Fourth-generation of computers

- Late 4th-generation computers, 2001 to the present,
- use grand-scale integrated (GSI) circuits to store and process information.
- With GSI, 1,000 million transistors can be placed on a chip.
- The first four generations of computer hardware were based on the Von Neumann architecture, which processed information sequentially, one instruction at a time.

Fifth-generation of computers

- uses massively parallel processing to process multiple instructions simultaneously.
- Massively parallel computers use flexibly connected networks linking thousands of inexpensive, commonly used chips to address large computing problems, attaining supercomputer speeds.
- With enough chips networked together, massively parallel machines can perform more than a trillion floating point operations per second—a teraflop.

	Generations					
Feature	**1st**	**2nd**	**3rd**	**4th (early)**	**4th (1988)**	**4th (2001)**
Circuitry	Vacuum tubes	Transistors	Integrated circuits	LSI and VLSI	ULSI	GSI
Primary storage	2 KB	64 KB	4 MB	16 MB	64 MB	128 MB
Cycle times	100 millisecs	10 microsecs	500 nanosecs	800 picosecs	2,000 picosecs	333 MHz
Average cost	$2.5 million	$250 thousand	$25 thousand	$2.5 thousand	$2.0 thousand	$1.5 thousand

- 2010
  - Primary storage: ~ 2 GB
  - Cycle time: ~ 2 GHz
  - Average cost : ~ $1.0 thousand
- 2023
  - Primary storage: ~ 8-32 GB
  - Cycle time: ~ 4 GHz
  - Average cost : ~ $500 - $1.0 thousand

Types of Computers

- Computers are distinguished on the basis of their processing capabilities.
  - Supercomputers
  - Mainframes
  - Minicomputers
  - Servers
  - Workstations
  - Microcomputers
  - Notebook computers
  - Mobile computing devices
  - Wearable computers

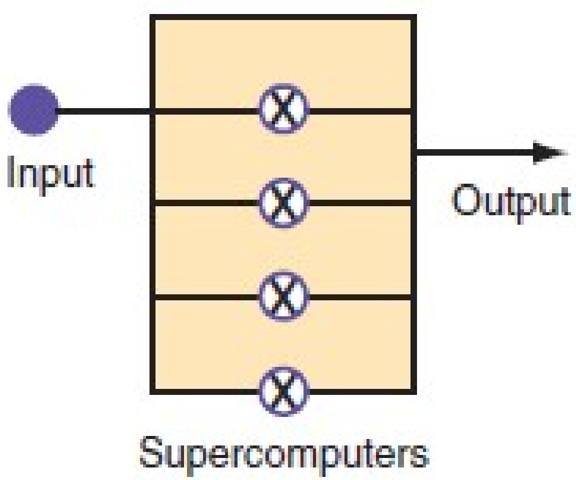
Supercomputers

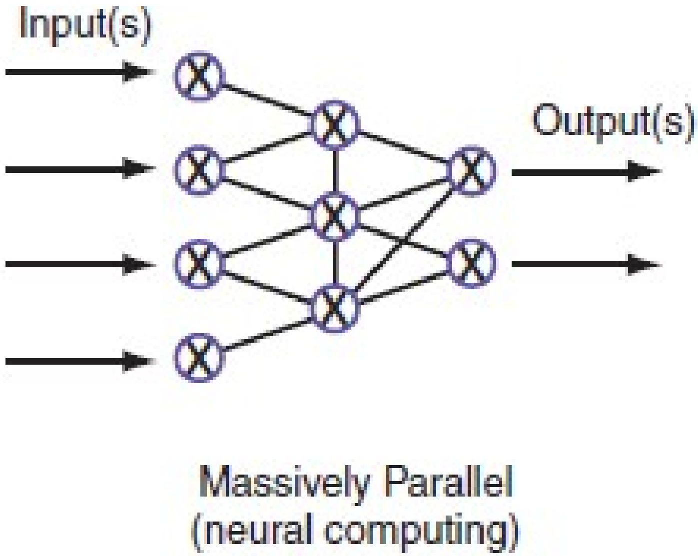
- computers with the most processing power.
- primary application: scientific and military work.
- valuable for large simulation models of real-world phenomena, where complex mathematical representations and calculations are required, or for image creation and processing.
  - used to model the weather for better weather prediction, to test weapons nondestructively, to design aircraft (e.g., the Boeing 777) for more efficient and less costly production, and to make sequences in motion pictures (e.g., *Jurassic Park)*.

Supercomputers

- use parallel processing technology.
  - use noninterconnected CPUs
- neural computing, which uses massively parallel processing,

Supercomputers vs. neural computing.





Cray-1

- The first Cray computer was developed by a team lead by the legendary Seymor Cray.
- It was a freon-cooled 64-bit system running at 80 MHz with 8 megabytes of RAM.
- Careful use of vector instructions could yield a peak performance of 250 megaflops.
- Together with its freon cooling system, the first model of the Cray-1 (Cray-1A) weighed 5.5 tons and was delivered to the Los Alamos National Laboratory in 1976.

Cray-1

IBM Roadrunner

- Capable of 1.71 petaflops
  - world's fastest computer (2008)
- It has 12,960 IBM PowerXCell 8i processors operating at 3.2 GHz and 6,480 dual-core AMD Opteron processors operating at 1.8 GHz,
  - a total of 130,464 processor cores.
- It also has more than 100 terabytes of RAM.
- 216 System x3755 I/O nodes
- 26 288-port ISR2012 Infiniband 4x DDR switches
- 2.35 MW power.

IBM Roadrunner

Frontier (HP)

- Capable of 2 exaflops (10^{18})
  - world's fastest computer (2023)
- Intel Xeon Max processors operating at 1.8 GHz,
  - a total of 130,464 processor cores.
- It also has more than 10 petabytes of RAM.
- 216 System x3755 I/O nodes
- 26 288-port ISR2012 Infiniband 4x DDR switches
- ~60 MW power.

Aurora (Intel and Cray)

- Capable of 2 exaflops (10^{18})
  - world's fastest computer (2023)
- Intel Xeon Max processors operating at 1.8 GHz,
  - a total of 130,464 processor cores.
- It also has more than 10 petabytes of RAM.
- 216 System x3755 I/O nodes
- 26 288-port ISR2012 Infiniband 4x DDR switches
- ~60 MW power.

Mainframes

- are not as powerful and generally not as expensive as supercomputers.
- used mainly by large organizations for critical applications, typically bulk data processing such as census, industry and consumer statistics, ERP, and financial transaction processing.
- The term originally referred to the large cabinets that housed the central processing unit and main memory of early computers.
- Later the term was used to distinguish high-end commercial machines from less powerful units.

Mainframes

- A mainframe has 1 to 16 CPU's (modern machines more)
- Memory ranges from 128 Mb over 8 Gigabyte on line RAM
- Its processing power ranges from 80 over 550 MIPS
- It has often different cabinets for
  - Storage, I/O, RAM
- Separate processes (program) for
  - task management
  - program management
  - job management
  - serialization
  - catalogs
  - inter address space
  - communication

ENIAC

CPU:	17,468 vacuum tubes, 70,000 resistors, 10,000 capacitors, 1,500 relays, and 6,000 manual switches
CPU speed	ENIAC could execute 5,000 additions, 357 multiplications, and 38 divisions in one second
introduced	1946
OS	hard wired
initial price	total cost approximately $500,000
footprint	167,3 m2
energy consumption	180 kW

IBM eServer zSeries 890

- Introduced in 2004
- can host up to 32 GBytes of memory.
- The four PCIX Crypto Coprocessor.
- can run several operating systems at the same time including z/OS, OS/390®, z/VM®, VM/ESA®, VSE/ESA, TPF and Linux for zSeries and Linux for S/390®.
- The z890 is upgradeable within z890 family and can also upgrade to z990 from select z890 configurations.

Minicomputers

- smaller and less expensive than mainframes.
- designed to accomplish specific tasks such as
  - process control, scientific research, and engineering applications.
- Larger companies gain greater corporate flexibility by distributing data processing with minicomputers in organizational units instead of centralizing computing at one location.
- They are connected to each other and often to a mainframe through telecommunication links.

Minicomputers

- introduced in the early 1960s
- Digital Equipment Corporation developed the PDP-1 minicomputer in 1960, and the PDP-8 virtualy conquered the market is a sweep and sold over 40,000 units.
- In time some 200 companies produced this type of minicomputers.
- DEC got at the top of the market with the PDP-11, and with the VAX 11/780 system.

Servers

- typically support computer networks, enabling users to share files, software, peripheral devices, and other network resources.
- Servers have large amounts of primary and secondary storage and powerful CPUs.
- Organizations with heavy e-commerce requirements and very large Web sites are running their Web and e-commerce applications on multiple servers in server farms.

Server farms

- large groups of servers maintained by an organization or by a commercial vendor and made available to customers.
- As companies pack greater numbers of servers in their server farms, they are using pizza-box-size servers called rack servers that can be stacked in racks.
  - These computers run cooler, and therefore can be packed more closely, requiring less space.
- To further increase density, companies are using a server design called a blade.
  - A blade is a card about the size of a paperback book on which memory, processor, and hard drives are mounted.

Workstations

- originally developed to provide the high levels of performance demanded by technical users such as designers.
- based on RISC architecture and provide both very-high-speed calculations and high-resolution graphic displays.
- found widespread acceptance within the scientific community and, more recently, within the business community.
- applications include electronic and mechanical design, medical imaging, scientific visualization, 3-D animation, and video editing.

Microcomputers

- also called personal computers (PCs),

- are the smallest and least expensive category of general-purpose computers.

Notebook computers

- small, easily transportable, lightweight microcomputers
- fit easily into a briefcase.
- Notebooks are allowing users to have access to processing power and data without being bound to an office environment.
- Laptop
- Netbook

Mobile computing devices

- PDAs or handheld personal computers.
- mobile phone handsets with wireless and internet access capabilities.
- use a micro version of a desktop OS, such as Pocket PC, Symbian, or Palm OS.
- Mobile devices have the following characteristics:
  - They cost much less than PCs.
  - Their OS are simpler than those on a desktop PC.
  - They provide good performance at specific tasks but do not replace the full functions of a PC.
  - They provide both computer and/or communications features.
  - They offer a Web portal that is viewable on a screen.

Mobile Devices and Their Uses

Device	Description and Use
Handheld companions	Devices with a core functionality of accessing and managing data; designed as supplements to notebooks or PCs
PC companions	Devices primarily used for personal information management (PIM), e-mail, and light data-creation capabilities
Personal companions	Devices primarily used for PIM activities and data-viewing activities
Classic PDAs	Handheld units designed for PIM and vertical data collection
Smart phones	Emerging mobile phones with added PDA, PIM, data, and e-mail or messaging creation/service capabilities
Vertical application devices	Devices with a core functionality of data access, management, creation, and collection; designed for use in vertical markets*
Pen tablets	Business devices with pen input and tablet form for gathering data in the field or in a mobile situation
Pen notepads	Pen-based for vertical data collection applications
Keypad handhelds	Business devices with an alphanumeric keypad used in specialized data-collection applications

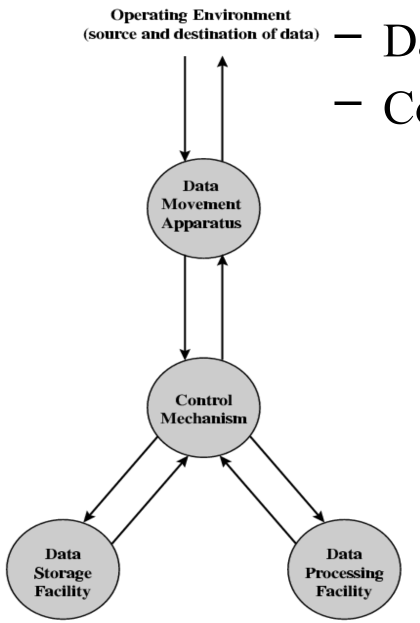
* Vertical markets refer to specific industries, such as manufacturing, finance, healthcare, etc.

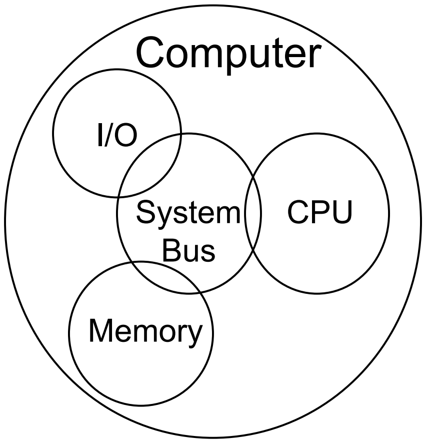
Wearable computers

- computers that are worn on the body.
  - used in behavioral modeling, health monitoring systems, information technologies and media development.
- useful for applications that require computational support while the user's hands, voice, eyes, arms or attention are actively engaged with the physical environment.
- "Wearable computing" is an active topic of research,
  - user interface design, augmented reality, pattern recognition, use of wearables for specific applications or disabilities, electronic textiles and fashion design.

