0117401: Operating System
计算机原理与设计

Chapter 1-2: CS Structure

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温馨提示：

为了您和他人的工作学习，
请在课堂上关机或静音。

不要在课堂上接打电话。

outline

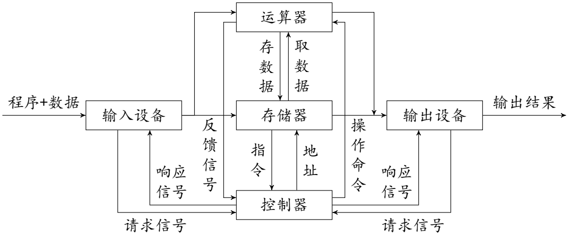
- Computer System Operation
  - A modern computer system
  - System boot
  - Interrupt
- I/O Structure
  - I/O Structure
  - I/O operation
  - DMA
- Storage Structure and Storage Hierarchy
  - Storage Structure
  - Storage hierarchy
- Hardware Protection
  - Hardware Protection
- General System Architecture
  - General System Architecture
  - system call
- Computing Environments
- 小结和作业

CS & Von Neumann architecture

- 计算机
  1. 不可编程的：强定制，高效
  2. 可编程的：灵活
     - 提供指令集，程序就是一个指令序列

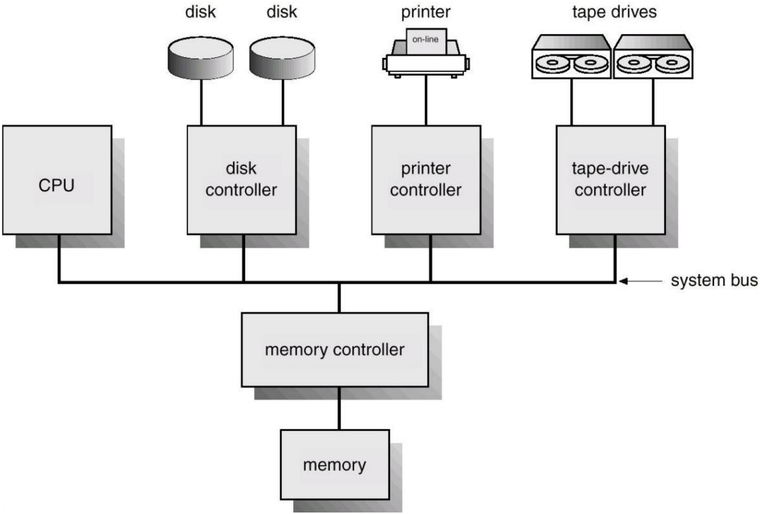
冯·诺伊曼体系结构

- 五大部件：运算器、控制器、存储器、I/O设备
- 存储器与CPU相分离；指令存储与数据存储共享存储器

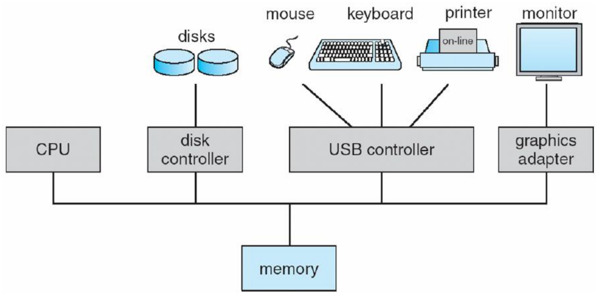


Outline

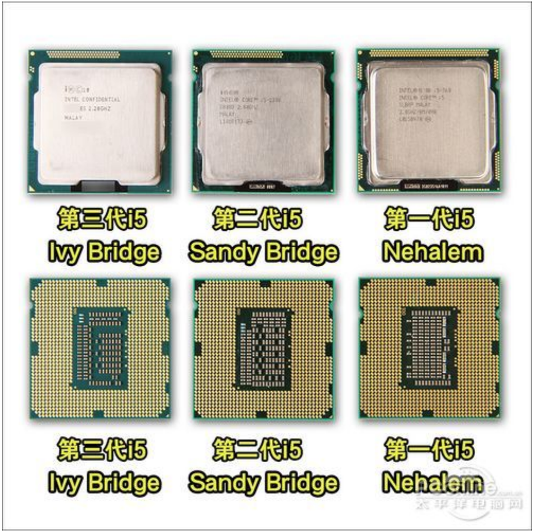
A modern computer system I



A modern computer system II

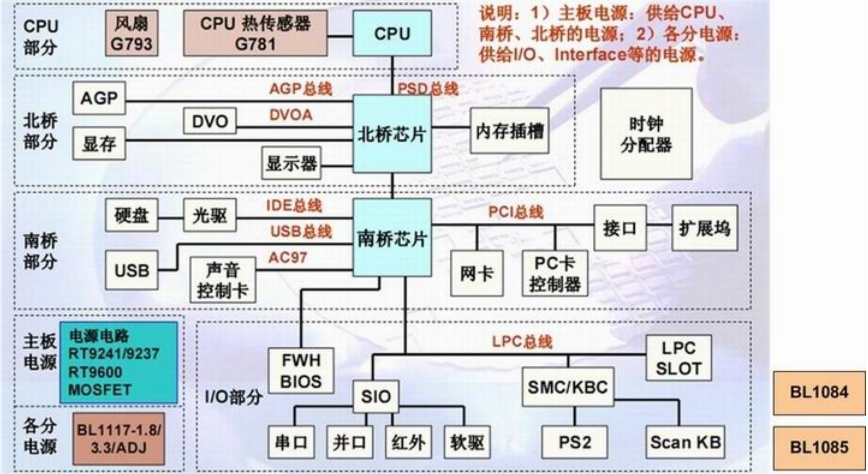


参考：三款core i5 CPU芯片外观比较



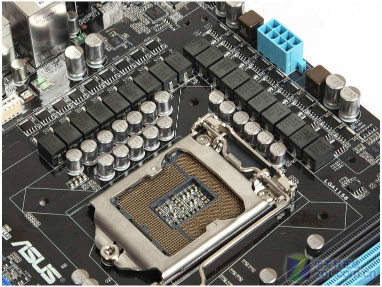
From: VB先睹為快！Intel三代Core i5搶先評測

参考：一个电脑主板芯片应用方案



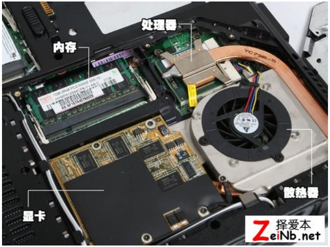
仅用作参考示意。From: http://www.chinesechip.com/news_4/ec3c0dbbed7f458cb7d06c012c86cc44.html

参考：华硕的一款主板



From: 中关村在线 华硕P7P55D Deluxe

参考：华硕F8H笔记本拆解



From：华硕F8H系列笔记本评测

Outline

System boot

- Booting the system: the procedure of starting a computer by loading the OS
- Bootstrap program or bootstrap loader: a small piece of code
  - Loaded at power-up or reboot
  - Typically stored in ROM or EPROM, generally known as firmware(固件)
  - initializes hardware
    - CPU registers, device controllers, memory content
  - Locate the OS, load at least a part of the OS into main memory & start executing it
