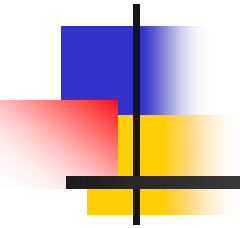
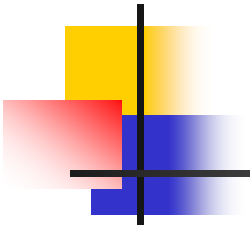
操作系统原理及应用

李　伟
xchlw@seu.edu.cn

计算机科学与工程学院、软件学院
江苏省网络与信息安全重点实验室

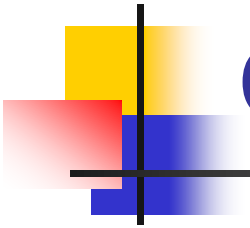


Chapter 1 Introduction



Outline

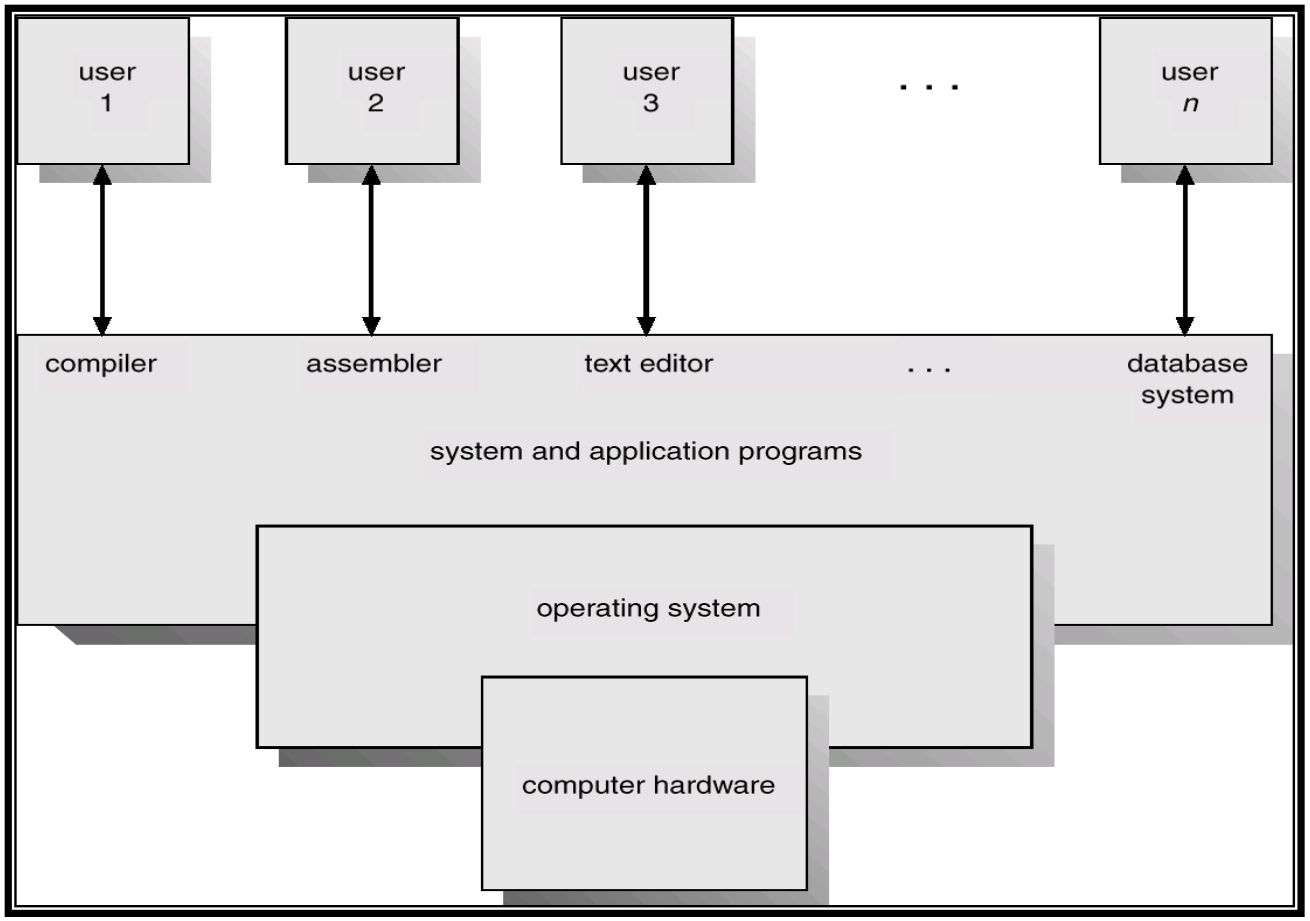
- **What is Operating System?**
- **OS-related Hardwares**
- **Development of Operating System**



Computer System Components

- **Hardware – provides basic computing resources (CPU, memory, I/O devices, etc).**
- **Operating system – controls and coordinates the use of the hardware among the various programs for the various users.**
- **Programs – (compilers, database, video, games, email systems, QQ, WeChat, etc) are used to solve user problems.**
- **Users (people, machines, other computers).**

Abstract View of Computer System Components



User View

- **PC Users**




An operating system is a interface program that provides an easy-to-use interface for using the hardware.

User View

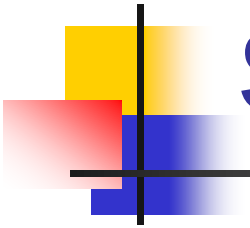
- **Mainframe/Minicomputer Users**

An operating system is a interface program that helps maximize the system resource utilization

User View

- **Workstation Users**

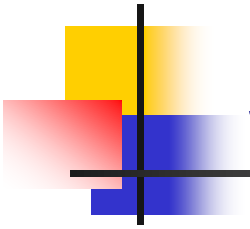
An operating system is a interface program designed to compromise between individual usability and resource utilization



System View

- A ***Resource Allocator***: the operating system allocates and reclaims the system hardware resources to and from user programs
- A ***Control Program***: the operating system controls the execution of user programs to prevent errors and improper use of the computer

What is an Operating System?(1/3)



- **There is *no* universal definition of what is an operating system.**
- **A common definition is that the operating system is the one *kernel program* running at all times on the computer. All other programs are systems/application programs.**

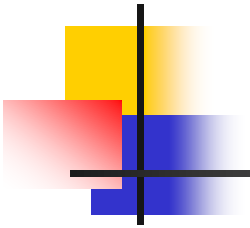
What is an Operating System?(2/3)

- **An operating system is a set of programs that acts as an intermediary between the user of a computer and the computer hardware.**
  - **Make the computer system convenient to use.**
  - **Execute user programs and make solving user problems easier.**
  - **Manage the computer hardware.**

What is an Operating System?(3/3)

- **General View**
  - **A interface program, a control program, a kernel program**
- **The Goals of Operating System**
  - **Primary Goal: *efficient* operation of the computer system.**