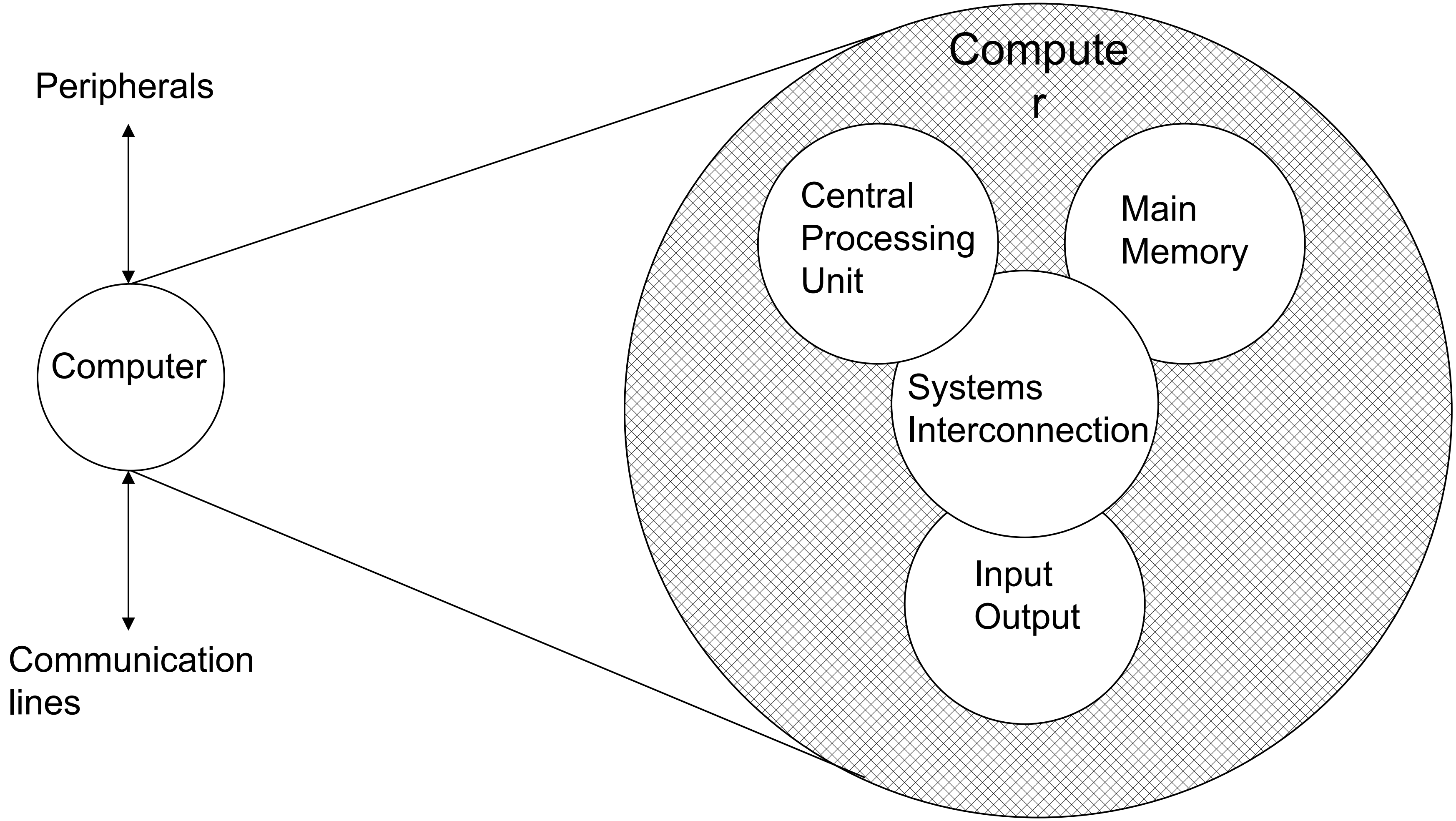
What is a computer?

- In terms of what?
  - Functional
    - All computer functions are:
      - Data processing
      - Data storage
      - Data movement
      - Control
  - Structural
    - Corresponding computer components are:
      - CPU
      - Memory
      - I/O
      - System interconnection

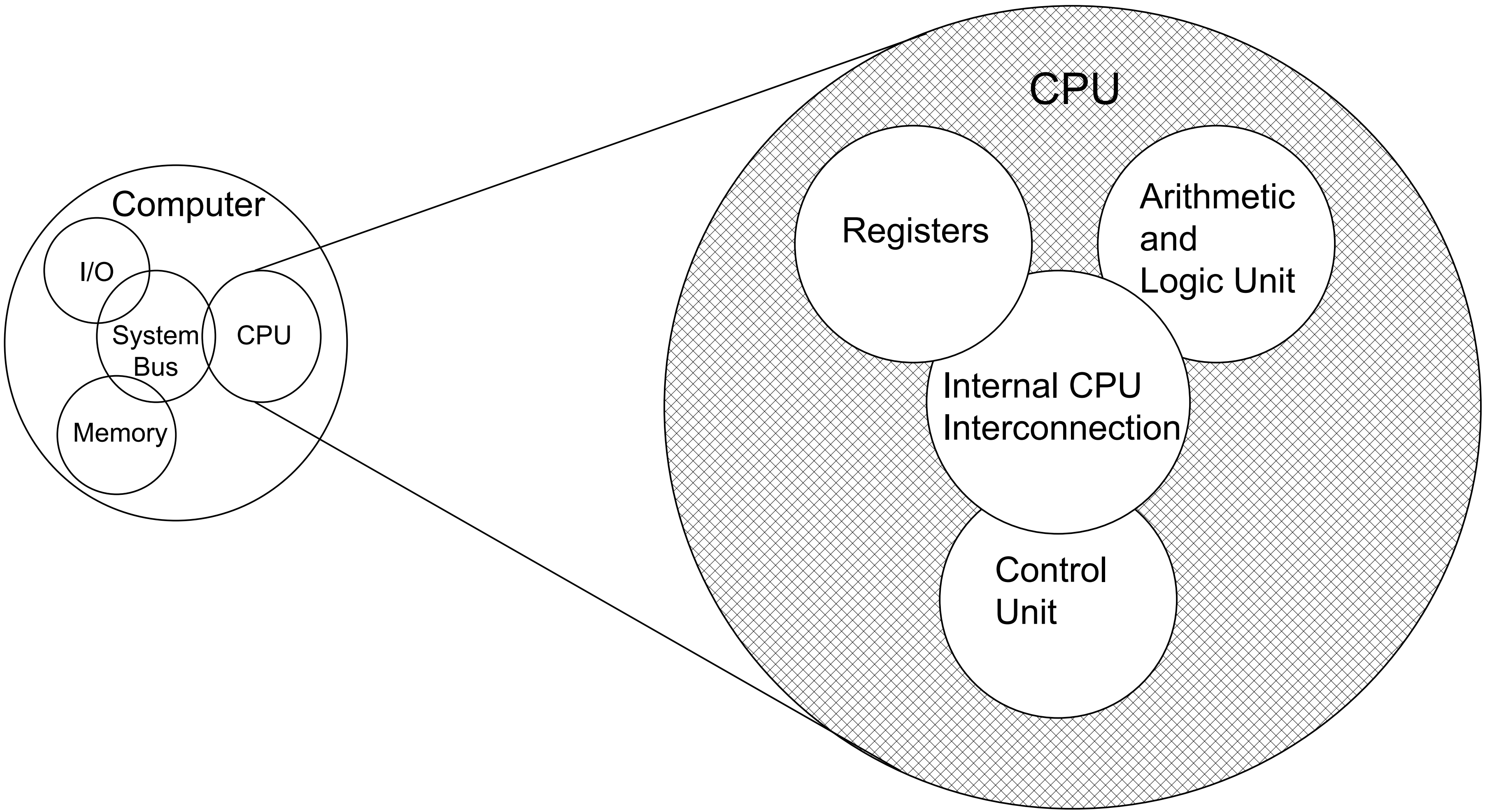




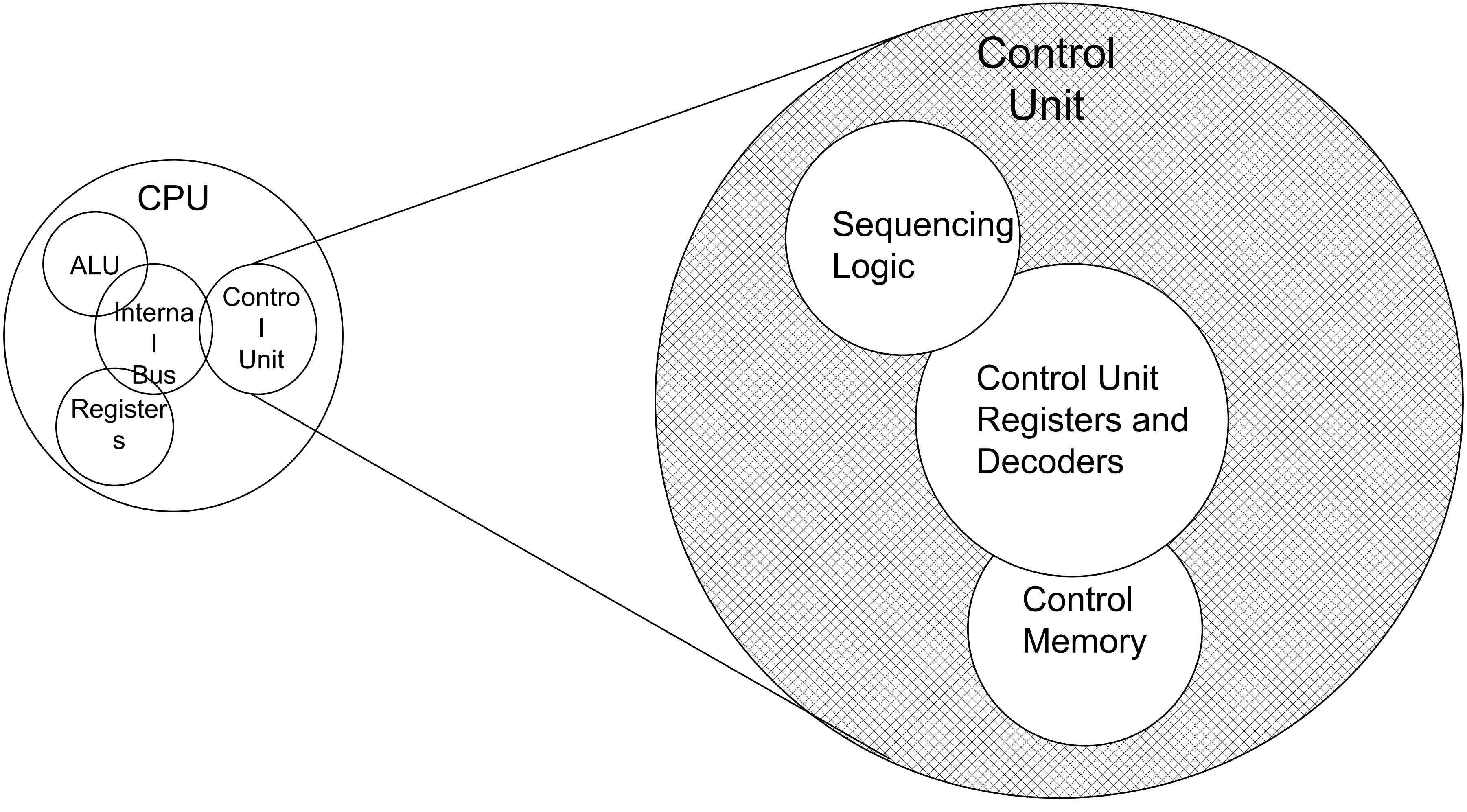
Structure - Top Level



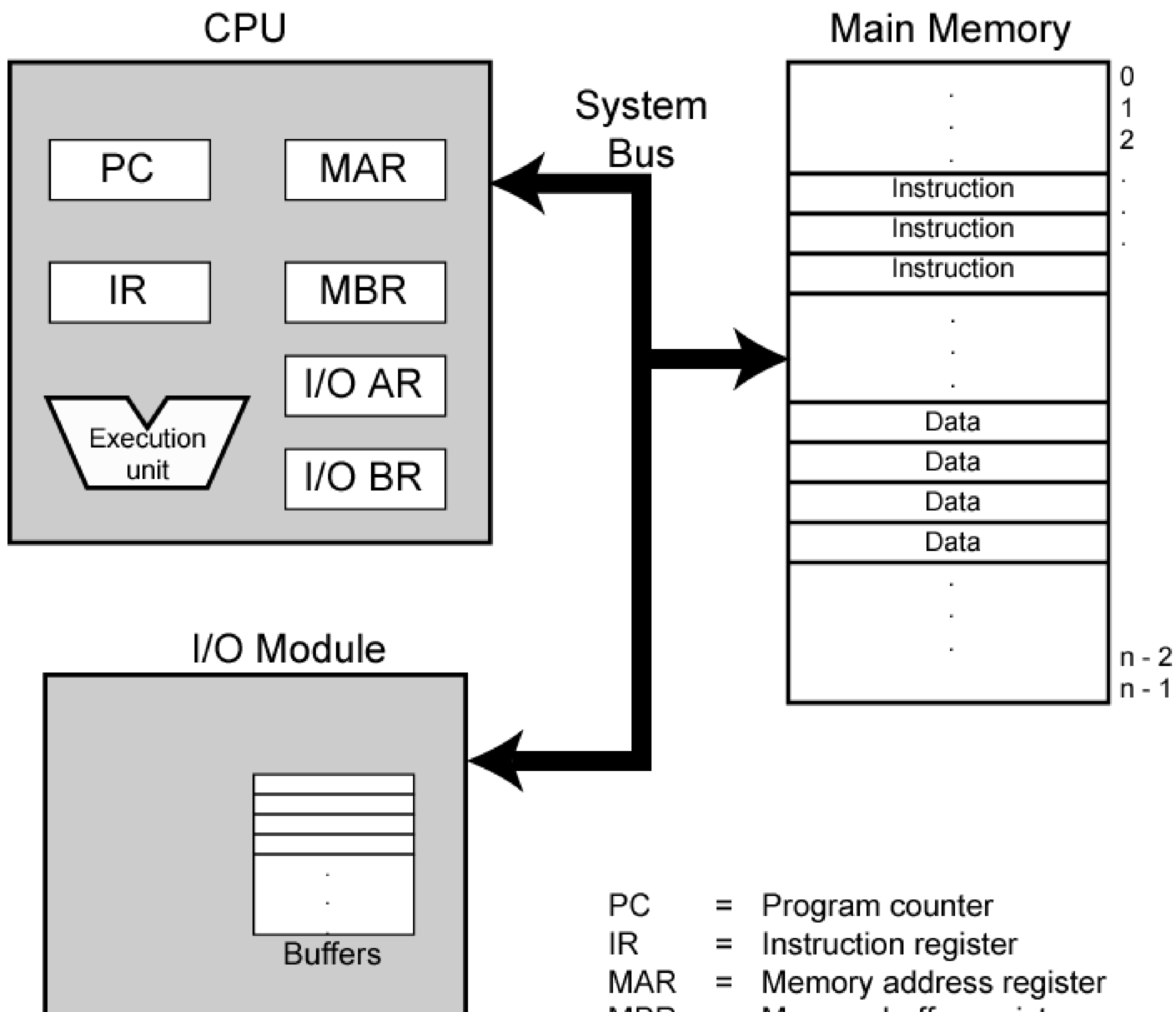
Structure - The CPU



Structure - The Control Unit



Von Neuman Computer Architecture



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IR = Instruction register
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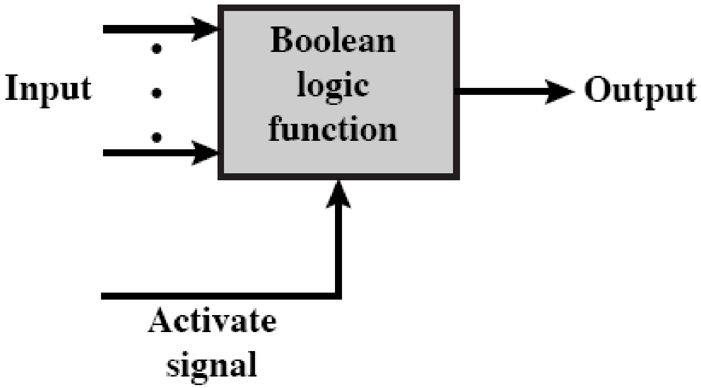
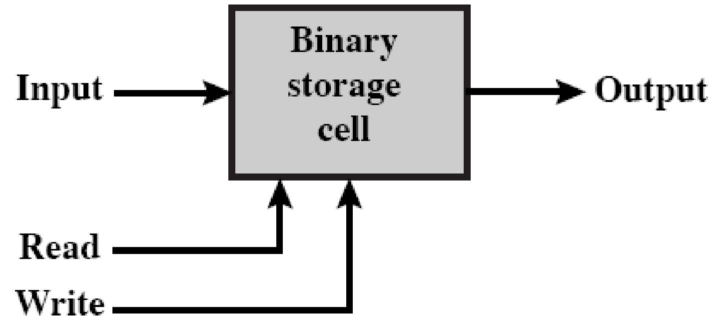
Fundamental computer elements