- Platform dependent(平台相关/体系结构相关)
- Some use two-step process: a simple bootstrap loader fetches a more complex boot program from disk, which in turn loads the OS
- Some systems store the entire OS in ROM

Example: Linux system startup

typical operating sytems startup course

Power-on→Bootstrap: BIOS→BootLoader: GRUB→OS: Linux

Linux (Intel i386)

Refer to appendix A of 《Understanding Linux Kernel》

- →RESET pin of the CPU
- cs:ip= 0xFFFF FFF0
- ROM BIOS (基本输入输出系统)

Example: Linux system startup (cont.)

BIOS（基本输入输出系统）

Basic I/O System (BIOS) : A set of programs stored in ROM, including

- Several interrupt-driven low-level procedures
- A bootstrap procedure, who
  - POST (Power On Self-Test)
  - Initializes hardware device
  - Searches for an OS to boot
    - Master Boot Record(MBR) on Hard drive, Boot Sector on floppy disk, network
  - Copies the first sector of the OS into RAM 0x0000 7C00, and jumps & executes

Example: Linux system startup (cont.)

Master Boot Record, MBR, 主引导记录

- the first sector on a hard drive, a special type of boot sector
- MBR = MBR code (also called boot loader) + partition table
  - MBR code: code necessary to startup the OS
  - typical boot loader: GRUB

Example: Linux system startup (cont.)

Master Boot Record, MBR, 主引导记录

Structure of a classical generic MBR

Address		Description		Size in bytes
Hex	Dec			
+000h	+0	Bootstrap code area		446
+1BEh	+446	Partition entry #1	Partition table (for primary partitions)	16
+1CEh	+462	Partition entry #2		16
+1DEh	+478	Partition entry #3		16
+1EEh	+494	Partition entry #4		16
+1FEh	+510	55h	Boot signature	2
+1FFh	+511	AAh		
Total size: 446 + 4*6 + 2				512

??? After starts up

- Executes prearranged process, or
- Waits for interrupt

Modern OSs are interrupt-driven（中断驱动的）.