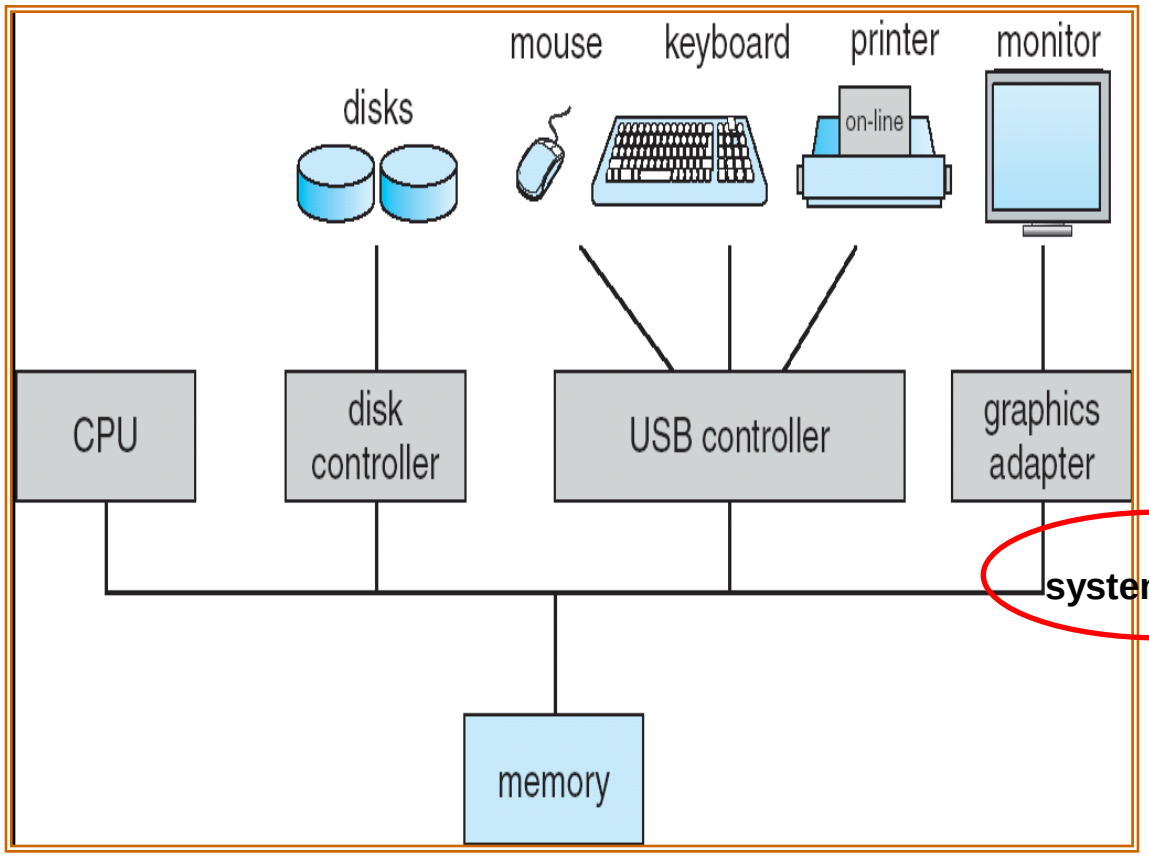
- ***The matter of what constitutes an operating system has become increasingly important.***



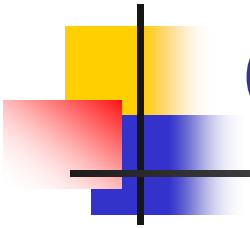
Outline

- What is Operating System?
- OS-related Hardwares
- Development of Operating System

Computer-System Architecture

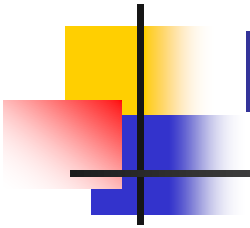


- How does the OS get into system?
- How do users request for services?
- How does the OS know something has happened?



Computer Startup

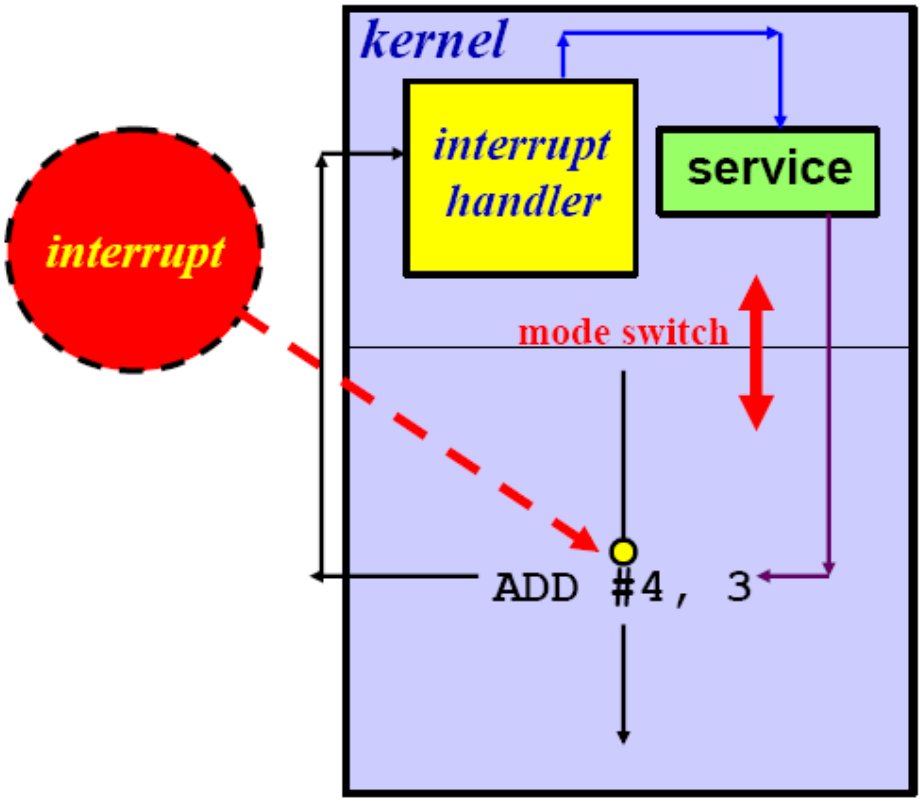
- **Bootstrap Program (引导程序)**
  - **Typically stored in ROM (Read-Only Memory) or EPROM (Erasable Programmable ROM) , generally known as firmware (固件)**
  - **Loaded at power-up or reboot**
  - **Initializates all aspects of system**
  - **Loads the operating system kernel into memory, which starts executing “init” and waits for some event to occur**



Interrupt

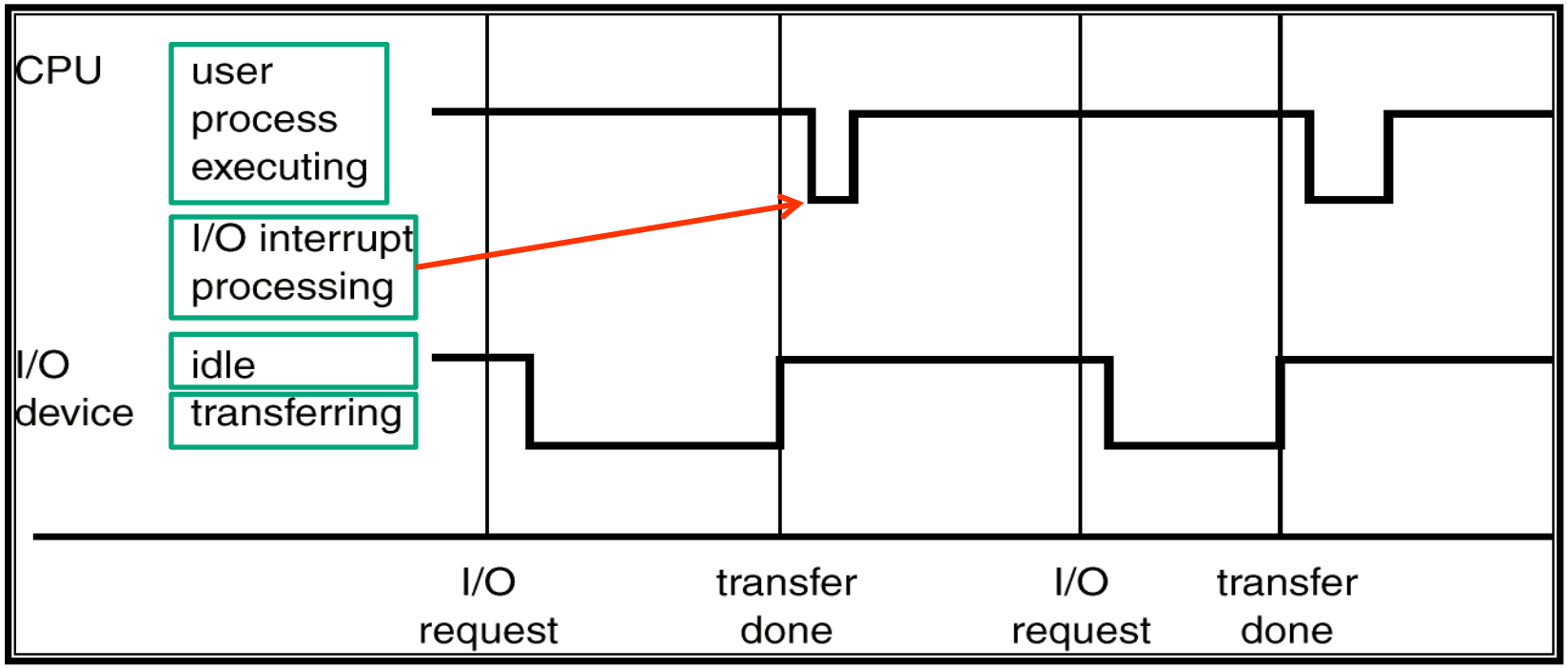
- **An event that requires the attention of the OS is an *interrupt*. These events include the completion of an I/O, a keypress, a request for service, a division by zero and so on.**
- **Interrupts may be generated by hardware or software. A trap is a software-generated interrupt caused either by an error or a user request.**
- **Modern operating systems are *interrupt driven*, meaning the OS is in action only if an interrupt occurs.**

What is Interrupt driven?