(a) Gate



(b) Memory cell

- Data storage:
  - Provided by memory cells
- Data processing:
  - Provided by gates
- Data movement:
  - The paths between components are used to move data from/to memory
- Control:
  - The paths between components can carry control signals

Levels of Representation

High Level Language Program

```
temp = v[k];
v[k] = v[k+1];
v[k+1] = temp;
```

Compiler

Assembly Language Program

```
lw    $15,    0($2)
lw    $16,    4($2)
sw    $16,    0($2)
sw    $15,    4($2)
```

Assembler

Machine Language Program

```
0000 1001 1100 0110 1010 1111 0101 1000
1010 1111 0101 1000 0000 1001 1100 0110
1100 0110 1010 1111 0101 1000 0000 1001
0101 1000 0000 1001 1100 0110 1010 1111
```

Machine Interpretation

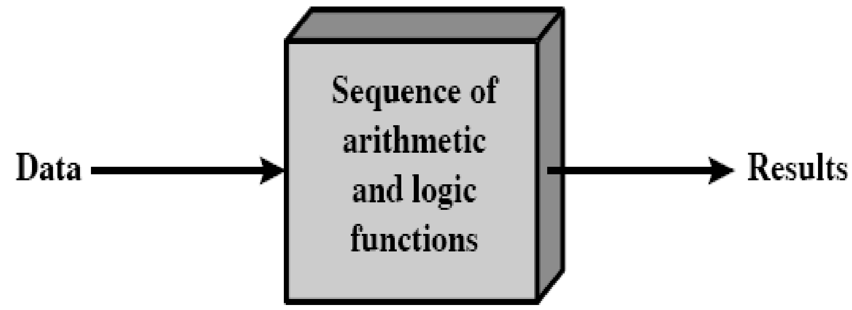
Control Signal Specification

ALUOP[0:3] <= InstReg[9:11] & MASK

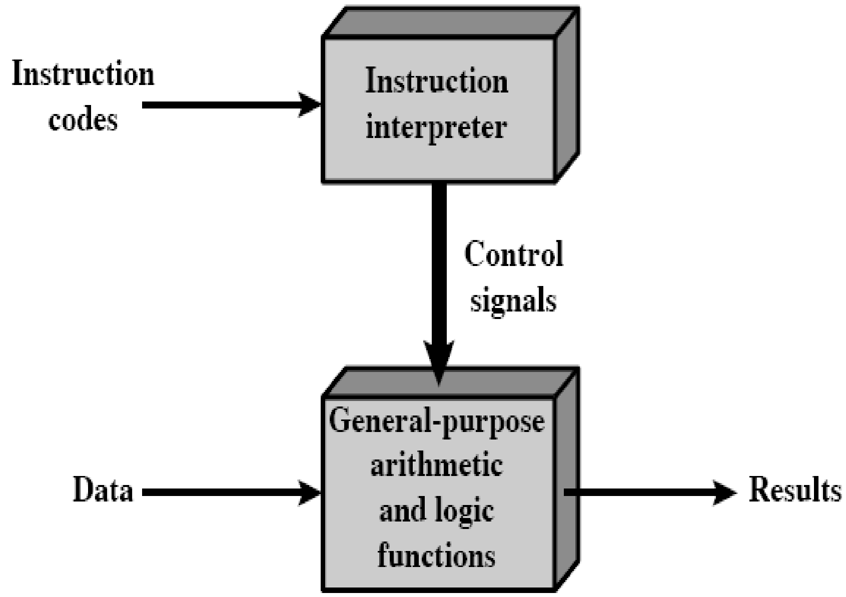
∘
∘

Program Concept

- Programming in hardware
  - Hardwired systems are inflexible
- Programming in software
  - General purpose hardware can do different tasks, given correct control signals
  - Instead of re-wiring, supply a new set of control signals



(a) Programming in hardware



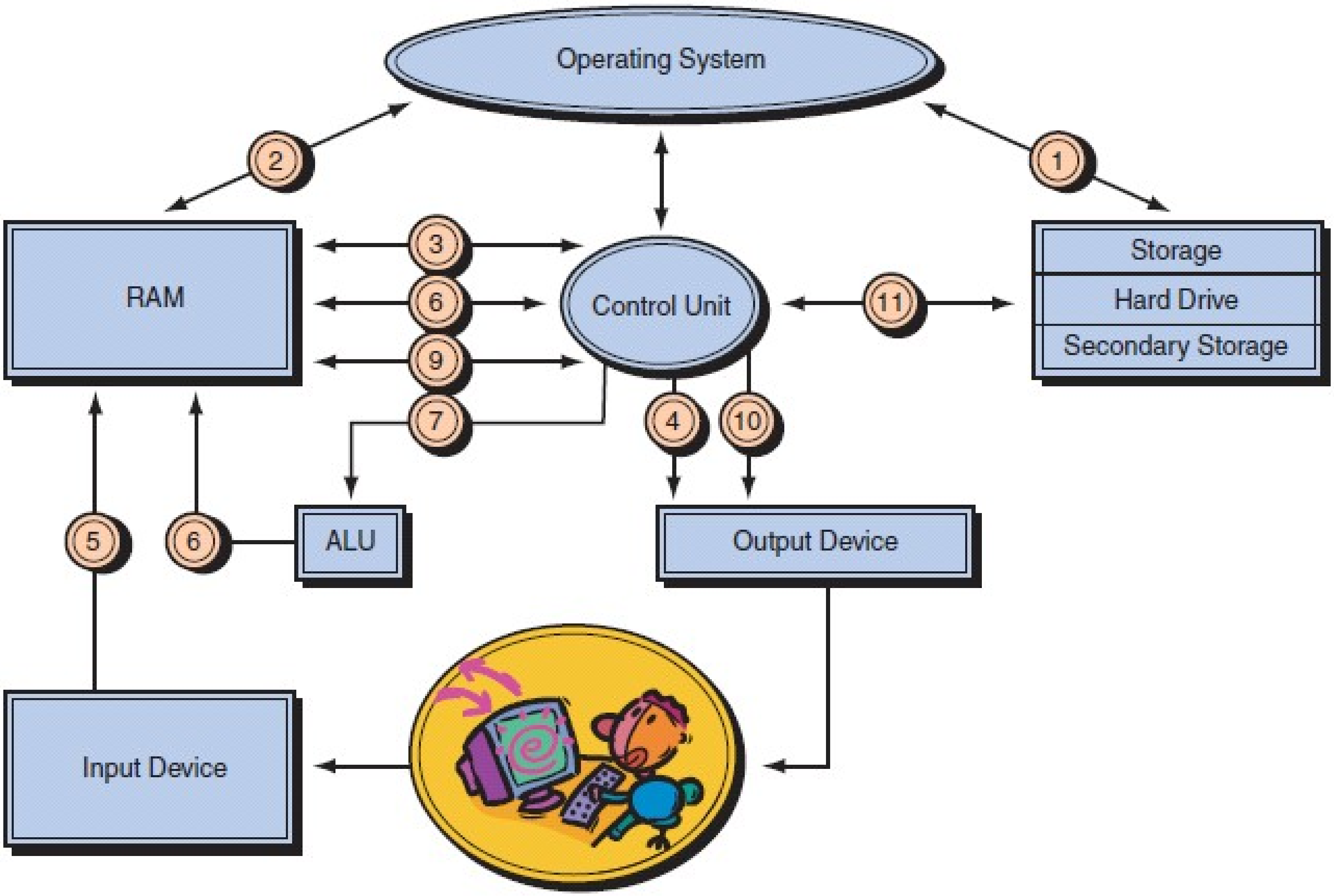
(b) Programming in software

What is a program?

- A sequence of steps
- For each step, an arithmetic or logical operation is done
- For each operation, a different set of control signals is needed
- For each operation a unique code is provided
  - e.g. ADD, MOVE
- A hardware segment accepts the code and issues the control signals

- We have a computer!

Running a Program on a Computer



Running a Program on a Computer

- A computer program can be stored on a disk or on the hard drive (drive “C”).
- To run this program,
  - the operating system will retrieve the program from its location (step 1 in the figure) and place it into the RAM (step 2).
  - Then the control unit “fetches” the first instruction in the program from the RAM (step 3) and acts upon it (step 4).
  - Once the message is answered (step 5), it is stored in the RAM.
    - This concludes the first instruction.
  - Then the control unit “fetches” the second instruction (step 6), and the process continues on and on

Running a Program on a Computer

- If one of the instructions calls for some computation, the control unit sends it, together with any relevant data stored in the RAM, to the arithmetic logic unit (ALU) (step 7).
- The ALU executes the processing and returns the results to the RAM (step 8).
- The control unit then “fetches” one more instruction (step 9), which tells what to do with the result
  - for example, display it (step 10) or store it on the hard drive (step 11).

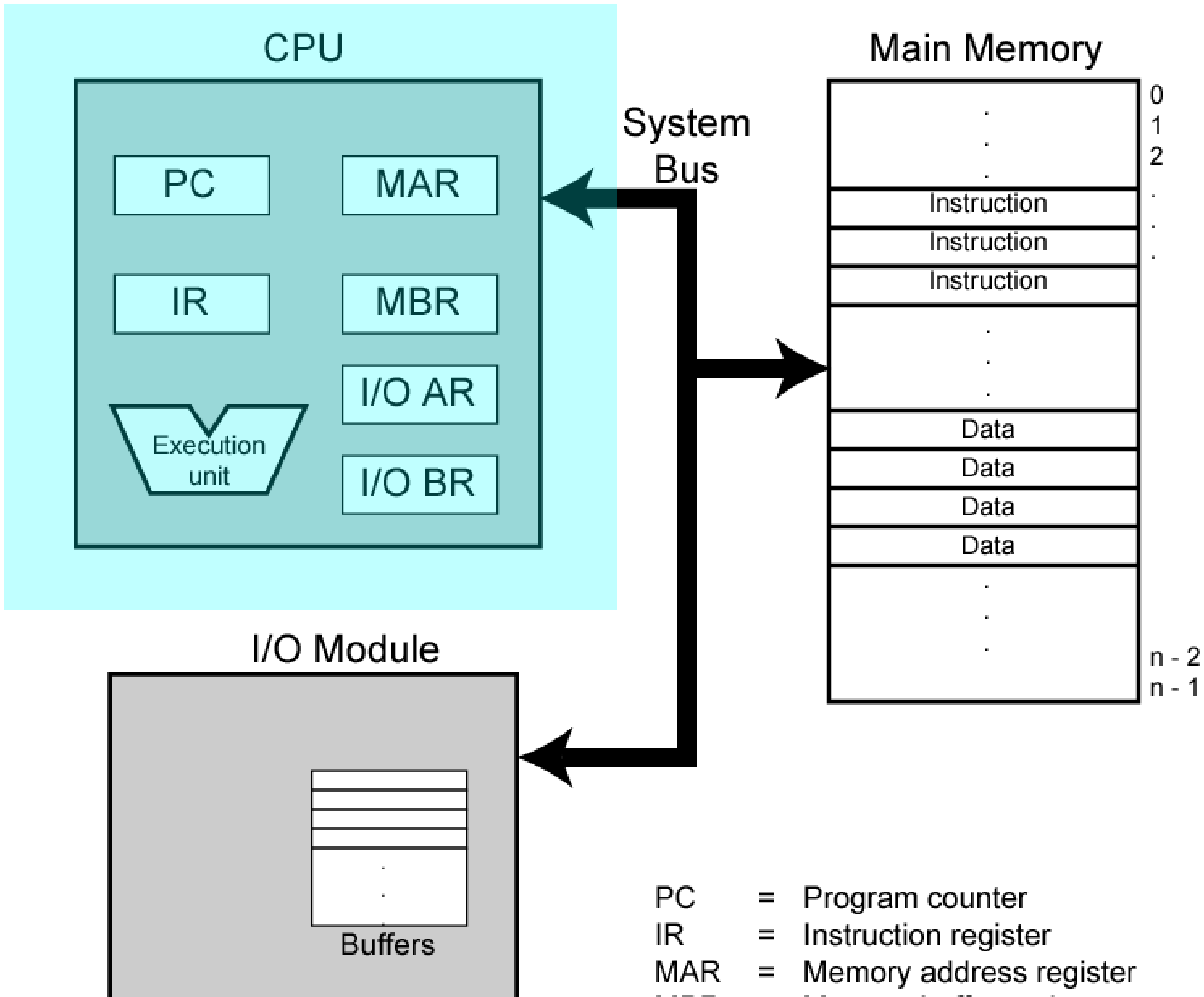
Running a Program on a Computer

- When instructions are “fetched,” they are decoded.