Outline

Computer System Operation

- A modern computer system
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- Interrupt

I/O Structure

- I/O Structure
- I/O operation
- DMA

Storage Structure and Storage Hierarchy

- Storage Structure
- Storage hierarchy

Hardware Protection

- Hardware Protection

General System Architecture

- General System Architecture
- system call

Computing Environments

小结和作业

Interrupt I

Interrupt represents an event to be handled

For hardware: Device interrupt

- The completion of an I/O operation
- a key stroke or a mouse move
- timer
- ...

For error (also hardware): exception

1. Trap for debug
2. Fault
   - example: page fault, division by zero, invalid memory access
3. Abort, a serious error

For software: System call

Interrupt II

- To request for some operating-system service
  - Linux: INT 0x80
  - MS/DOS, windows: INT 0x21

Modern OSs are interrupt-driven（中断驱动的）

Interrupt handling I

When the CPU is interrupted

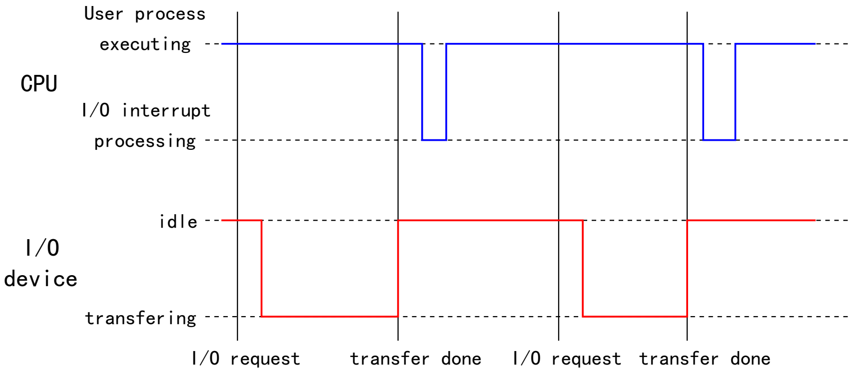
1. Stops what it is doing
2. Incoming interrupts are disabled to prevent a lost interrupt
3. Transfers control to the ISR (Interrupt Service Routine, 中断服务例程)
   - ISR: A generic routine in fixed location and then call the interrupt-specific handler
   - interrupt vector table (中断向量表)

When the ISR completed,
Back to interrupted program

Interrupt handling II

- HOW ?
  —— OS preserves the state of the CPU by storing registers and the program counter.
  also called context（上下文，硬件上下文）.
  - Old: Fixed location, or a location indexed by the device number
  - Recent: system stack（Linux: 内核态栈）

Interrupt time line for a single process doing output

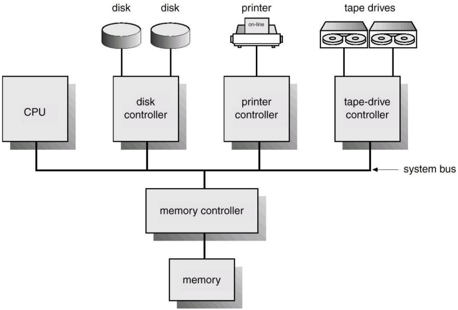


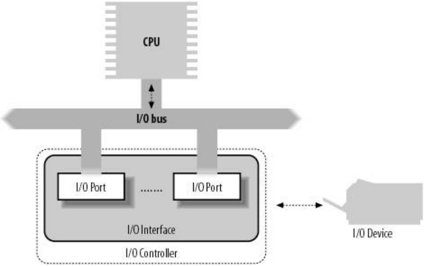
Example: interrupts in I386

- protect mode （保护模式）
  - IDT （Interrupt Descriptor Table,中断描述符表）
  - OS填写IDT表，包括每个中断处理例程的入口地址等信息
  - 中断发生的时候，CPU根据从中断控制器获得的中断向量号在IDT表中
    索引到对应的中断处理例程（ISR）入口地址，并跳转过去运行
    - 保存上下文
    - 处理中断
    - 恢复上下文

Outline

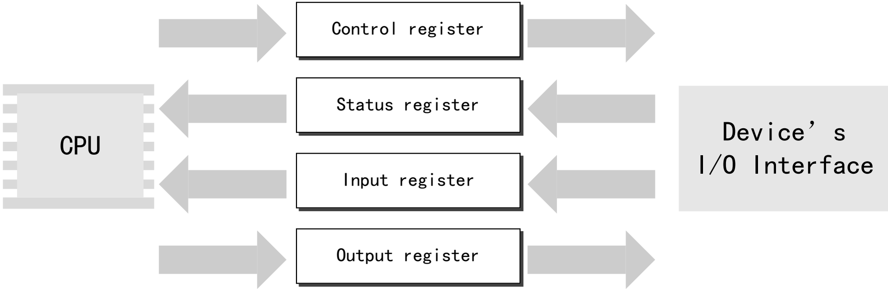
I/O structure





I/O structure

- Each device controller is in charge of a particular device type
- Each device controller has
  - a local buffer & a set of special-purpose registers
- Data transfer, two phrase
  - Main memory $\leftarrow$(CPU)$\rightarrow$ local buffer of controller
  - device $\leftarrow$(device controller)$\rightarrow$ local buffer
- I/O devices & CPU can execute concurrently（并发地）
  - Share/compete memory cycle
  - Memory controller


