

# CS420: Operating Systems

## Introduction

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# Introduction

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- **What Operating Systems Do**
- **Computer-System Organization**
- **Computer-System Architecture**
- **Operating-System Structure**
- **Operating-System Operations**
- **Process Management**
- **Memory Management**
- **Storage Management**
- **Protection and Security**
- **Distributed Systems**
- **Special-Purpose Systems**
- **Computing Environments**
- **Open-Source Operating Systems**

# What is an Operating System?

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- **A program that acts as an intermediary between a user of a computer and the computer hardware**
- **Operating system goals:**
  - Execute user programs and make solving user problems easier
  - Make the computer system convenient to use
  - Use the computer hardware in an efficient manner

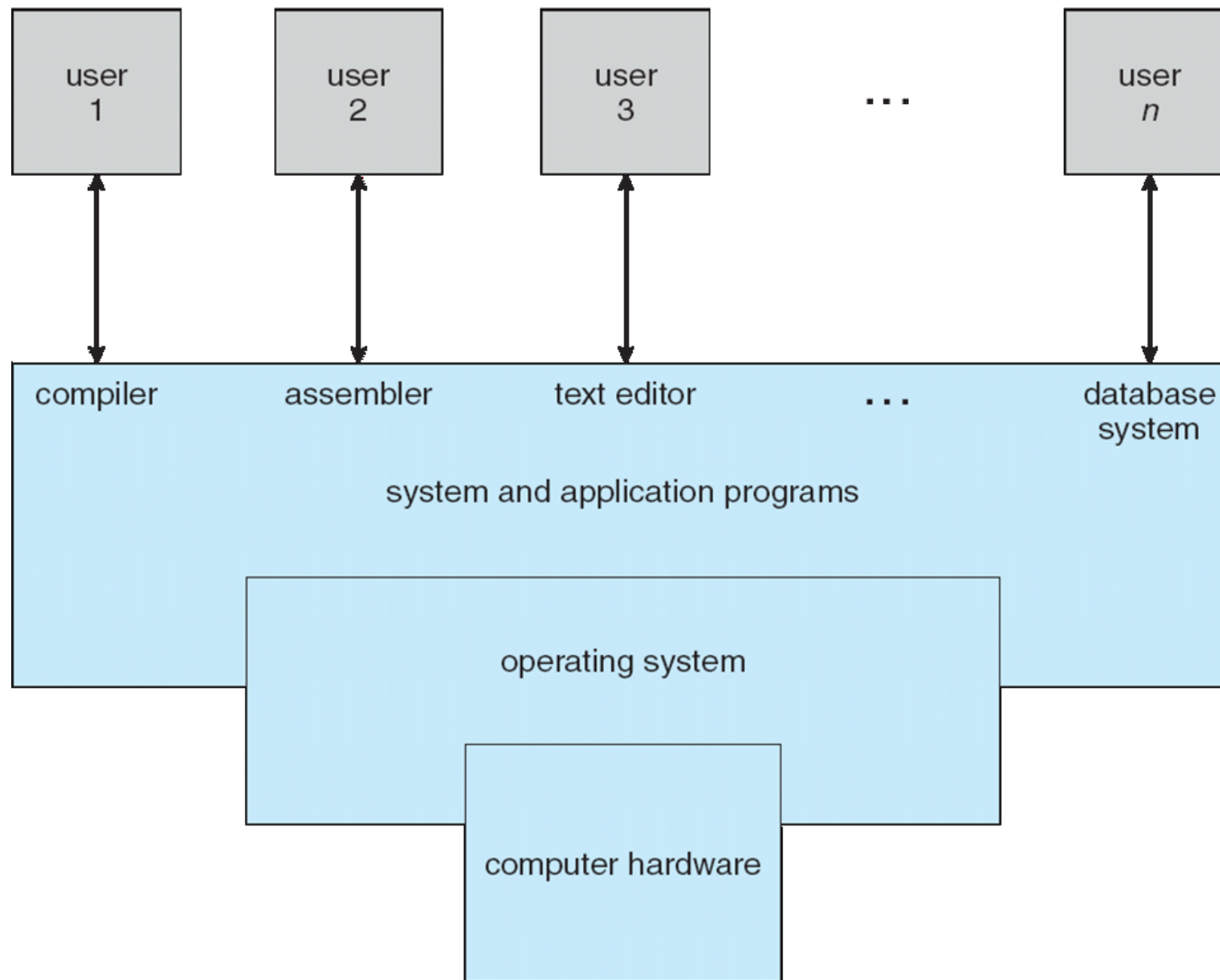
# Computer System Structure

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- **Computer system can be divided into four components:**
  - Hardware – provides basic computing resources
    - CPU, memory, I/O devices
  - Operating system
    - Controls and coordinates use of hardware among various applications and users
  - Application programs – define the ways in which the system resources are used to solve the computing problems of the users
    - Word processors, compilers, web browsers, database systems, video games
  - Users
    - People, machines, other computers

# Four Components of a Computer System

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# What Do Operating Systems Do?

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- **Depends on the who is using the OS**

- Users want convenience, ease of use
  - Don't care about resource utilization