- The computer can process large numbers of instructions per second, usually millions.

- Therefore, we measure the speed of computers by millions of instructions per minute (MIPS).

Computer Components-CPU



PC = Program counter
IR = Instruction register
MAR = Memory address register
MBR = Memory buffer register
I/O AR = Input/output address register
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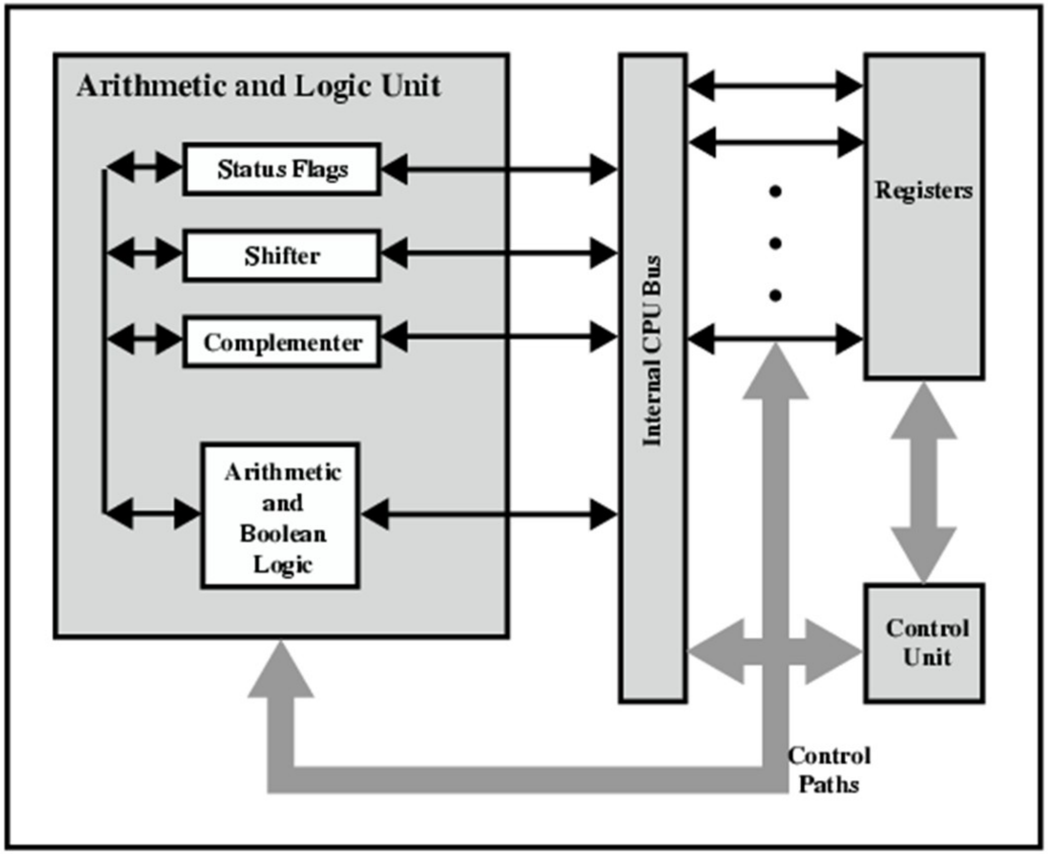
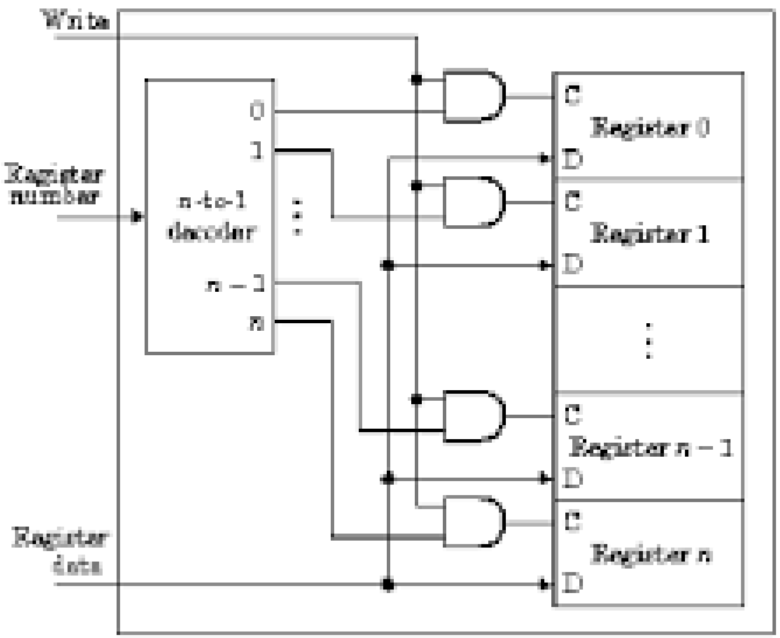
CPU Structure

- CPU must:
  - Fetch instructions
  - Interpret instructions
  - Fetch data
  - Process data
  - Write data



Registers

- CPU must have some working space (temporary storage)
  - Called registers



- Manipulated directly by the Control Unit
- Number and function vary between processor designs
- One of the major design decisions
- Size in bits or bytes (not MB like memory)

- Can hold data, an address or an instruction
- Top level of memory hierarchy

Registers in the µP perform two roles:

- User-visible registers
    - Enable the machine- or assembly language programmer to minimize main memory references by optimizing use of registers
  - General Purpose registers
  - Data registers
  - Address registers
  - Condition Code Registers (flags)
    - Sets of individual bits
      - e.g. result of last operation was zero
    - Can be read (implicitly) by programs
      - e.g. Jump if zero
    - Can not (usually) be set by programs

Registers in the µP perform two roles:

- Control and status registers
    - Used by the control unit to control the operation of the processor and by priviliged, operating system programs to control the execution of programs
  - Program Counter (PC)
    - Also called instruction pointer
    - Contains the address of an instruction to be fetched
  - Instruction Decoding Register (IR)
    - Stores instruction fetched from memory
  - Memory Address Register (MAR)
    - Contains the addres of location in memory
  - Memory Buffer Register (MBR)
    - Also called Memory Data Register (MDR)
    - Contains a word or data to be written to memory or the word most recently read

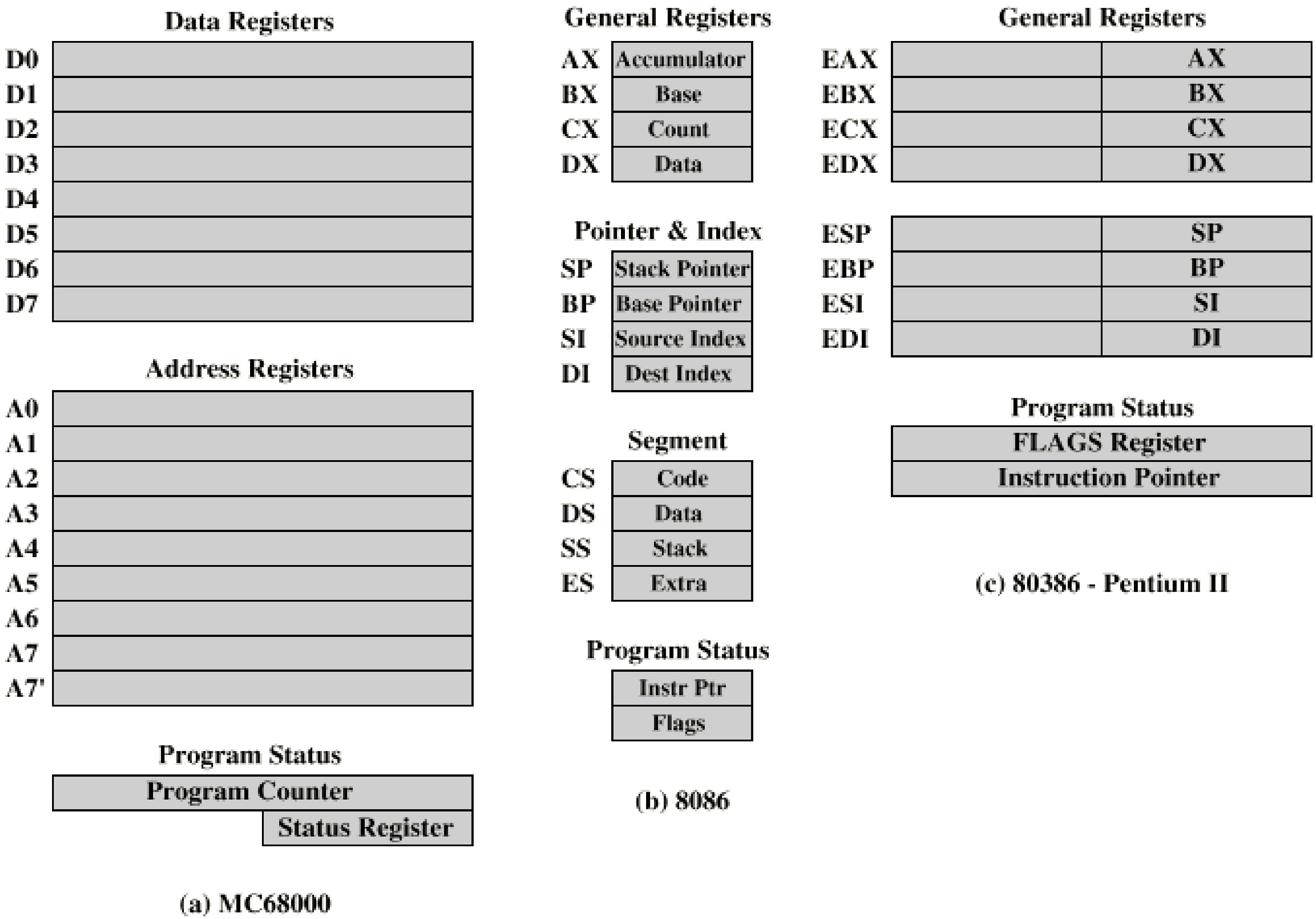
Program Status Word (Status Registers)

- A set of bits containing status information
- Includes Condition Codes (flags)
  - Sign
    - sign of last result
  - Zero
    - set when the result is 0
  - Carry
    - set if an operation resulted in a carry (addition) into or borrow (subtraction) out of a high order bit
  - Equal
    - set if a logical compare result is equality
  - Overflow
    - used to indicate arithmetic overflow
  - Interrupt enable/disable
    - used to enable or disable interrupts

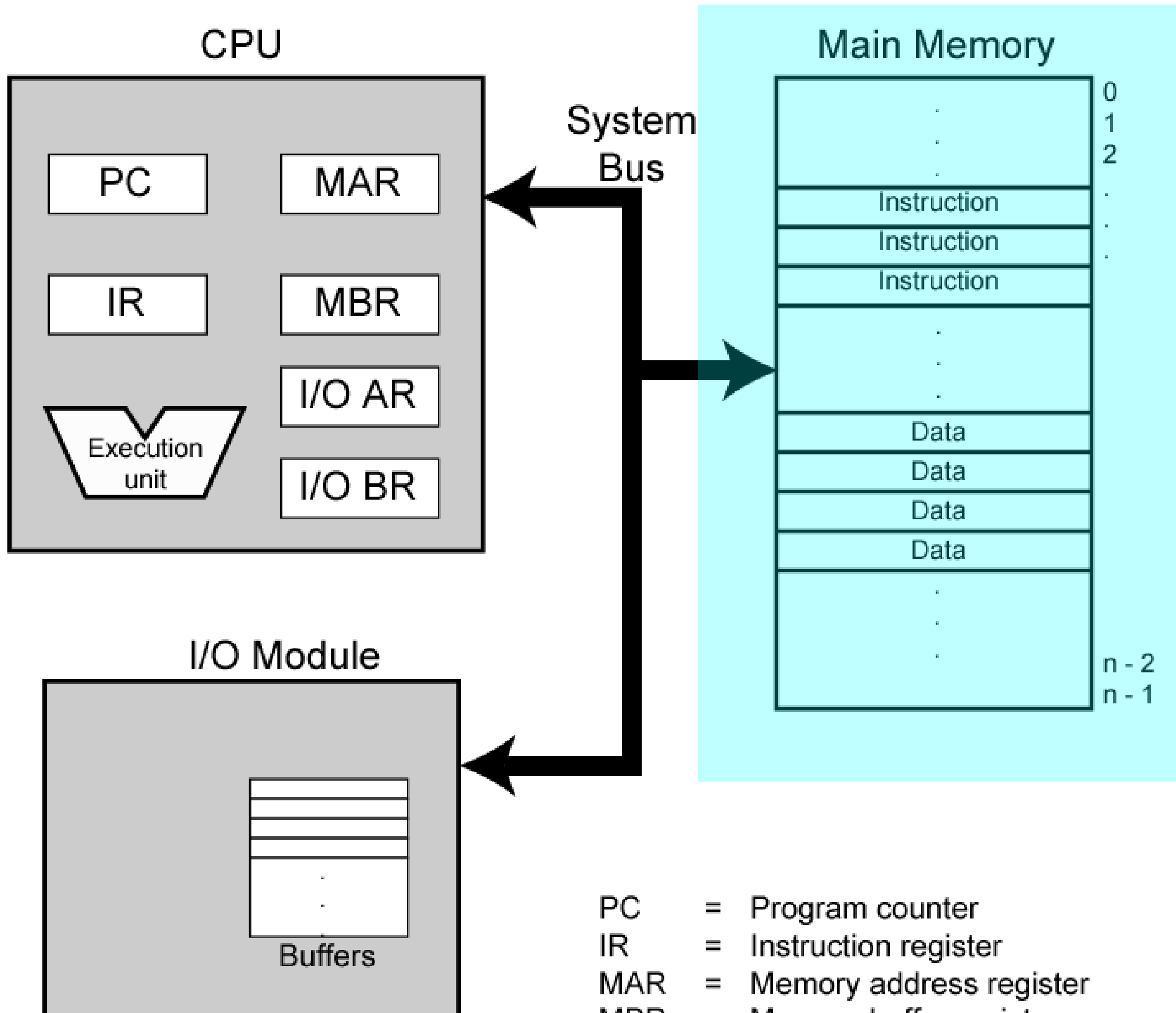
Register Operations

- Stores values from other locations such as
  - registers and memory
- Addition and subtraction
- Shift or rotate data
- Test contents for conditions such as zero or positive