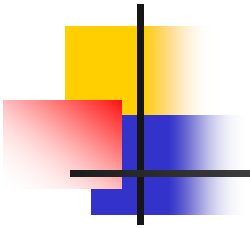
- OS is activated by an interrupt.
- The executing program is suspended.
- Control is transferred to OS.
- Program continues when the service completes.

Interrupt Time Line For a Single Process Doing Output



Common Functions of Interrupts

- **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*.**



Interrupt Handling

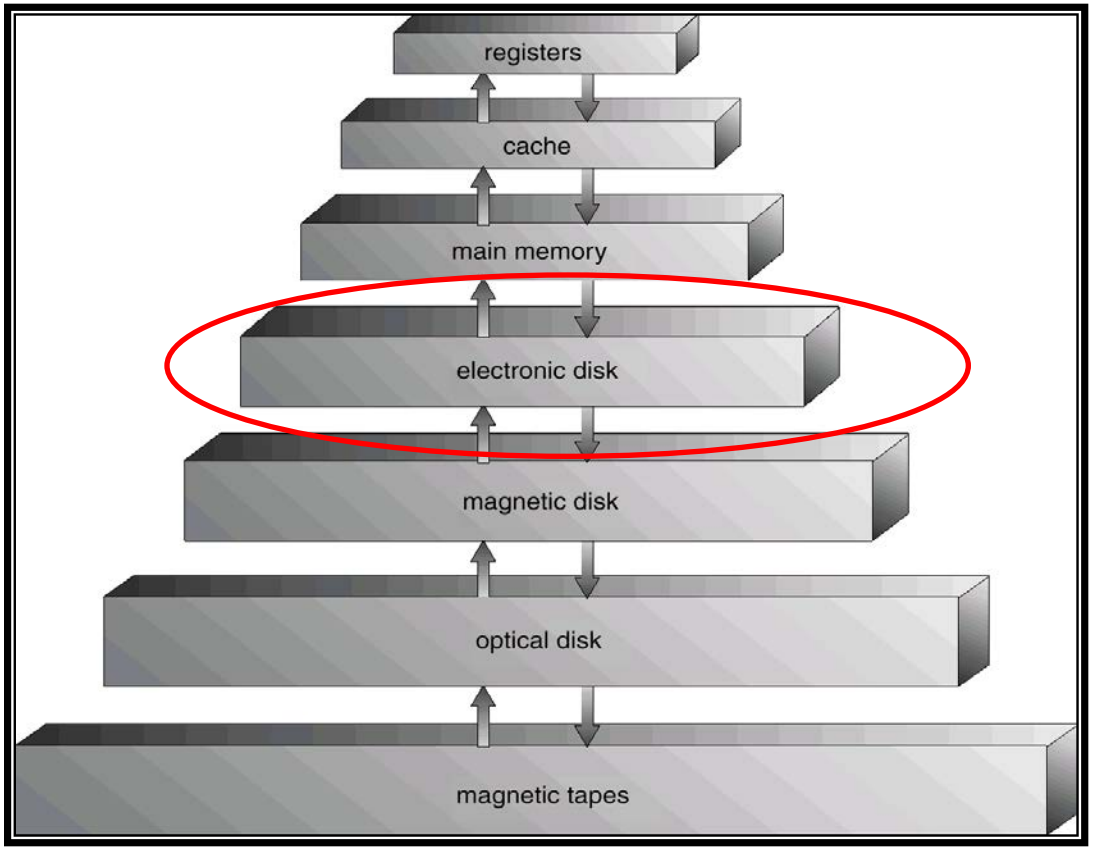
- **The operating system preserves the state of the CPU by storing registers and the program counter.**
- **Determines which type of interrupt has occurred:**
  - ***polling***
  - ***vectored* interrupt system**
- **Separate segments of code determine what action should be taken for each type of interrupt**

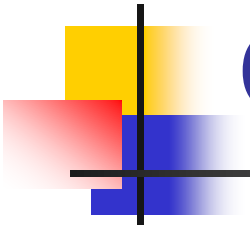
Storage Structure

- Computer programs must be in main memory to be executed.
- Main memory – only large storage media that the CPU can access directly. *Why?*
  - a volatile storage device
  - too small to store all needed programs and data permanently
- Secondary storage – extension of main memory that provides large nonvolatile storage capacity.

Storage Hierarchy

- **Storage systems organized in hierarchy.**
  - **Speed**
  - **Cost**
  - **Volatility**





Caching

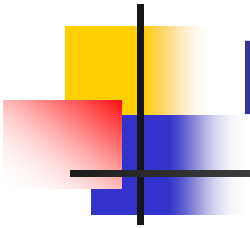
- **Use of high-speed memory to hold recently-accessed data.**
- **Requires a *cache management* policy.**
- **Cache Coherency ——this requires data that is simultaneously stored in more than one level to be *consistent*.**

I/O Structure

- I/O devices and the CPU can execute concurrently. *Why?*

This form of interrupt-driven I/O is fine for moving small amounts of data but can produce high overhead when used for bulk data movement such as disk I/O.

- CPU moves data from/to main memory to/from local buffers.
- Device controller informs CPU that it has finished its operation by causing an *interrupt*.