- However, a shared computer, such as mainframe or minicomputer, must keep all users happy
- Users of dedicated systems such as workstations have dedicated resources but frequently use shared resources from servers
- Handheld computers are resource poor, optimized for usability and battery life
- Some computers have little or no user interface, such as embedded computers in devices and automobiles

# Operating System Definition

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- **OS is a resource allocator**

- Manages all system resources
- Decides between conflicting requests for efficient and fair resource use

- **OS is a control program**

- Controls execution of programs to prevent errors and improper use of the computer

# Operating System Definition (Cont.)

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- **No universally accepted definition**
- **“Everything a vendor ships when you order an operating system” is good approximation**
  - But varies wildly
- **“The one program running at all times on the computer” is the kernel. Everything else is either a system program (ships with the operating system) or an application program.**



# Computer Startup / System Boot

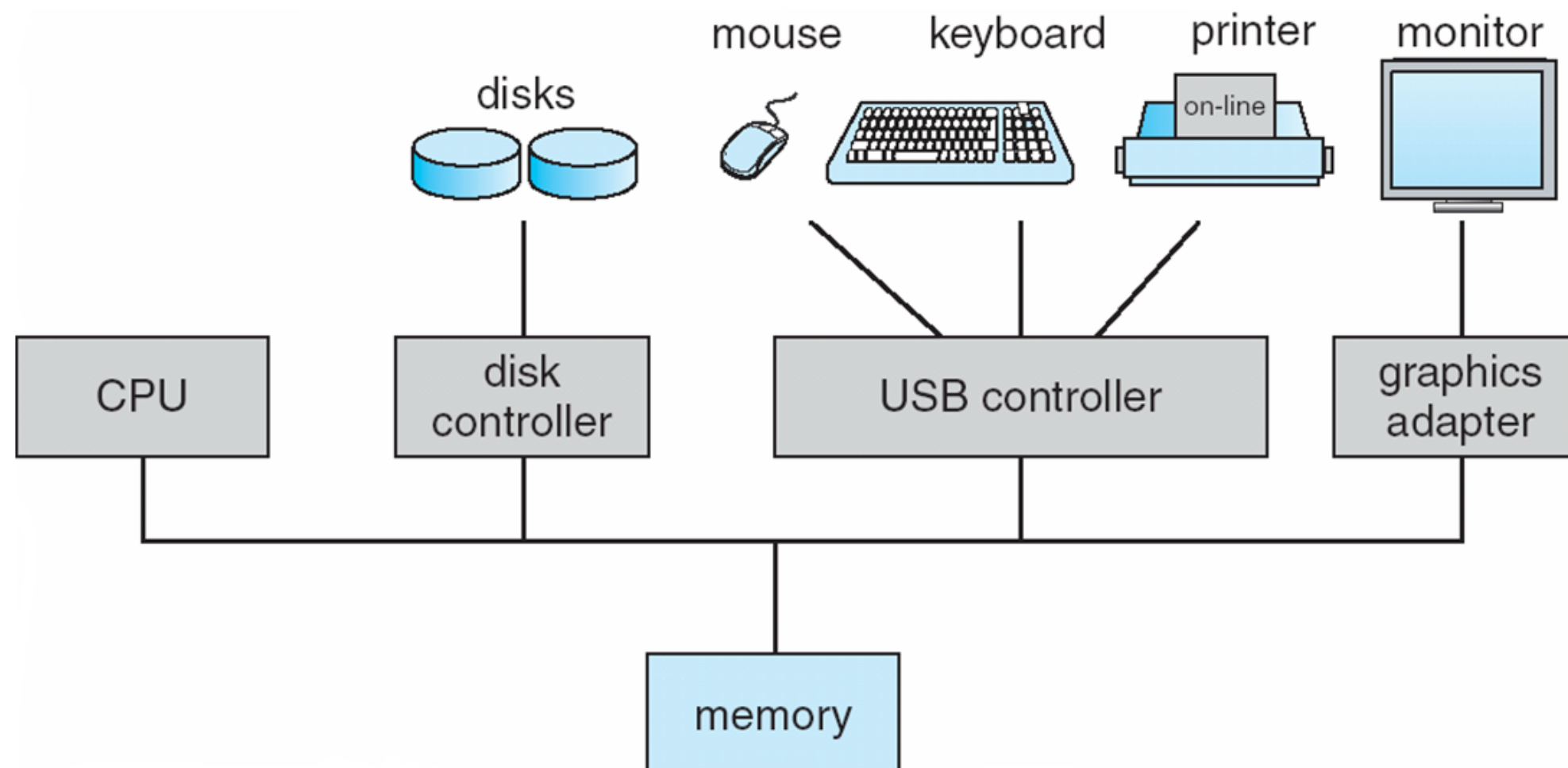
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- **Bootstrap program is loaded at power-up or reboot**
  - Typically stored in ROM or EPROM, generally known as firmware
  - Initializes all aspects of system
  - Loads operating system kernel and starts execution
- **Operating system must be made available to hardware so hardware can start it**
  - Small piece of code – bootstrap loader, locates the kernel, loads it into memory, and starts it
  - Sometimes two-step process where boot block at fixed location loads bootstrap loader
  - When power initialized on system, execution starts at a fixed memory location
    - **Firmware used to hold initial boot code**