Example Register Organizations



Computer Components-Memory



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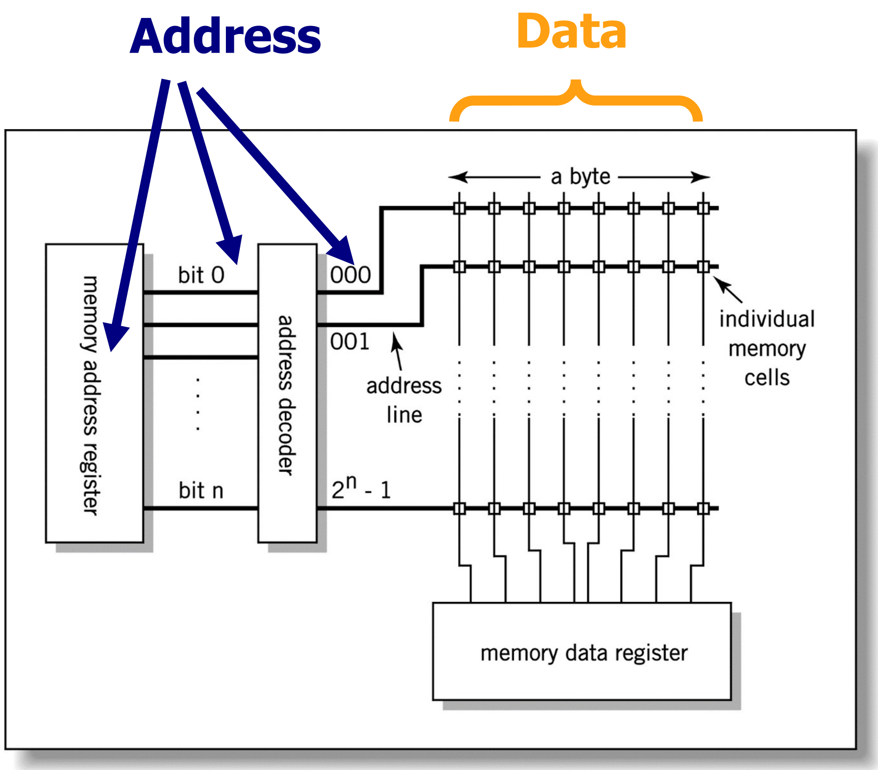
Operation of Memory

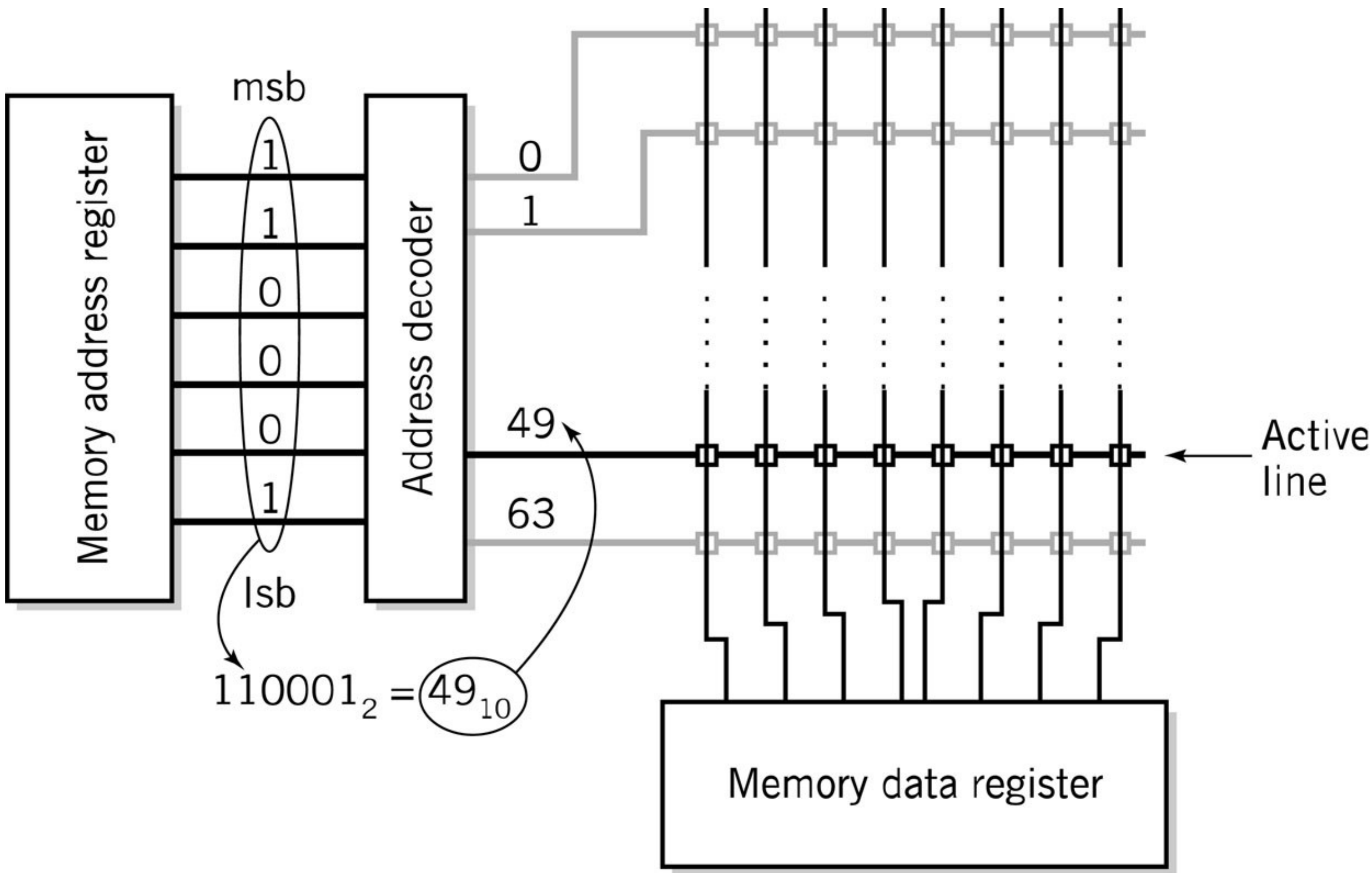
- Each memory location has a unique address
- Address from an instruction is copied to the MAR which finds the location in memory



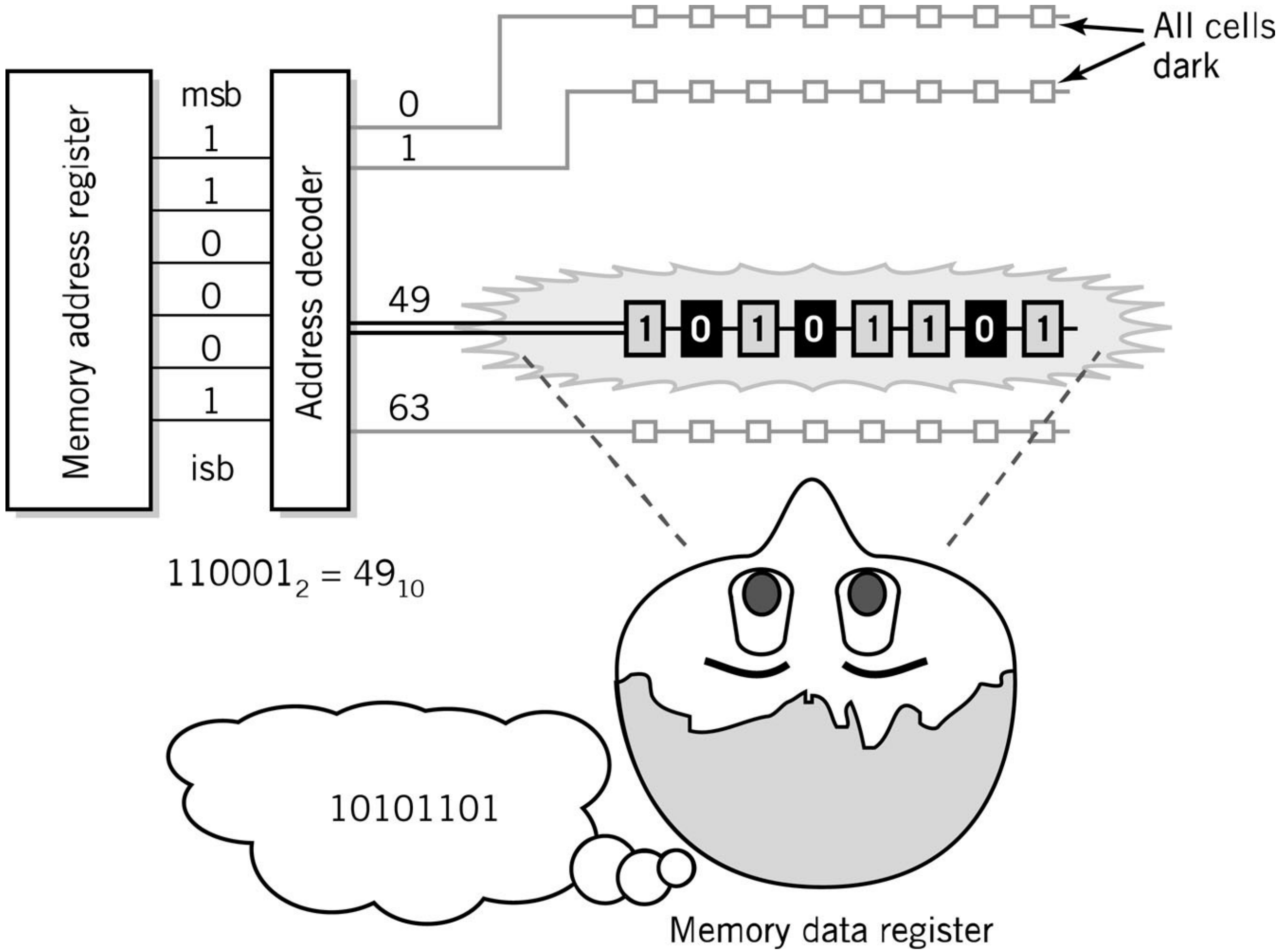
Relationship between MAR, MDR and Memory

- CPU determines if it is a store or retrieval
- Transfer takes place between the MDR and memory
- MDR is a two-way register