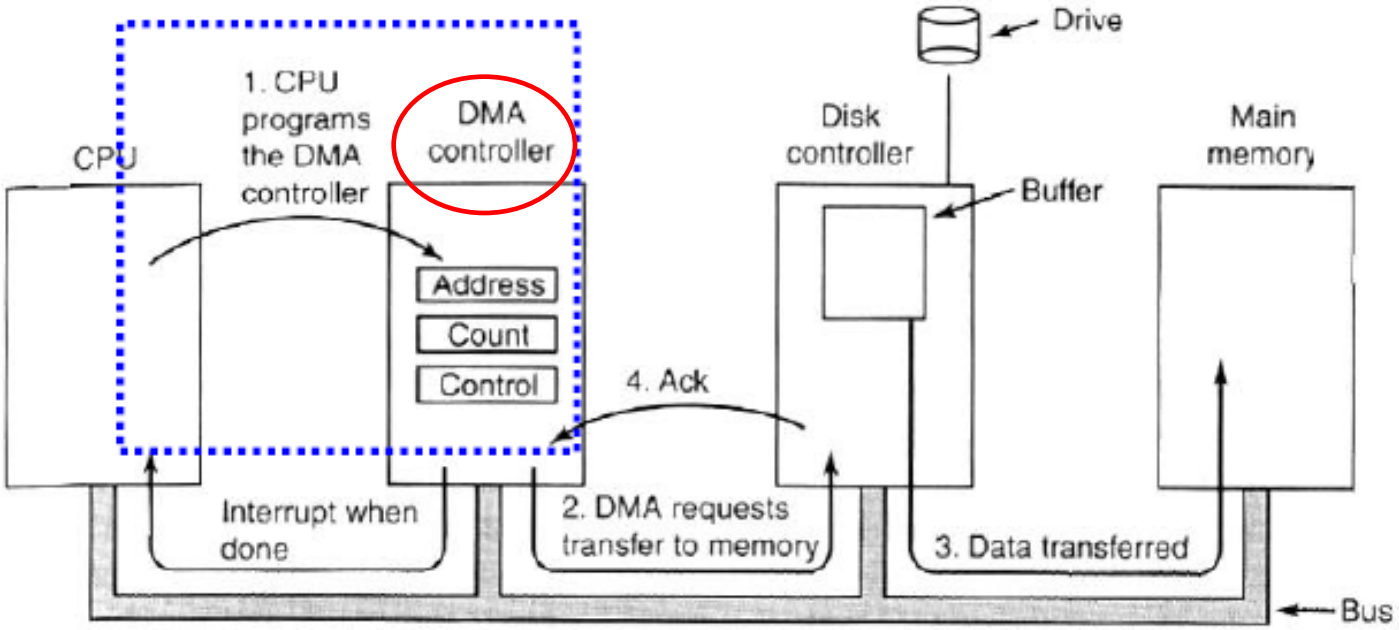


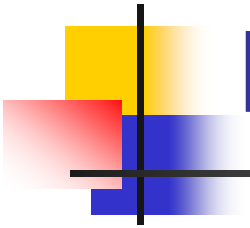
Direct Memory Access (DMA)

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

Direct Memory Access (DMA)

The CPU gives the controller (1) disk address, (2) memory address for storing the block, and (3) a byte count. Then, the CPU goes back to work.





Hardware Protection

- Dual-Mode Operation
- CPU Protection
- Memory Protection
- I/O Protection

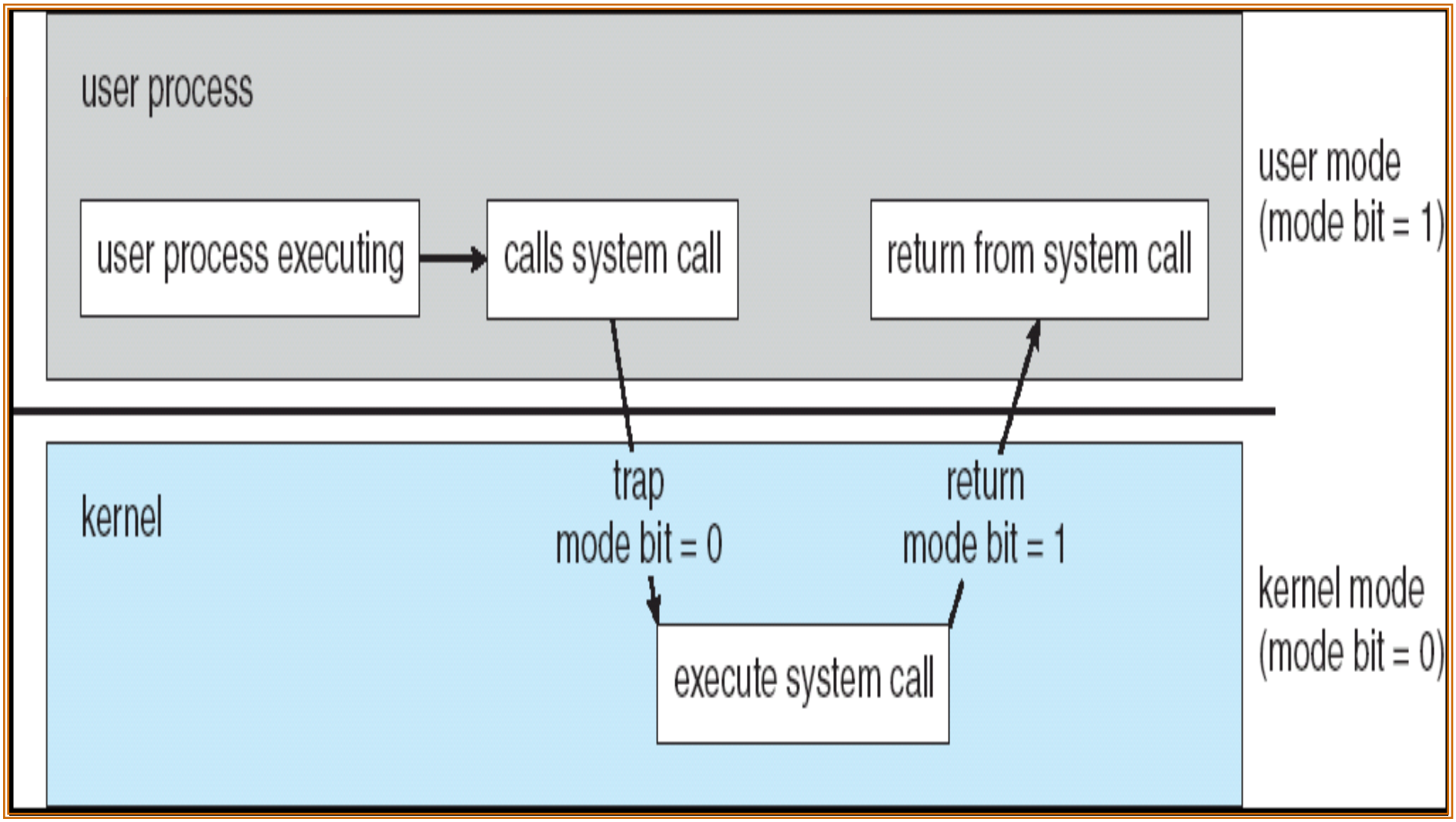
Dual-Mode Operation

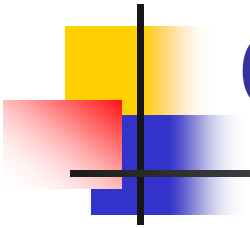
- **Sharing system resources requires operating system to ensure that an incorrect program cannot cause other programs to execute incorrectly.**
- **Provide hardware support to differentiate between at least two modes of operations.**
  - ***User mode*** **– execution done on behalf of a user.(用户态或目态)**
  - ***Kernel mode*** **(also *monitor mode* or *system mode*) – execution done on behalf of operating system. (核心态或管态)**

Dual-Mode Operation

- ***Mode bit*** **added to computer hardware to indicate the current mode: kernel (0) or user (1).**
- **When an interrupt or fault occurs, hardware switches from user mode to kernel mode.**
- **The dual mode of operation provides us with the means for protecting the operating system from errant user programs.**

Privileged Instruction ***——Some of the machine instructions that may cause harm and can be executed only in kernel mode.***


user process
user process executing
calls system call
return from system call
user mode
(mode bit = 1)
kernel
trap
mode bit = 0
return
mode bit = 1
execute system call
kernel mode
(mode bit = 0)