# Computer System Organization

- **Computer-system operation**

- One or more CPUs, device controllers connect through common bus providing access to shared memory
- Concurrent execution of CPUs and devices competing for memory cycles



# Computer System Operation

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- **I/O devices and the CPU can execute concurrently**
- **Each device controller is in charge of a particular device type**
- **Each device controller has a local buffer**
  - CPU moves data from/to main memory to/from local buffers
  - I/O is from the device to local buffer of controller
- **Device controller informs CPU that it has finished its operation by causing an interrupt**

# Common Functions of Interrupts

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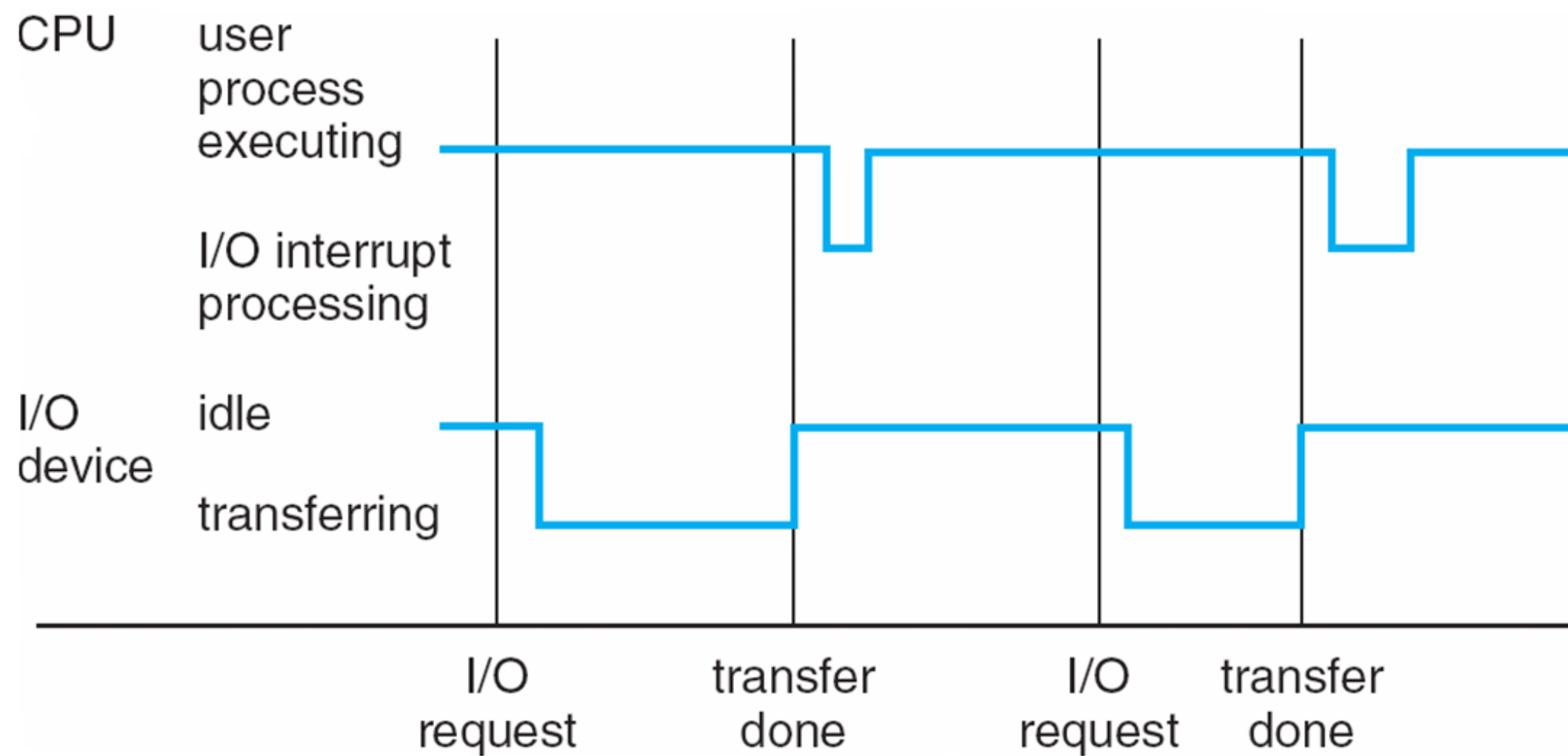
- **Interrupt transfers control to the interrupt service routine generally, through the interrupt vector, which contains the addresses of all the service routines**
- **Interrupt architecture must save the address of the interrupted instruction**
- **Incoming interrupts are disabled while another interrupt is being processed to prevent a lost interrupt**
- **A trap is a software-generated interrupt caused either by an error or a user request**
- **An operating system is interrupt driven**

# Interrupt Handling

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- **The operating system preserves the state of the CPU by storing registers and the program counter**
- **Separate segments of code determine what action should be taken for each type of interrupt**

# Interrupt Timeline



# I/O Structure

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- **After I/O starts, control returns to user program only upon I/O completion**
  - Wait instruction idles the CPU until the next interrupt
  - Wait loop (contention for memory access)
  - At most one I/O request is outstanding at a time, no simultaneous I/O processing
- **After I/O starts, control returns to user program without waiting for I/O completion**
  - System call – request to the operating system to allow user to wait for I/O completion
  - Device-status table contains entry for each I/O device indicating its type, address, and state
  - Operating system indexes into I/O device table to determine device status and to modify table entry to include interrupt

# Direct Memory Access Structure

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- **Used for high-speed I/O devices able to transmit information at close to memory speeds**
- **Device controller transfers blocks of data from local storage buffer directly to main memory without CPU intervention**
- **Only one interrupt is generated per block, rather than the one interrupt per byte**



# Storage Structure

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- **Main memory – only large storage media that the CPU can access directly**
  - Random access
  - Typically volatile
- **Secondary storage – extension of main memory that provides large nonvolatile storage capacity**
  - Typically magnetic disks – rigid metal or glass platters covered with magnetic recording material
    - Disk surface is logically divided into tracks, which are subdivided into sectors
    - The disk controller determines the logical interaction between the device and the computer
  - Solid State Disks (SSDs) are quickly replacing magnetic disks
    - Cost/MB is still higher than magnetic disks