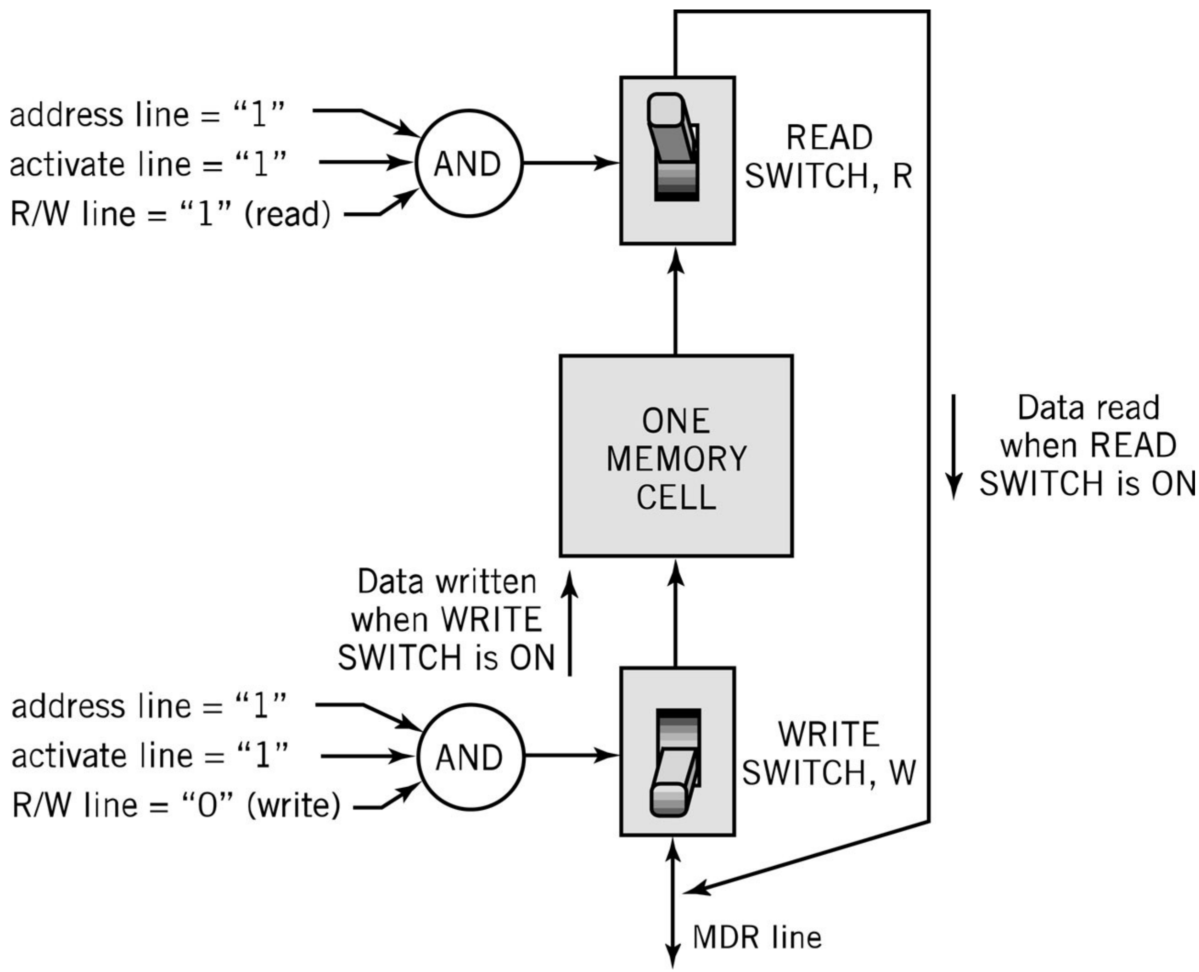
MAR-MDR Example



Visual Analogy of Memory



Individual Memory Cell

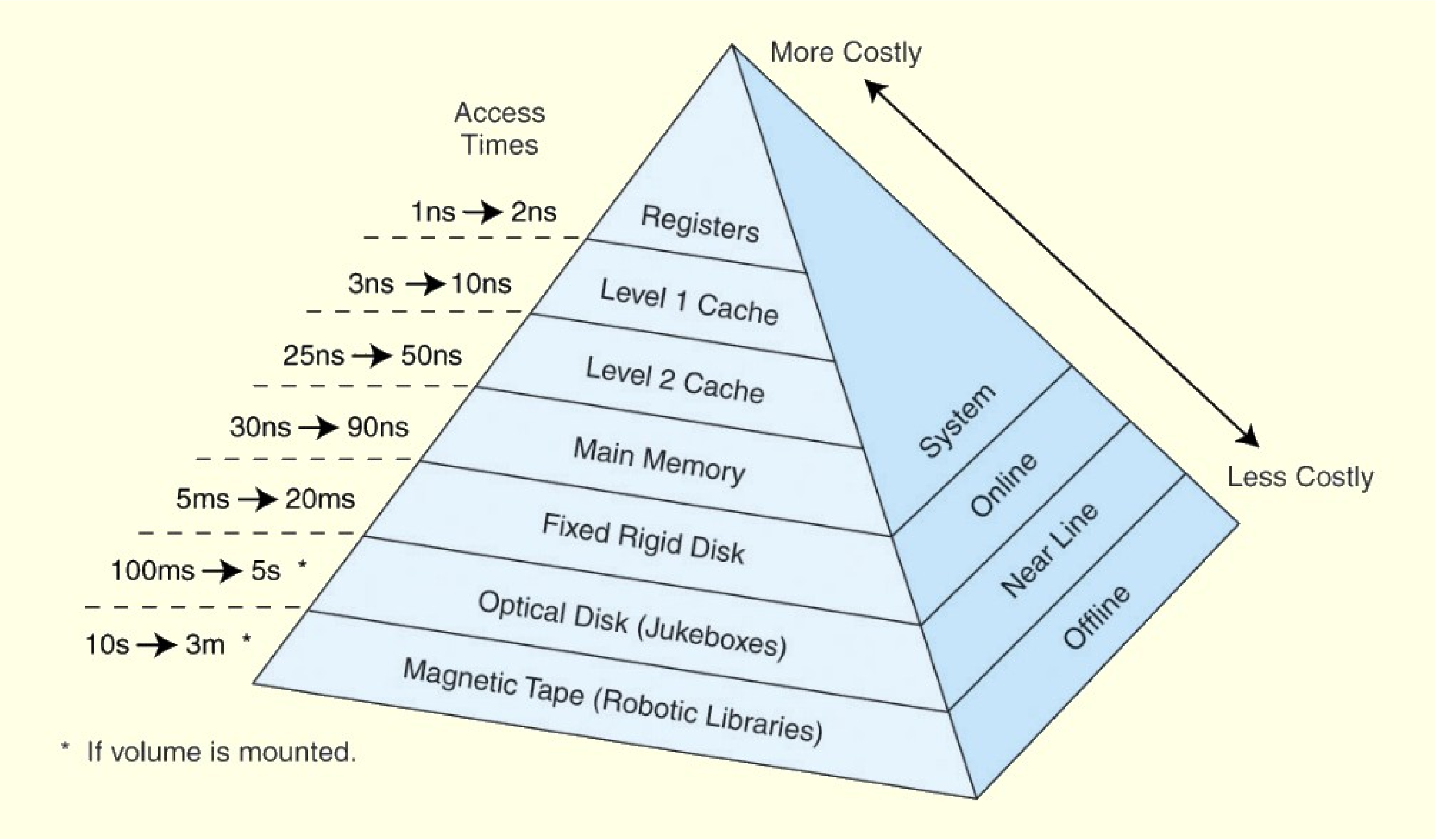


Memory Capacity

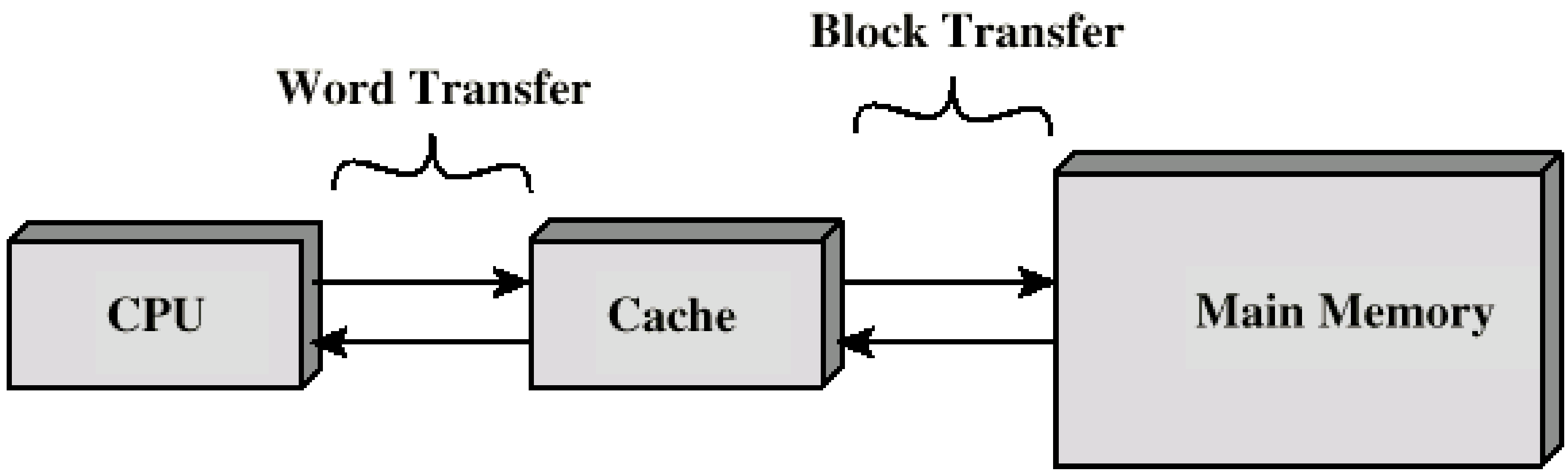
- Determined by two factors
  1. Number of bits in the MAR
     - 2^K where K = width of the register in bits
  2. Size of the address portion of the instruction
     - 4 bits allows 16 locations
     - 8 bits allows 256 locations
     - 32 bits allows 4,294,967,296 or 4 GB
- Important for performance
  - Insufficient memory can cause a processor to work at 50% below performance

Memory Hierarchy

- This storage organization can be thought of as a pyramid:



Cache



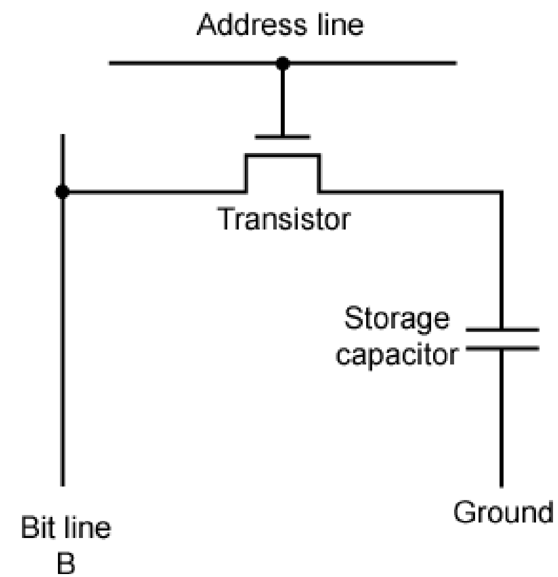
- Small amount of fast memory
- Sits between normal main memory and CPU
- May be located on CPU chip or module

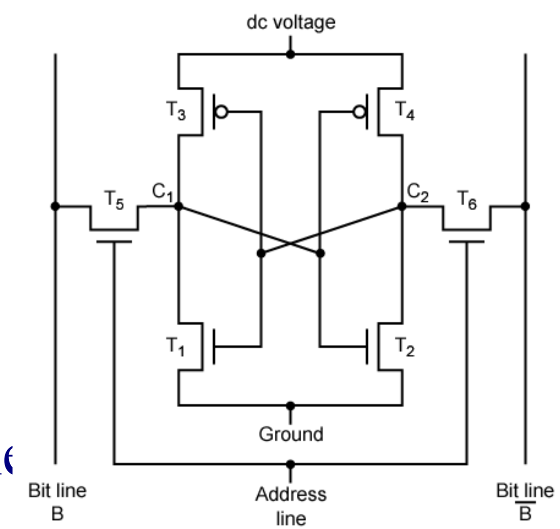
Virtual Memory

- Cache memory enhances performance by providing faster memory access speed.
- Virtual memory enhances performance by providing greater memory capacity, without the expense of adding main memory.
  - Instead, a portion of a disk drive serves as an extension of main memory.
- If a system uses paging, virtual memory partitions main memory into individually managed page frames, that are written (or paged) to disk when they are not immediately needed.

RAM: Random Access Memory

- DRAM (Dynamic RAM)
  - Most common, cheap
  - Volatile:
    - must be refreshed (recharged with power) 1000's of times each second
- SRAM (static RAM)
  - Faster than DRAM and more expensive than DRAM
  - Volatile
    - Frequently small amount used in cache memory for high-speed access used





ROM - Read Only Memory

- Permanent storage
  - Non-volatile memory to hold software that is not expected to change over the life of the system
- Used in...
  - Microprogramming
  - Library subroutines
  - Systems programs (BIOS)
    - initial boot instructions and diagnostics
  - Function tables

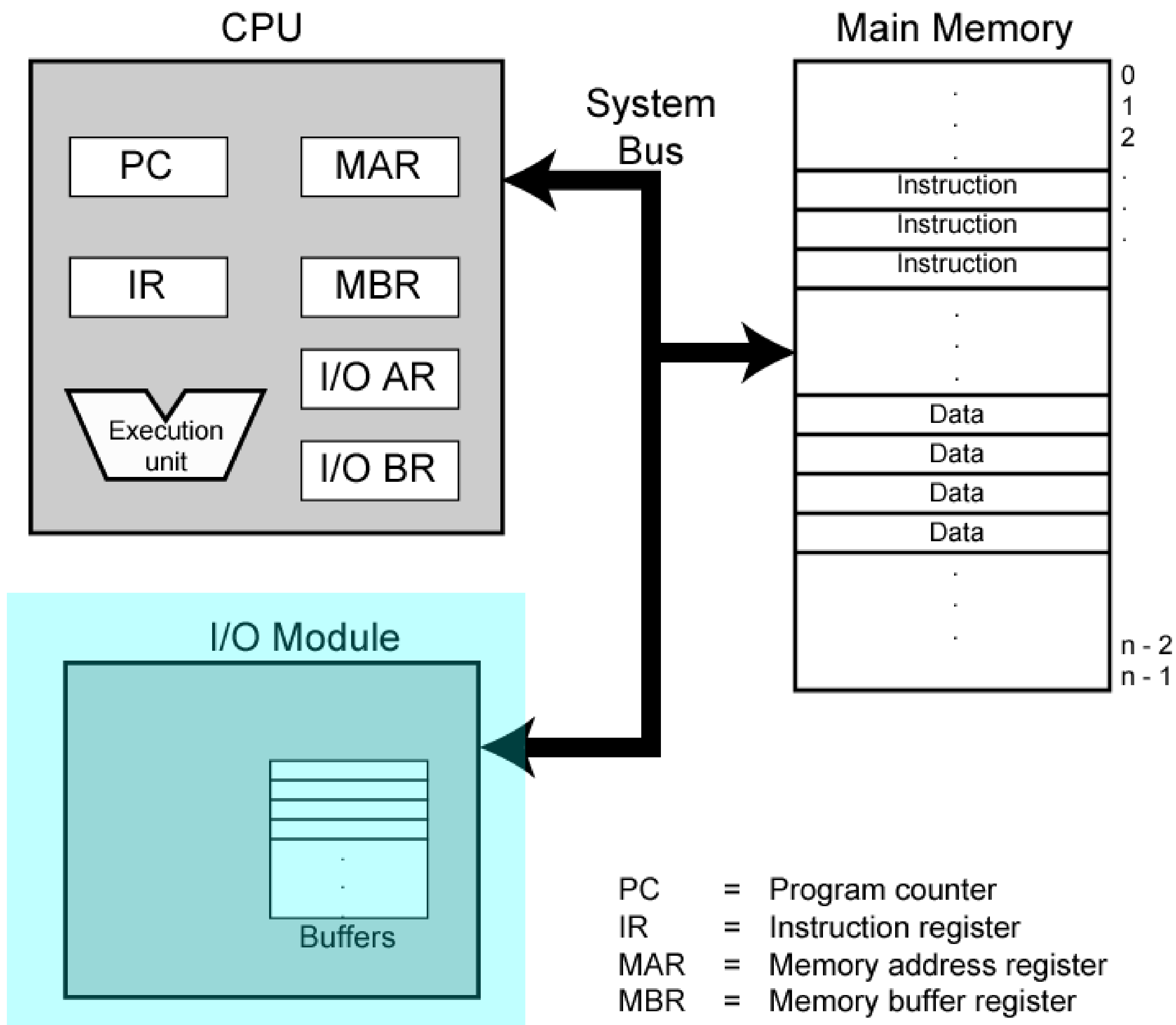
Types of ROM

- Written during manufacture
  - Very expensive for small runs
- Programmable (once)
  - PROM
  - Needs special equipment to program
- Read “mostly”
  - Erasable Programmable (EPROM)
    - Erased by UV
  - Electrically Erasable (EEPROM)
    - Takes much longer to write than read
  - Flash memory
    - Erase whole memory electrically