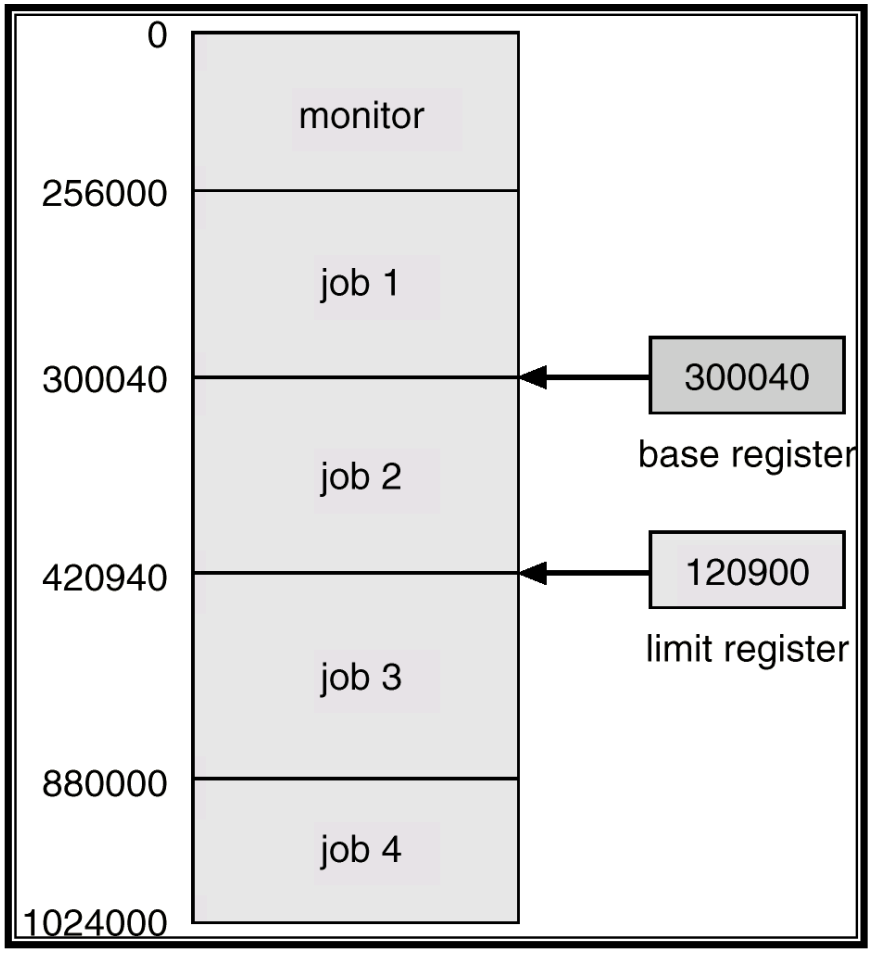
CPU Protection

- *Timer* – interrupts computer after specified period to ensure operating system maintains control.
  - Timer is decremented every clock tick.
  - When timer reaches the value 0, an interrupt occurs.
- Timer commonly used to implement time sharing.
- Timer also used to compute the current time.
- Load-timer is a privileged instruction.

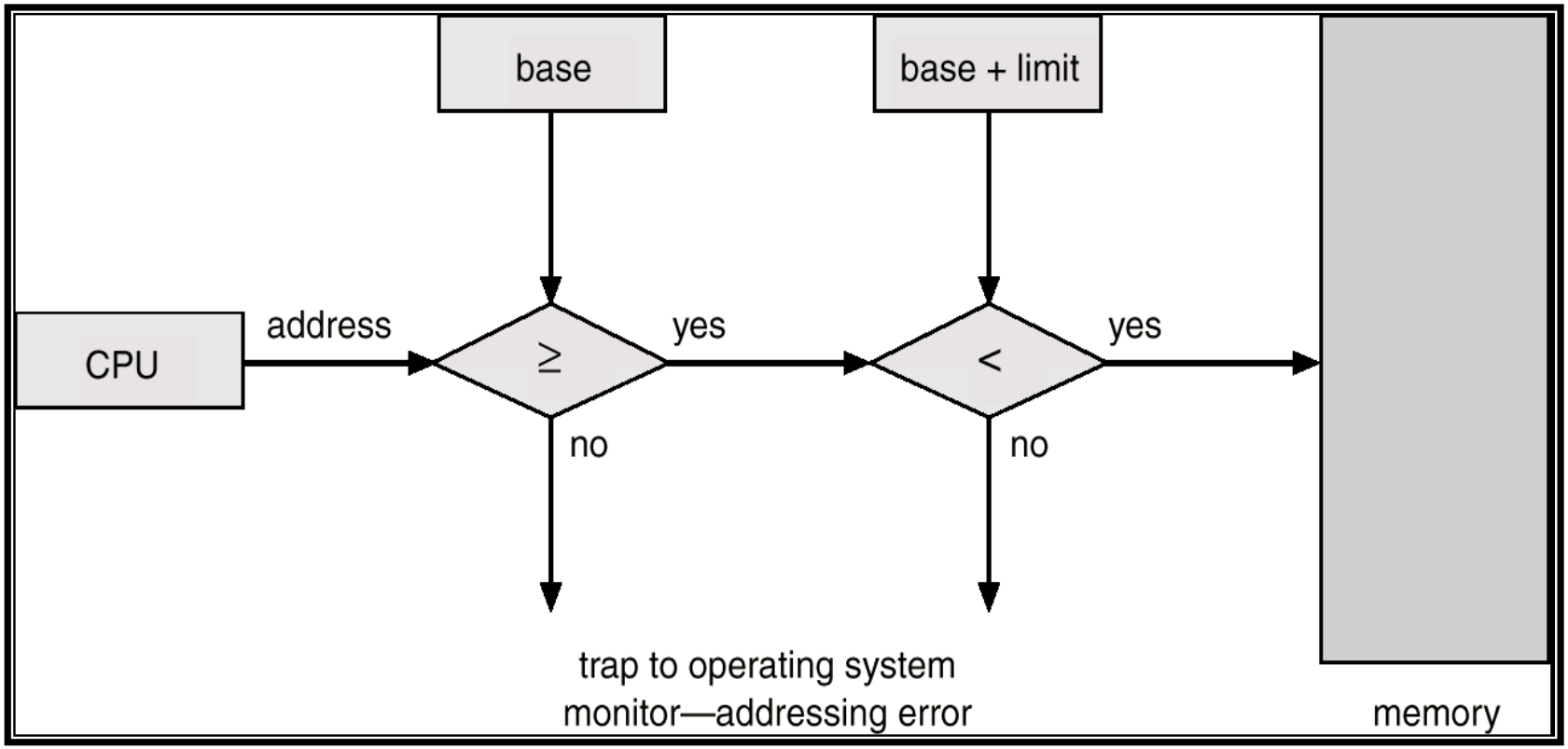
Memory Protection

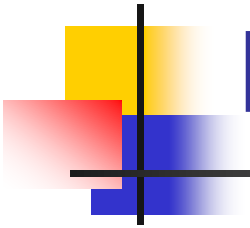
- Must provide memory protection at least for the interrupt vector and the interrupt service routines.
- In order to have memory protection, add two registers that determine the range of legal addresses a program may access
  - Base register（基址寄存器）– holds the smallest legal physical memory address.
  - Limit register（界限寄存器） – contains the size of the range
- Memory outside the defined range is protected.

Use of a Base and Limit Register



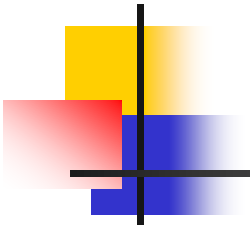
Memory Address Protection





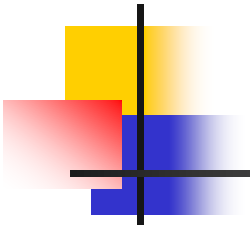
Memory Protection

- **When executing in kernel mode, the operating system has unrestricted access to both kernel and user's memory.**
- **The load instructions for the *base* and *limit* registers are privileged instructions.**



I/O Protection

- All I/O instructions are privileged instructions.
- Must ensure that a user program could never gain control of the computer in kernel mode (i.e., a user program that, as part of its execution, stores a new address in the interrupt vector).