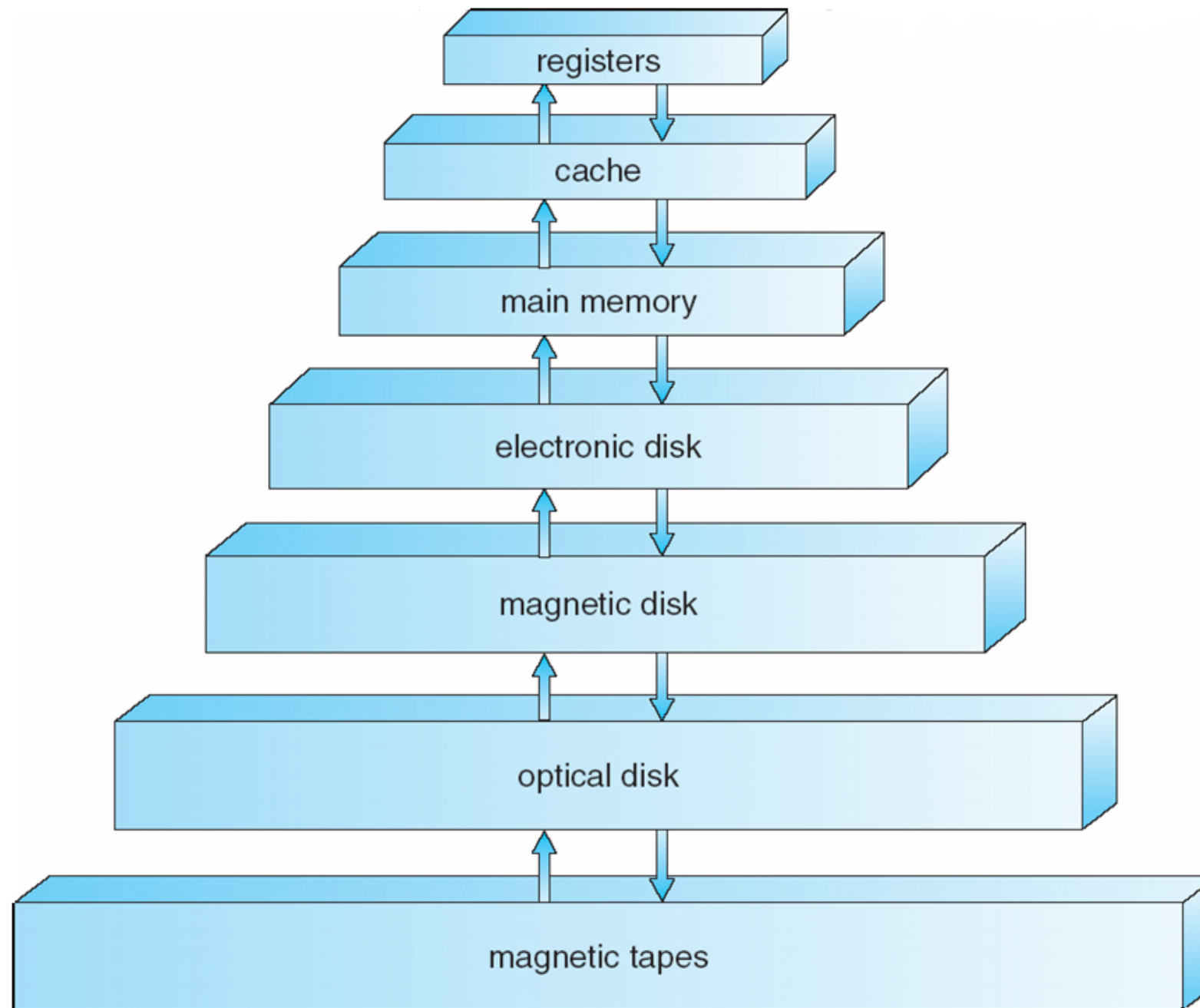
# Storage Hierarchy

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- **Storage systems organized in hierarchy**
  - Speed
  - Cost
  - Volatility
- **Caching – copying information into faster storage system; main memory can be viewed as a cache for secondary storage**

# Storage-Device Hierarchy

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# Caching

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- **Important principle, performed at many levels in a computer (in hardware, operating system, software)**
- **Information in use copied from slower to faster storage temporarily**
- **Faster storage (cache) checked first to determine if information is there**
  - If it is, information used directly from the cache (fast)
  - If not, data copied to cache and used there
- **Cache smaller than storage being cached**
  - Cache management important design problem
  - Cache size and replacement policy