Types of External Memory

- SSD
  - Fast
  - Expensive (relatively)
- Magnetic Disk
  - RAID
  - Removable
- Optical
  - CD-ROM
  - CD-Recordable (CD-R)
  - CD-R/W
  - DVD
- Magnetic Tape

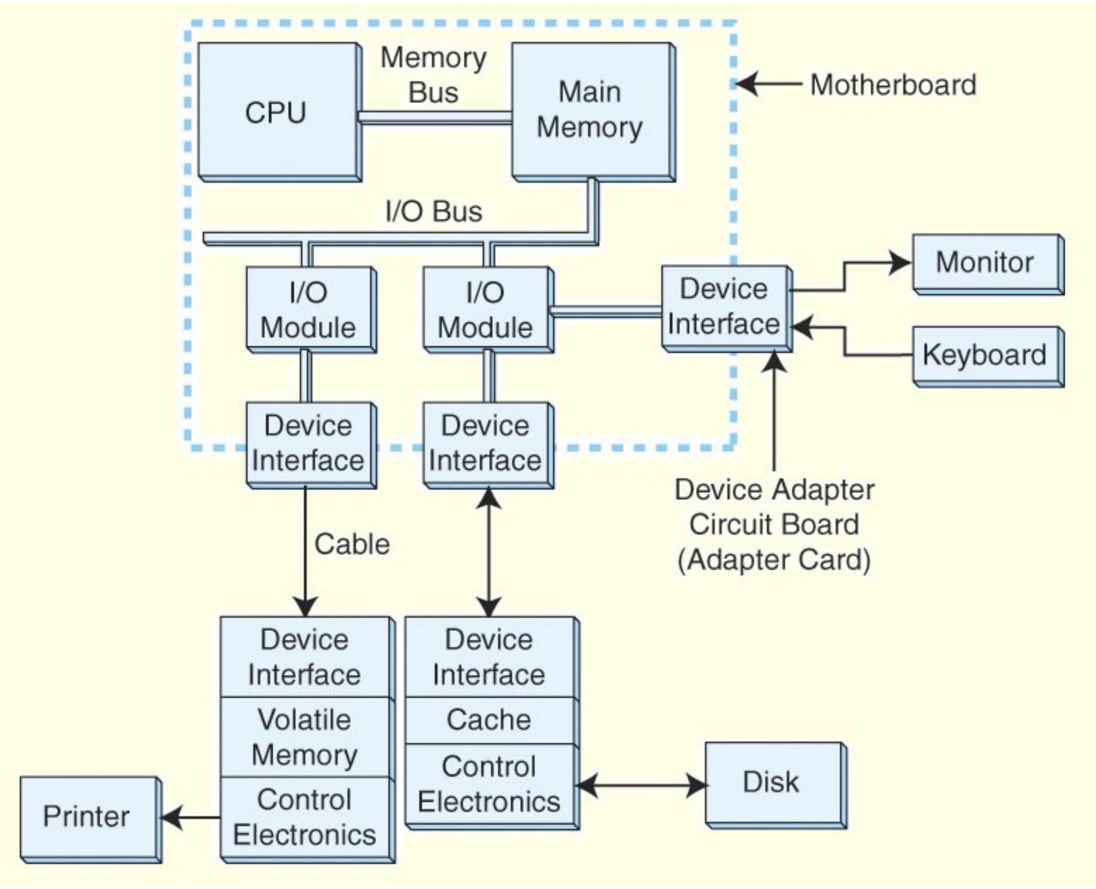
Computer Components-I/O



PC = Program counter
IR = Instruction register
MAR = Memory address register
MBR = Memory buffer register
I/O AR = Input/output address register
I/O BR = Input/output buffer register

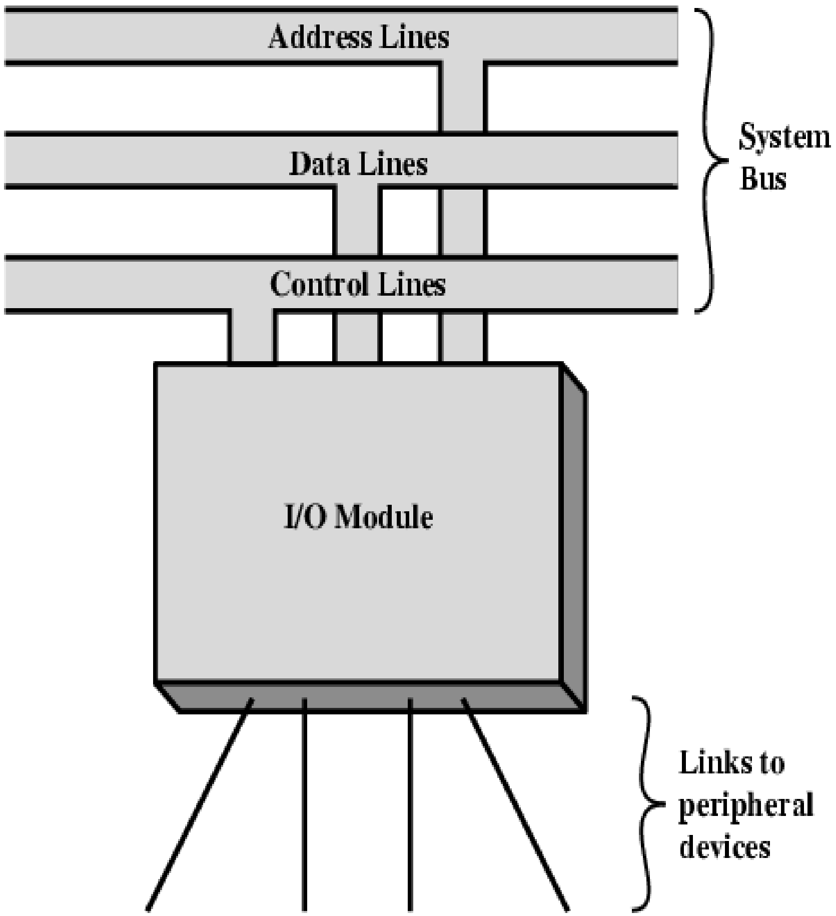
Input/Output Problems

- Wide variety of peripherals
  - Delivering different amounts of data
  - At different speeds
  - In different formats
- All slower than CPU and RAM
- Need I/O modules



Input/Output Module

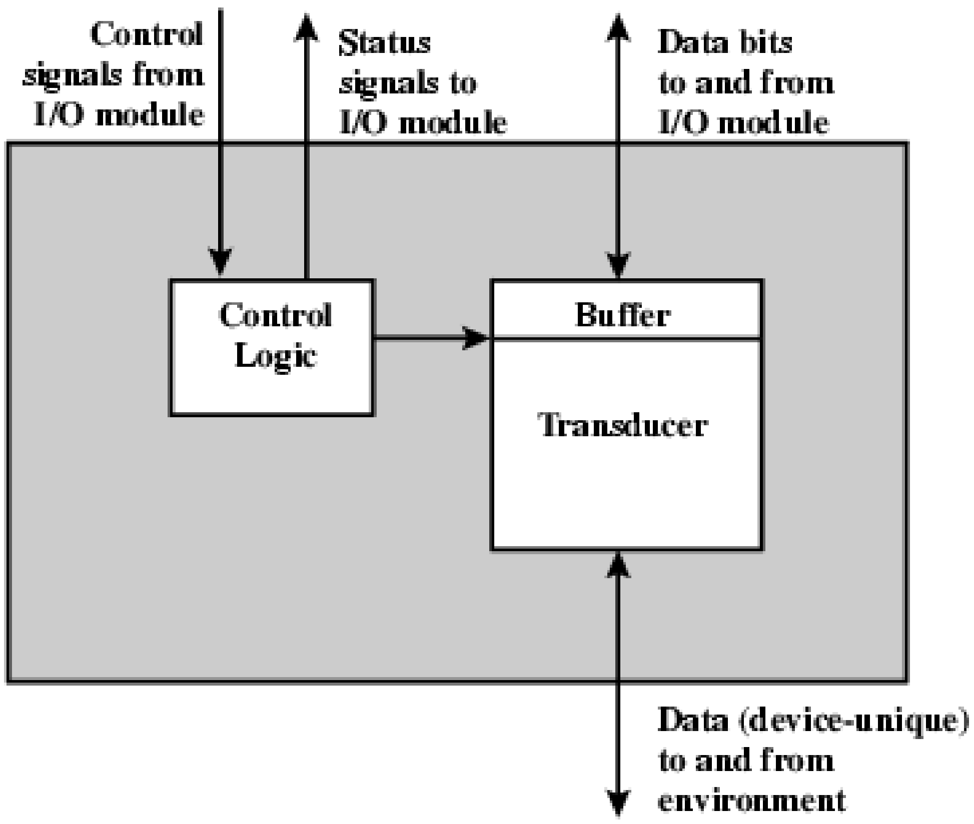
I/O Module Block Diagram



- Interface to CPU and Memory
- Interface to one or more peripherals
- I/O Module Function:
  - Control & Timing
  - CPU Communication
  - Device Communication
  - Data Buffering
  - Error Detection

External Devices

External Device Block Diagram



- External Devices:
  - Human readable
    - Screen, printer, keyboard
  - Machine readable
    - Monitoring and control
  - Communication
    - Modem
    - Network Interface Card (NIC)

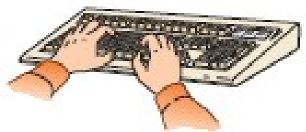
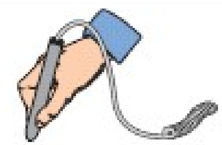
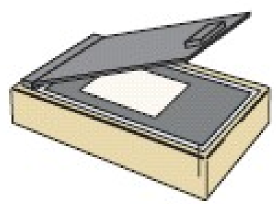
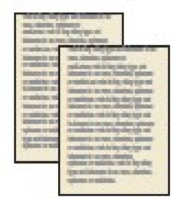
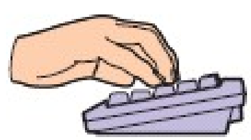
I/O Steps

- CPU checks I/O module device status
- I/O module returns status
- If ready, CPU requests data transfer
- I/O module gets data from device
- I/O module transfers data to CPU
- Variations for output, DMA, etc.

I/O Architectures

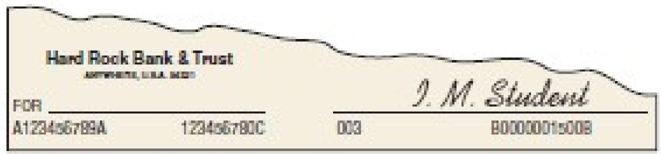
- I/O can be controlled in four general ways:
  - Programmed I/O
    - Reserves a register for each I/O device.
    - Each register is continually polled to detect data arrival.
  - Interrupt-Driven I/O
    - Allows the CPU to do other things until I/O is requested.
  - Direct Memory Access (DMA)
    - Offloads I/O processing to a special-purpose chip that takes care of the details.
  - Channel I/O
    - Uses dedicated I/O processors.

Input device examples

Device	Use
 Mouse  Keyboard  Light Pen or Stylus  Touch Screen	Most common forms of data entry.
Bar Code Reader or Scanner  Wand Reader	The data entered are stored as printed bars of different widths.
Optical Scanner  	The data entered are stored on typed pages or even handwritten forms.
Point-of-sale Device 	The data are entered at the point where a transaction is made.

Input device examples

Magnetic Ink Character Reader

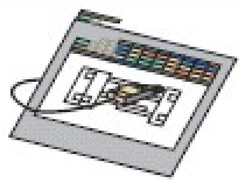


The data entered are imprinted with magnetic ink. This system is mostly used on bank checks.

Voice Recognition

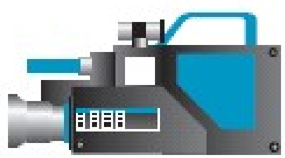
Voice input is entered, interpreted, and displayed on a screen or saved to disk.

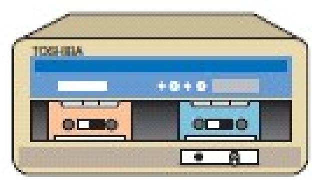
Digitizer



Graphic images are digitized and transmitted to the computer.