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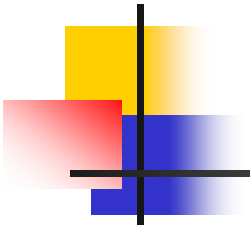
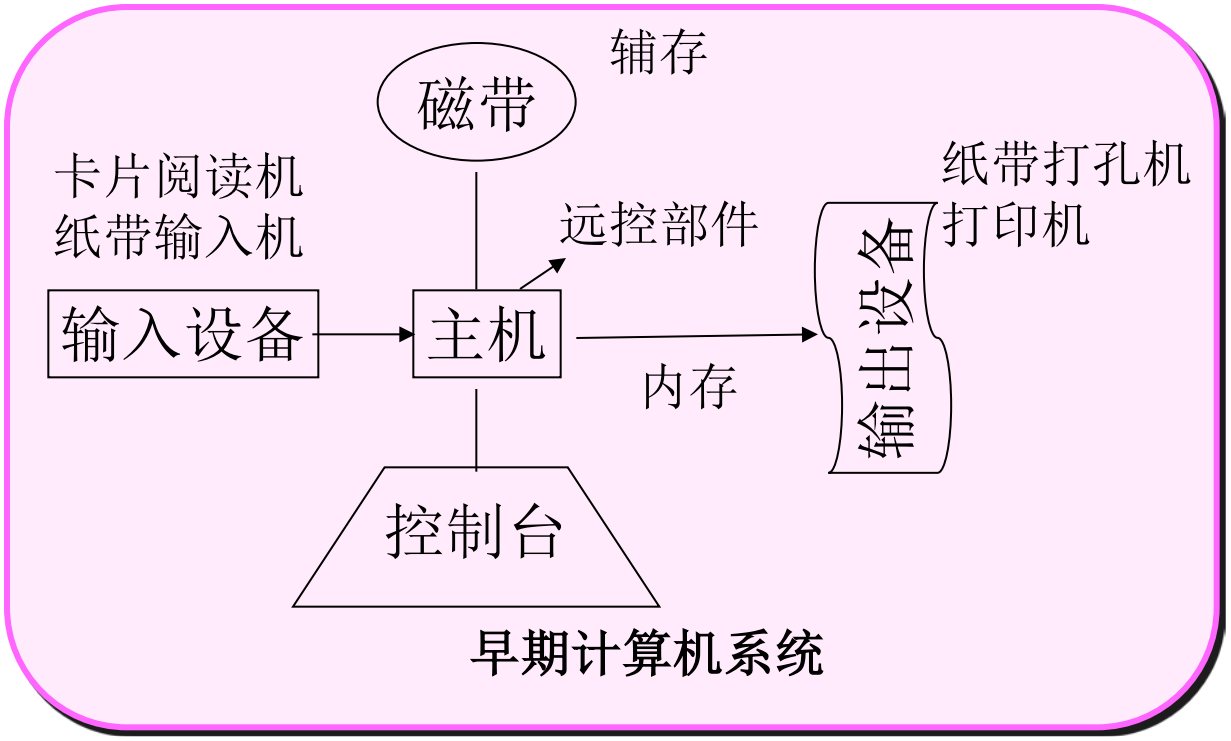


Development of OS

- Mainframe Systems
- Desktop Systems
- Multiprocessor Systems
- Distributed Systems
- Clustered Systems
- Real-Time Systems
- Handheld Systems

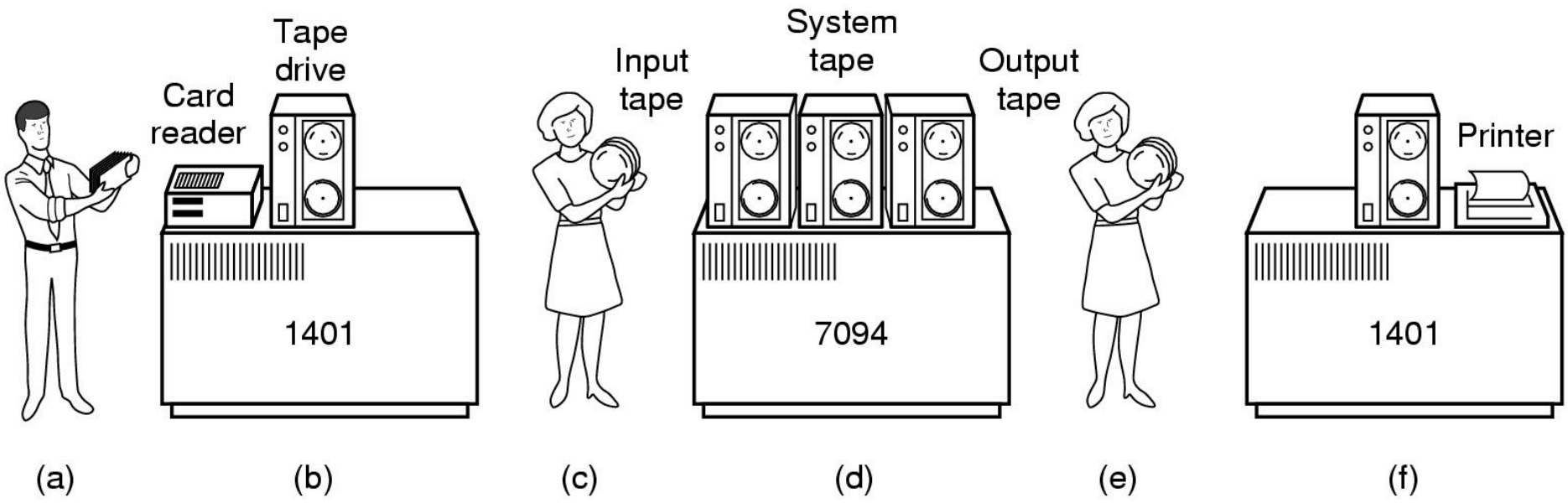
Mainframe Systems

No OS→Batch Systems→Multiprogramming Systems→Time Sharing Systems

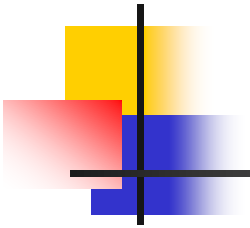


- 用户独占全机资源
- 程序运行前准备时间过长
- 人机速度不匹配

Batch Systems (1/2)



- bring cards to IBM 1401
- IBM 1401 read cards to tape
- put tape on IBM 7094 which does computing
- put tape on IBM 1401 which prints output

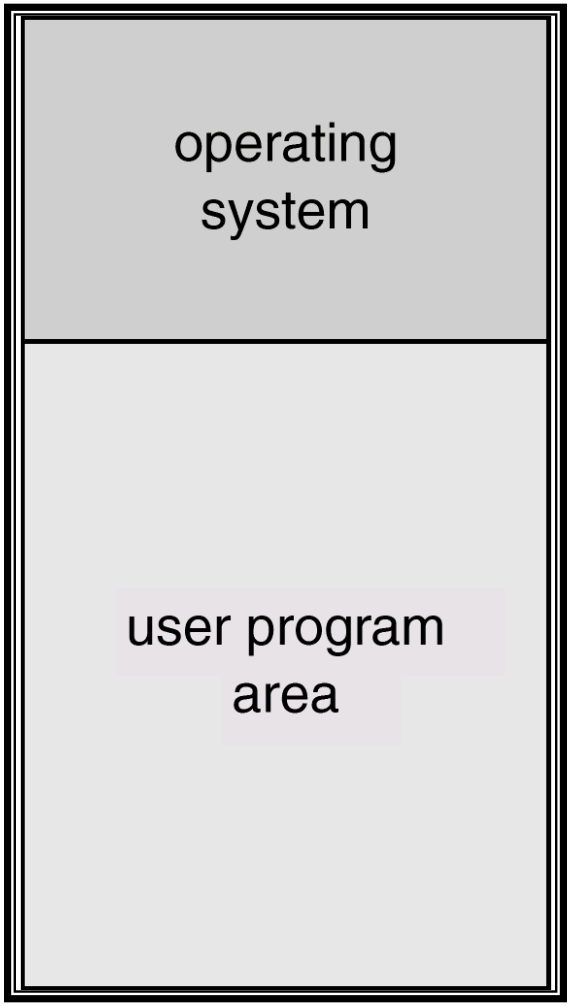


Batch Systems(2/2)

- Reduce setup time by batching similar jobs
- Automatic job sequencing – automatically transfers control from one job to another.
- Resident monitor
  - initial control in monitor
  - control transfers to job
  - when job completes control transfers back to monitor

First rudimentary operating system

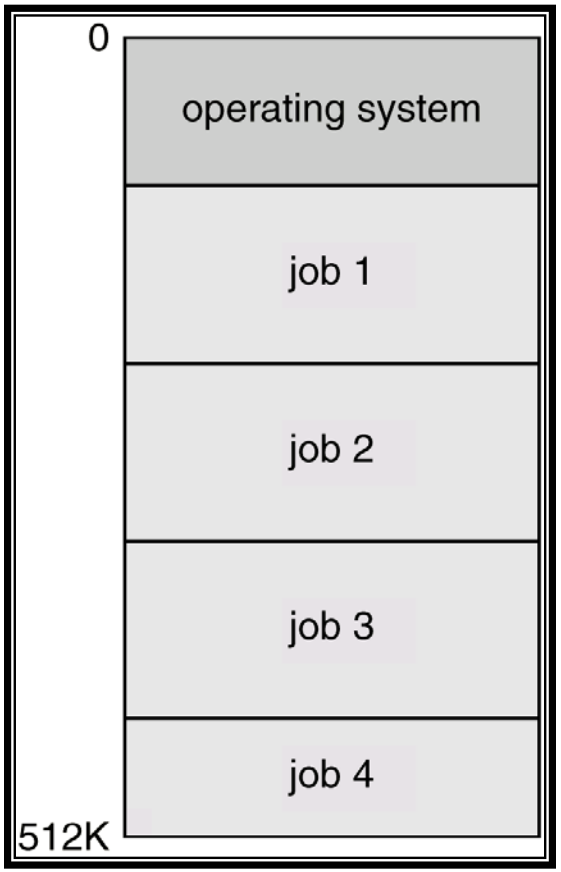
Memory Layout for a Simple Batch System



Multiprogramming Batch Systems

Several jobs are kept in main memory at the same time, and the CPU is multiplexed among them.