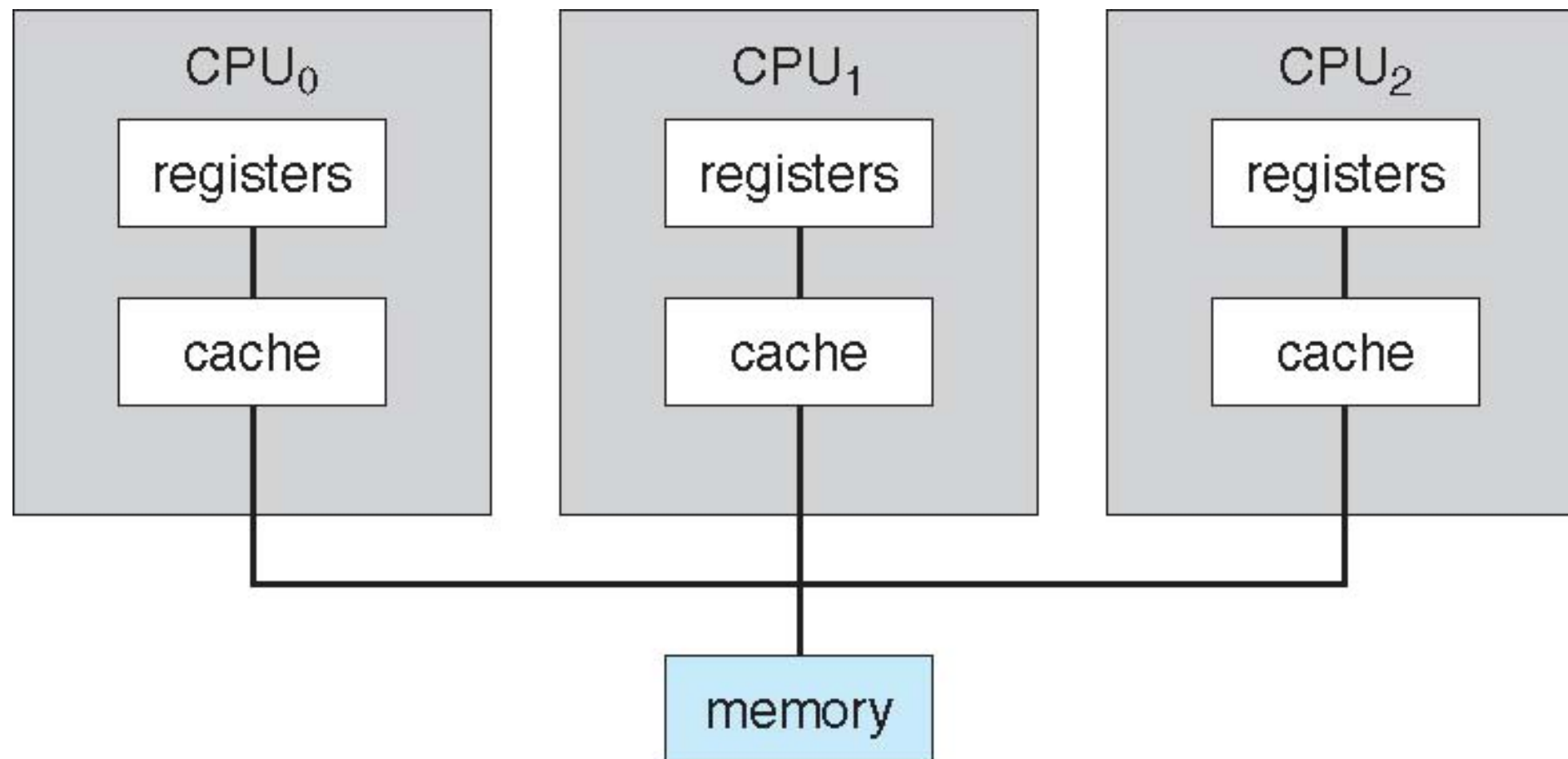
# Computer-System Architecture

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- **Most systems use a single general-purpose processor (from cell phones to mainframes)**
  - Most systems have special-purpose processors as well
- **Multiprocessors systems growing in use and importance**
  - Also known as parallel systems, tightly-coupled systems
  - Advantages include:
    - Increased throughput
    - Economy of scale
    - Increased reliability – graceful degradation or fault tolerance
  - Two types:
    - Asymmetric Multiprocessing - each processor is assigned a specific task
    - Symmetric Multiprocessing - each processor performs all tasks