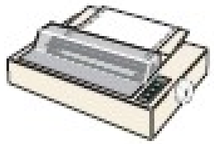
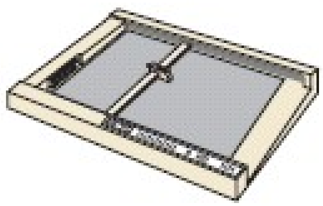
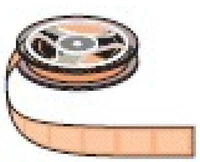
Camera, Tape Recorder



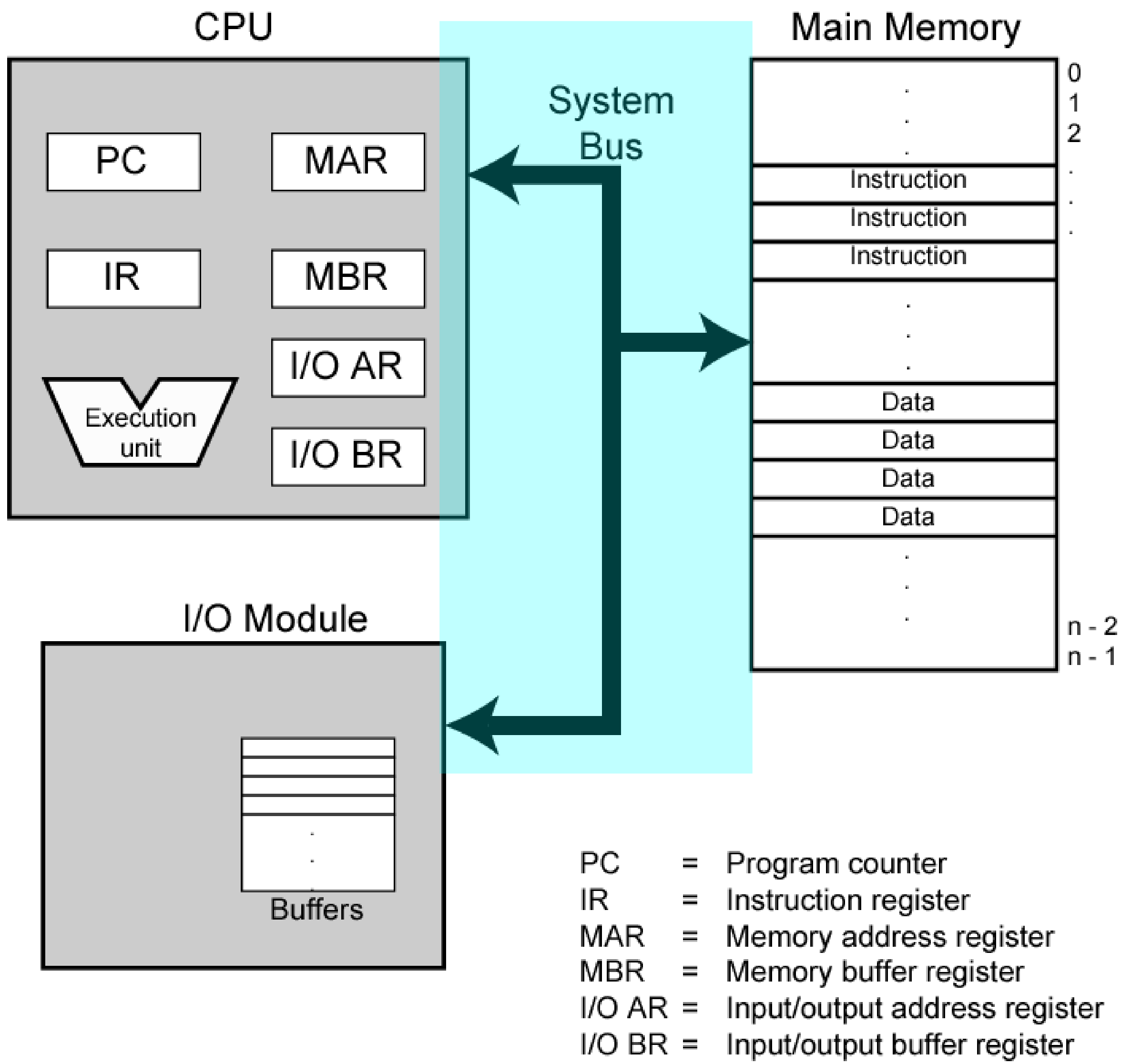


Video, photos, graphics, sound, and text can be entered to create multimedia presentations that educate, inform, and entertain.

Output device examples

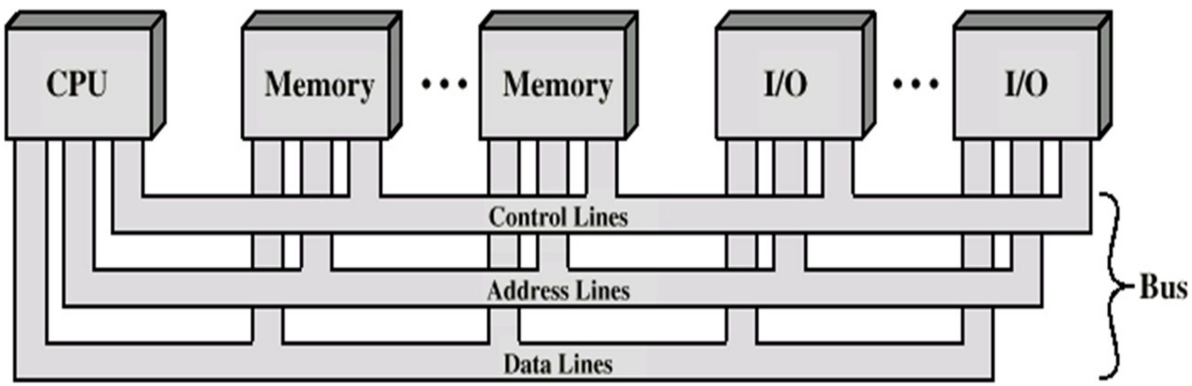
Output Device	Use
 Printer	Prints reports, fills in forms, prints high-quality graphics.
 Monitor	Displays keyed, computer-stored, or computer-produced information.
 Plotter	Draws computer-produced color graphics and charts.
 Audio response	Responds to users with verbal messages or music, and sound and voice overlays for multimedia presentations.
 Image processing equipment 	Stores documents, photos, graphics, videos, animations and sound on film, compact disk or laser disk.

Computer Components- Bus



Bus

- The physical connection that makes it possible to transfer data from one location in the computer system to another
- Group of electrical conductors for carrying signals from one location to another
- 4 kinds of signals
  - Data
    - Alphanumeric
    - Numerical
    - instructions
  - Addresses
  - Control signals
  - Power (sometimes)



Bus

- Connect
  - CPU and Memory
  - I/O peripherals:
    - on same bus as CPU/memory or separate bus
- Physical packaging commonly called backplane
  - Also called system bus or external bus
  - Example of broadcast bus
  - Part of printed circuit board called motherboard that holds CPU and related components

Bus Characteristics

- Protocol
  - Documented agreement for communication
  - Specification that spells out the meaning of each line and each signal on each line
- Throughput, i.e., data transfer rate in bits per second
- Data width in bits carried simultaneously

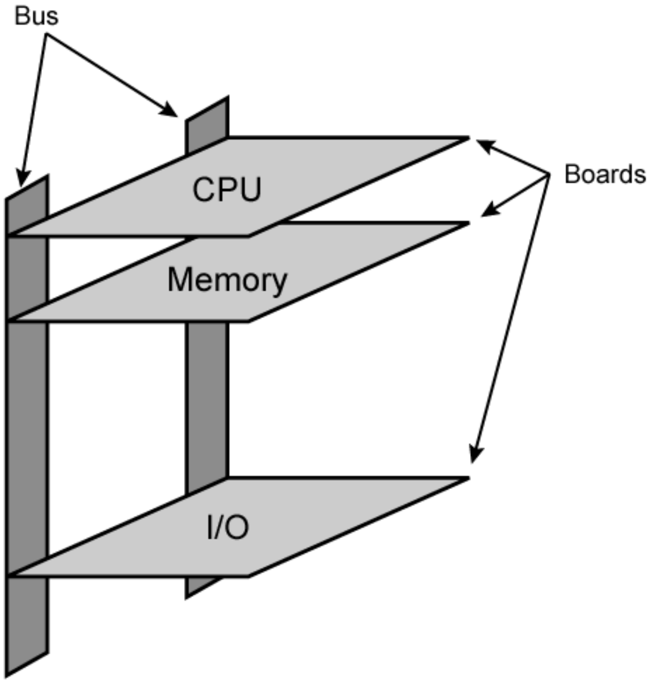
Bus types

- Data Bus
  - Carries data
  - Width is a key determinant of performance
    - 8, 16, 32, 64 bit
- Address bus
  - Identify the source or destination of data
  - Bus width determines maximum memory capacity of system
    - e.g. 8080 has 16 bit address bus giving 64k address space
- Control Bus
  - Control and timing information
    - Memory read/write; I/O read/write; Transfer acknowledge; Bus request; Bus grant; Interrupt request; Interrupt acknowledge; Clock; Reset

What do buses look like?

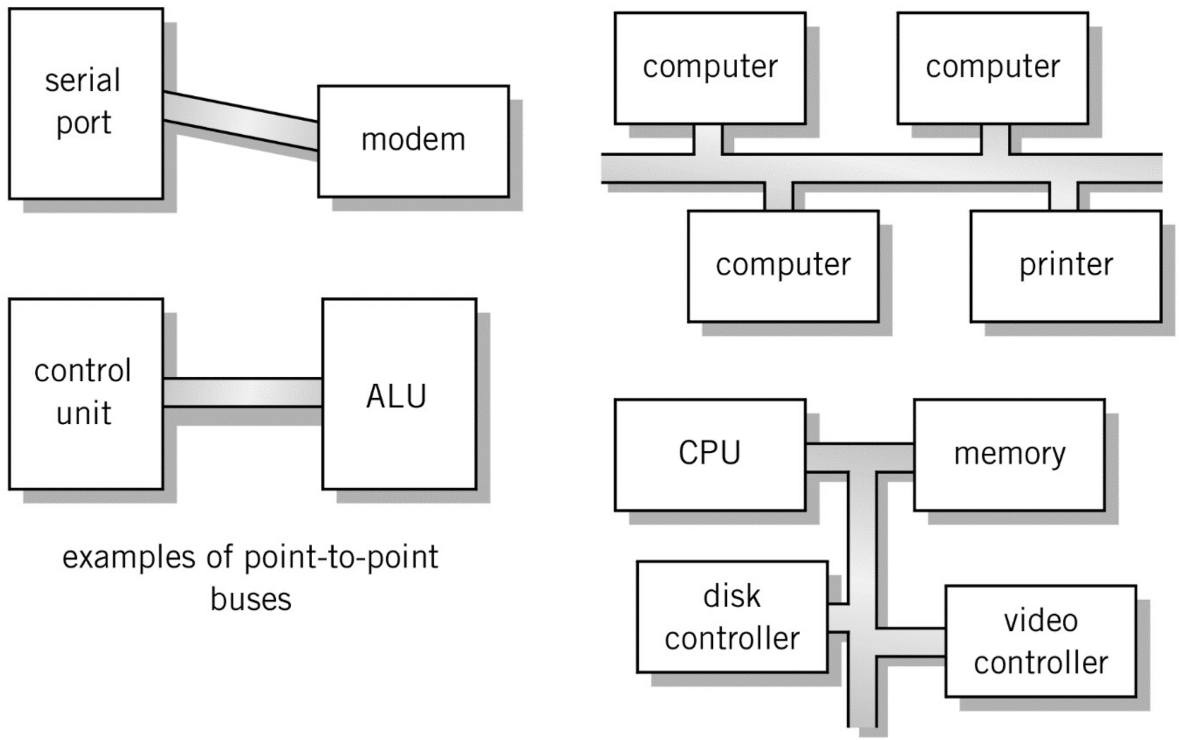
- Parallel lines on circuit boards
- Ribbon cables
- Strip connectors on mother boards
  - e.g. PCI
- Sets of wires

Physical Realization of Bus Architecture



Point-to-point vs. Multipoint

Plug-in device



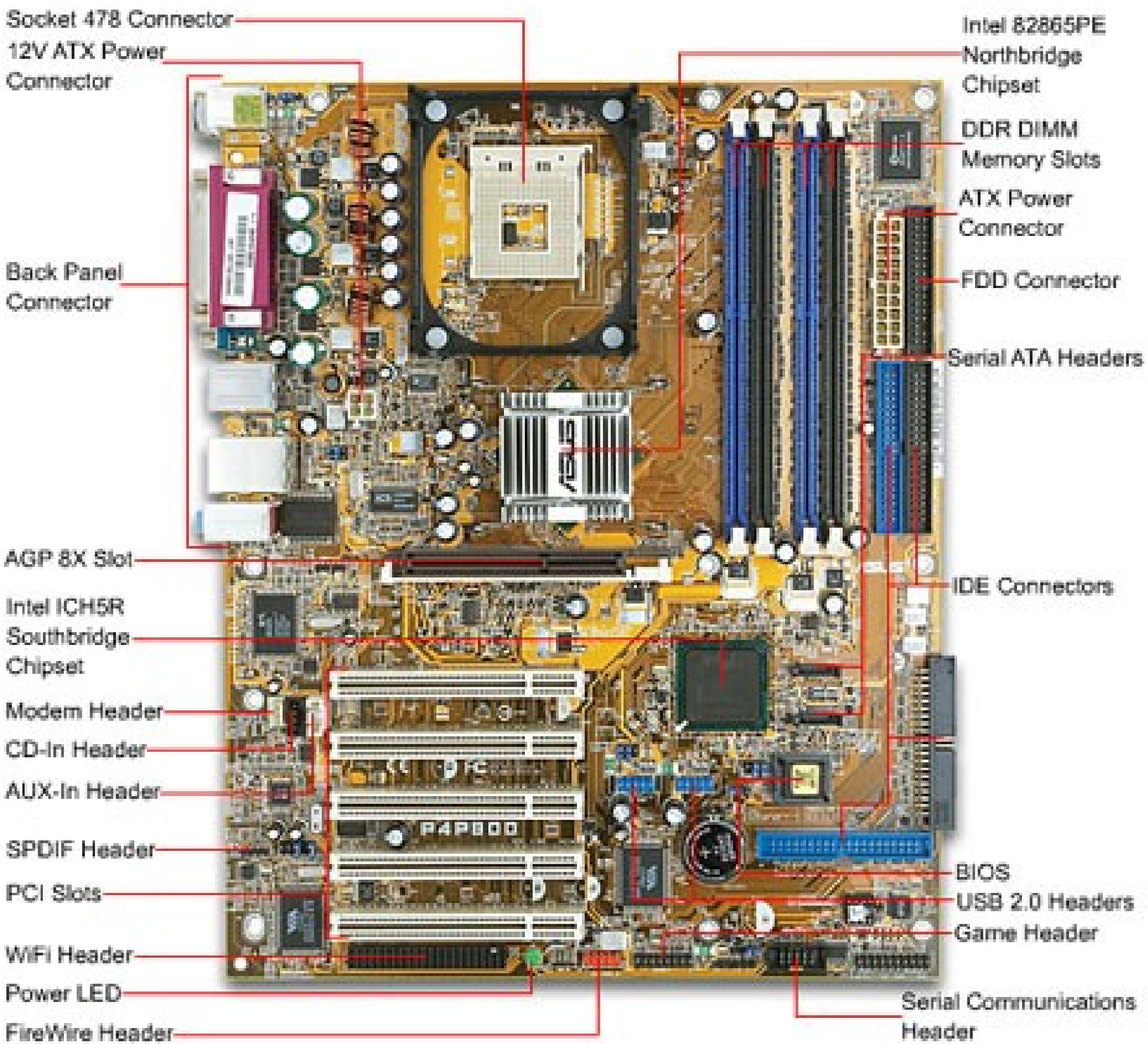
examples of point-to-point buses

examples of multipoint buses

Broadcast bus Example: Ethernet

Shared among multiple devices

Motherboard



- Printed circuit board that holds CPU and related components including backplane

Motherboard