- **Keeps serval jobs in memory simultaneously**
- **Picks and begins to execute one**
- **If that job needs to wait, CPU is switched to another one**

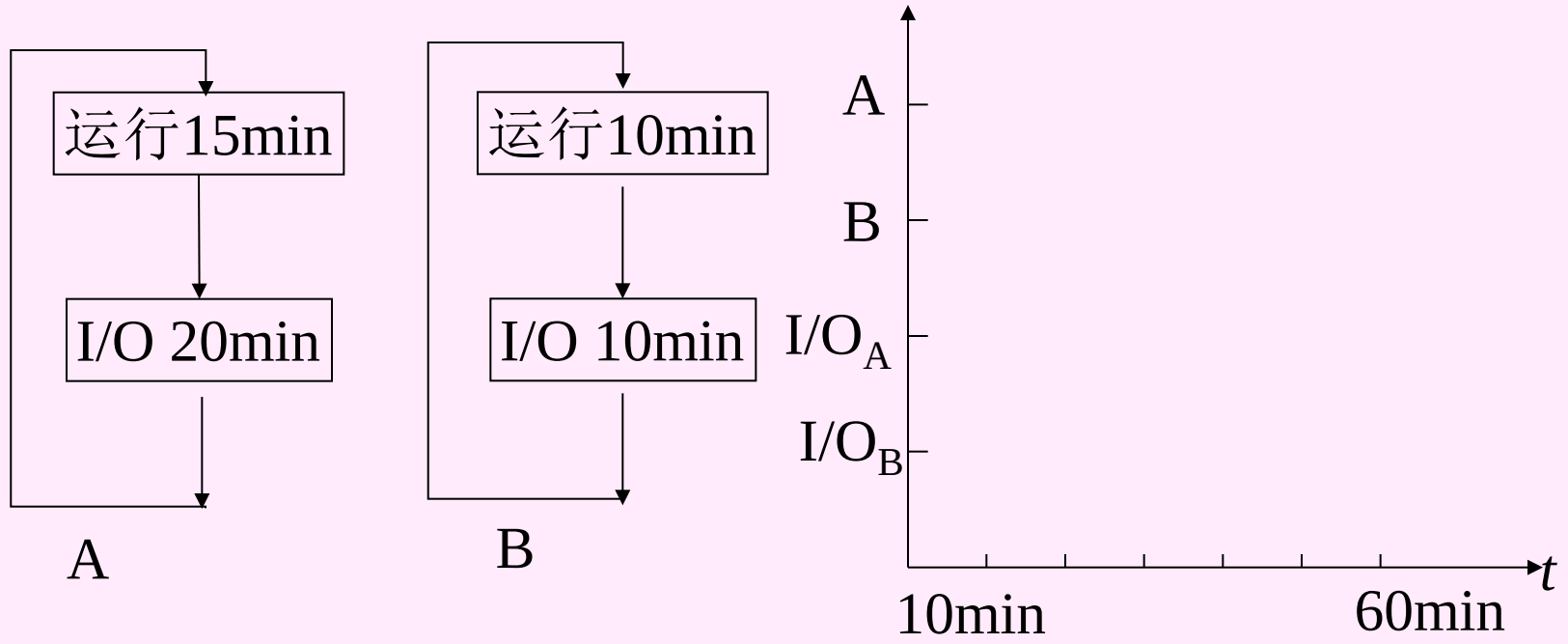


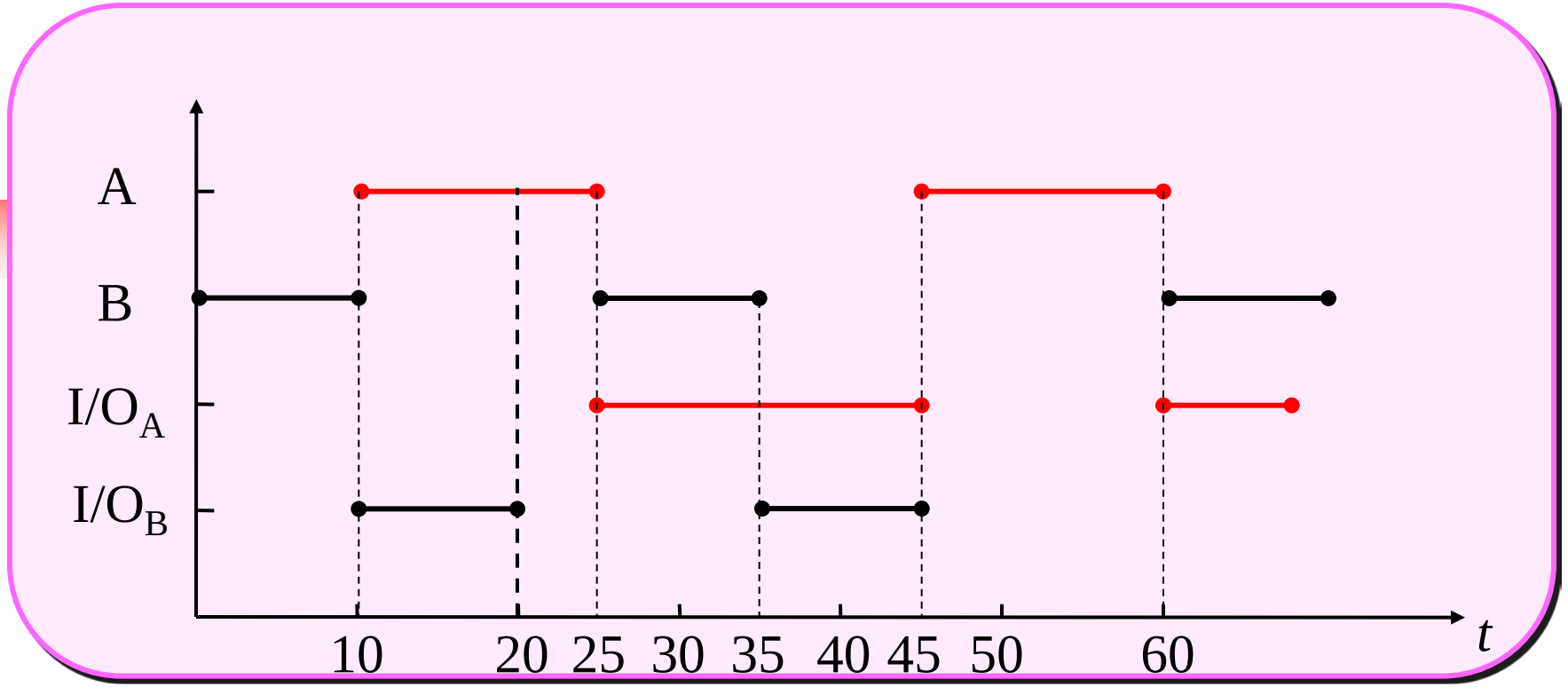
It's the first instance where the operating system must make decisions for the users

OS Features Needed for Multiprogramming

- **Memory management** – the system must allocate the memory to several jobs.
- **CPU scheduling** – the system must choose among several ready jobs to run.
- **Job scheduling** – the system must choose among ready jobs to be brought into memory.
- **I/O system management** – Allocation of devices and I/O routine supplied by the system.