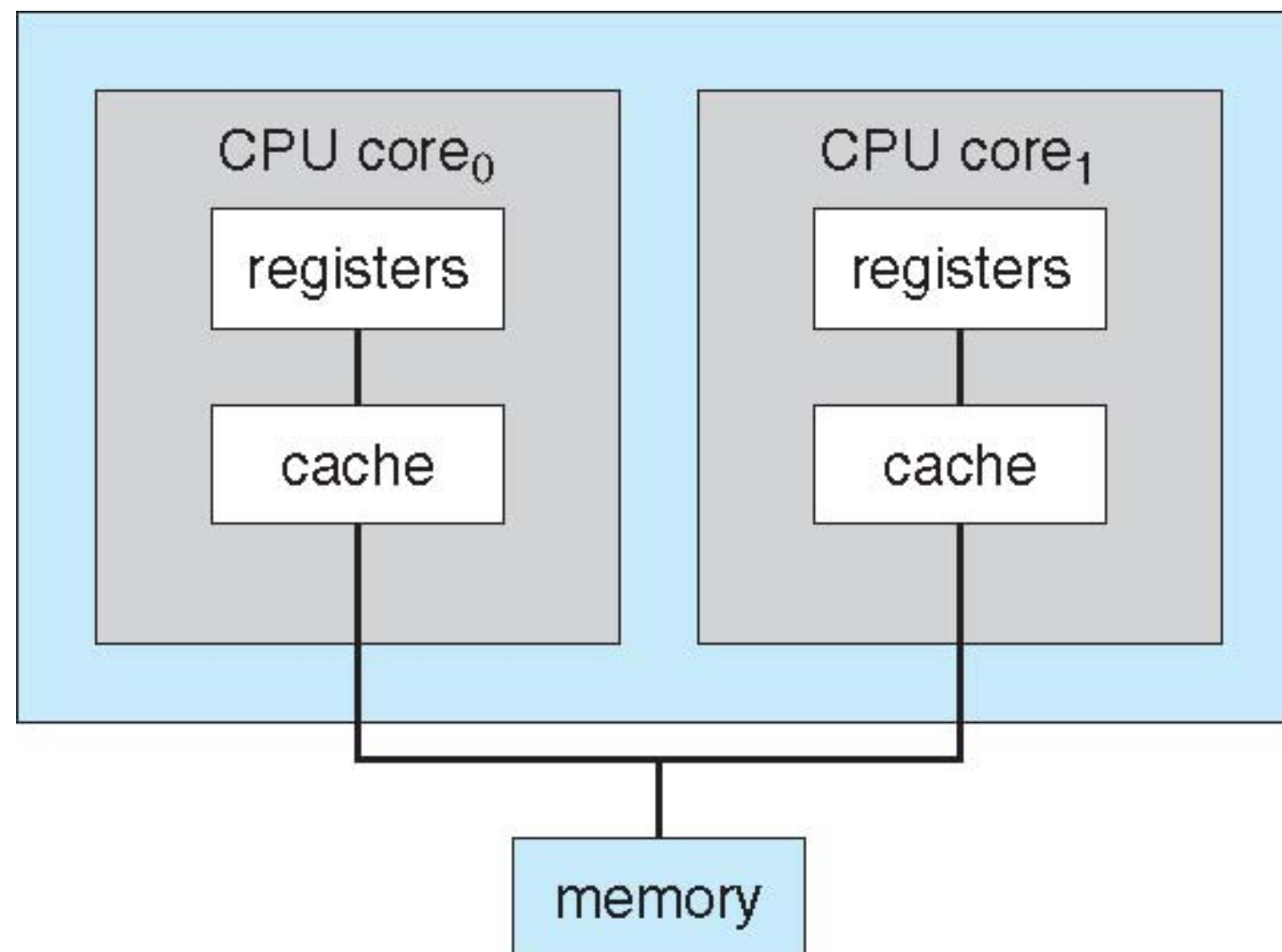
# Symmetric Multiprocessing Architecture

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# A Dual-Core Design

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# Clustered Systems

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- **Like multiprocessor systems, but multiple systems working together**
  - Usually sharing storage via a storage-area network (SAN)
  - Provides a high-availability service which survives failures
    - Asymmetric clustering has one machine in hot-standby mode
    - Symmetric clustering has multiple nodes running applications, monitoring each other
  - Some clusters are for high-performance computing (HPC)
    - Applications must be written to use parallelization



# Clustered Systems

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