例子： 有两道程序A、B，按下图以多道程序方式运行，要求在右图画出它们的运行轨迹，并计算在60min内CPU的利用率，假设起始时首先运行B，I/O_A和I/O_B不相同，并允许忽略监督程序切换A、B的时间。





$$P_{CPU} = \frac{60-(45-35)}{60} \times 100\% = \frac{50}{60} \times 100\% = 83.3\%$$

若在单道程序系统中， **CPU的利用率是多少？**

Advantages and disadvantages of multiprogramming

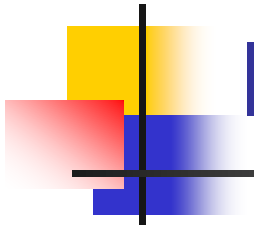
提高CPU的利用率，充分发挥并发性，这包括：程序之间、设备之间、设备与CPU之间均并发工作。

操作系统的特征：

并发性（Concurrence）、共享性（Sharing）、虚拟性（Virtual）、异步性（Asynchronism）

用户独占资源，无交互性，延迟大

Time-Sharing Systems–Interactive Computing（1/2）



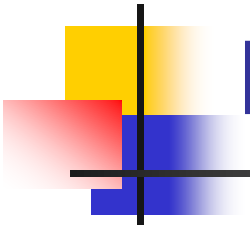
- **Time-sharing operating system allows many users to share the computer simulataneously**
  - **Switches rapidly from one user to the next**
  - **Gives users the impression: the entire computer system is dedicated for his use.**

Time-Sharing Systems–Interactive Computing（2/2）

- The CPU is multiplexed among several jobs that are kept in memory and on disk
- Sophisticated CPU-scheduling schemes are required for concurrent execution
- To obtain a reasonable response time, a job needs to be swapped in and out of memory to the disk (virtual memory).
- Disk management must be provided
- Job synchronization mechanisms are needed
- It may ensure that jobs do not get stuck in a deadlock

作业1

从技术发展的角度，简要介绍批处理系统、多道程序系统和分时系统各自的技术特性。（在该技术出现以前系统存在哪些问题，该技术是如何解决这些问题的）



Desktop Systems(1/2)

- **Personal Computers – computer system dedicated to a single user.**
- **I/O devices – keyboards, mouse, display screens, printers.**
- **User convenience and responsiveness.**

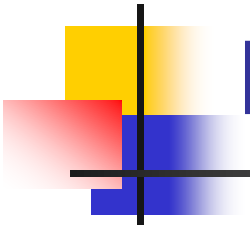
Desktop Systems(2/2)

- **Can adopt technology developed for larger**

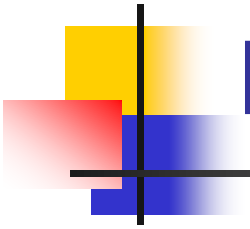
Single-Processor Systems:

there is one main CPU capable of executing a general-purpose instruction set.

Parallel Systems(1/2)

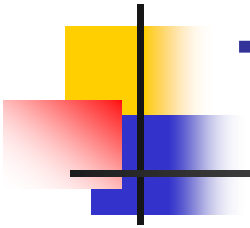


- **Multiprocessor systems with more than one CPU in close communication.**
- ***Tightly coupled system* – processors share the computer bus, memory and a clock; communication usually takes place through the shared memory.**



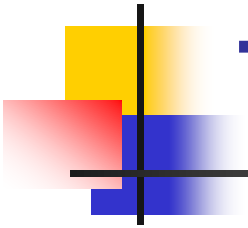
Parallel Systems (2/2)

- **Advantages of parallel system**
  - **Increased throughput: Gets more jobs done**
  - **Economy of scale: Because of resource sharing, multiprocessor systems is cheaper than multiple single processor systems**
  - **Increased reliability: the failure of one processor will not halt the whole system**



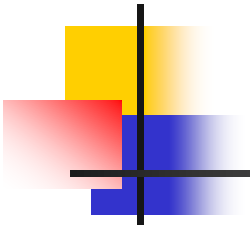
Types of Parallel Systems

- **Asymmetric multiprocessing**
  - **Each processor is assigned a specific task.**
  - **A master processor controls the system. The other processors either look to the master for instructions or have predefined tasks.**
  - **Thus, this defines a master-slave relationship**
  - **Master processor schedules and allocated work to slave processors.**
  - **More common in extremely large systems**



Types of Parallel Systems

- **Symmetric multiprocessing (SMP)**
  - **Each processor runs an identical copy of the operating system.**
  - **Many processes can run at once without performance deterioration.**
  - **Must carefully control I/O to ensure that the data reach the appropriate processor**
  - **May result in inefficiencies**
  - **Most modern operating systems support SMP**

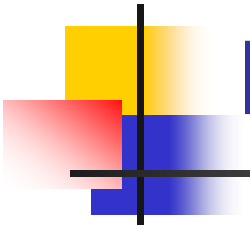


Distributed Systems (1/3)

- **Distribute the computation among several physical processors.**
- ***Loosely coupled system*** **– each processor has its own local memory; processors communicate with one another through various communications lines, such as high-speed buses or telephone lines.**

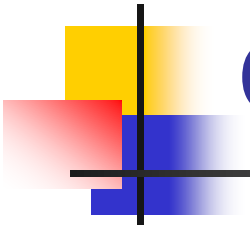
Distributed Systems (2/3)

- A distributed system is a collection of physically *separate*, possible *heterogeneous* computer systems that are *networked* to provide the users with access to the various resources that the system maintains
- Advantages of distributed systems.
  - Resources Sharing
  - Computation speed up – load sharing
  - Reliability
  - Communications



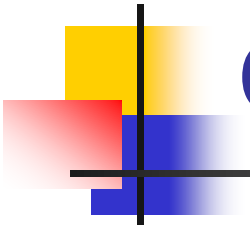
Distributed Systems (3/3)

- **Requires networking infrastructure.**
- **Local area networks (LAN) or Wide area networks (WAN).**
- **May be either client-server or peer-to-peer systems.**



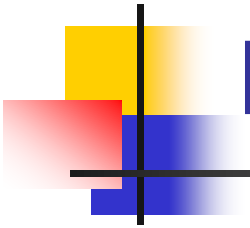
Clustered Systems (1/2)

- A clustered system has two or more individual systems shared storage and closely linked via LAN networking.
- The key of clustered system is high availability.



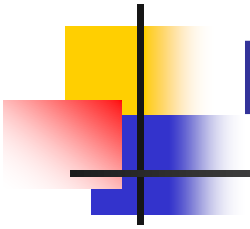
Clustered Systems (2/2)

- **Asymmetric Clustering**
  - **One machine is in hot-standby mode while others are running applications.**
  - **The hot-standby machine (*i.e.*, does nothing but) monitors other machines and becomes active if one server fails.**
- **Symmetric Clustering**
  - **Two or more hosts are running applications and monitor each other.**
  - **This is more efficient as it uses all available hardware**



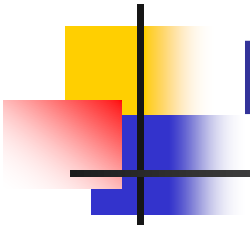
Real-Time Systems (1/3)

- **Often used as a control device in a dedicated application such as controlling scientific experiments, medical imaging systems, industrial control systems, and some display systems.**



Real-Time Systems (2/3)

- A real-time operating system has well-defined, fixed time constraints.
- Processing *must* be done within the defined constraints, or the system will fail.
- Embedded systems almost always run real-time operating systems



Real-Time Systems (3/3)

- **Real-Time systems may be either *hard* or *soft* real-time.**
  - ***Hard Real-Time Systems* guarantee that critical tasks be completed on time.**
  - ***Soft Real-Time Systems* prioritize critical tasks. That is, a critical task get priority over other tasks, and retains that priority until it completes.**

Handheld Systems

- Personal Digital Assistants (PDAs)
- Pocket-PC
- Cellular telephones
- Advantages
  - Convenience and Portability
- Issues
  - Limited memory
  - Slow processors
  - Small display screens