CPU
Control register
Status register
Input register
Output register
Device’ s
I/O Interface

Outline

I/O operation

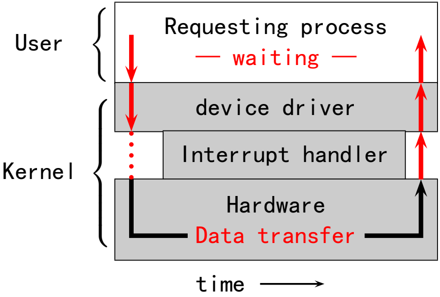
- CPU start an I/O operation by
  - Loading the appropriate registers within the device controller
  - When complete, device controller informs CPU by
    - Triggering an interrupt, or
    - Simply set a flag in one of their registers
- Two I/O methods
  - synchronous VS. asynchronous

I/O method —— analysis

1. Synchronous(同步)

- Waiting
  - Wait instruction
  - Dead loop like

    Loop: jmp Loop



- At most one I/O request is outstanding at a time
  - Advantage: always knows exactly which device is interrupting
  - Disadvantage: excludes concurrent I/O operations & the possibility of overlapping useful computation with I/O

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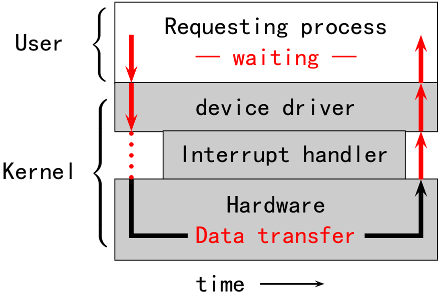

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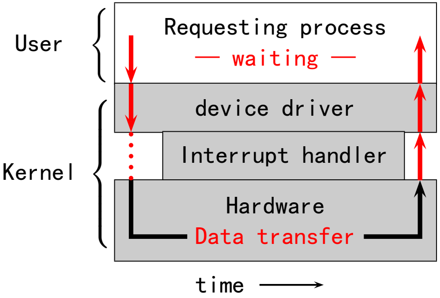

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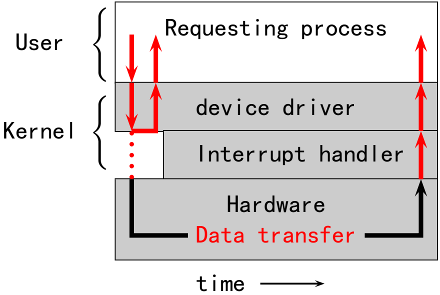
I/O method —— analysis (cont.)

2. Asynchronous(异步)

- Start & cont.
  - with a wait system call
  - os execute other programs, or, if no other program, idle



- Need to keep track of many I/O request
  1. Device-status table, 设备状态表
  2. A wait queue for each device
  3. When an interrupt occurs, OS indexes into I/O device table to determine device status and to modify table entry to reflect the occurrence of interrupt
- Main advantage: system efficiency↑

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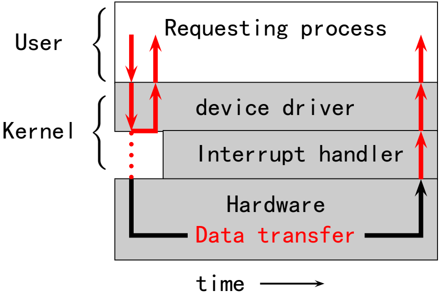

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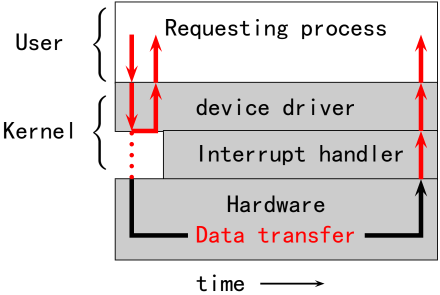

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I/O method —— analysis (cont.)

2. Asynchronous(异步)

- Need to keep track of many I/O request, HOW?
  1. Device-status table, 设备状态表
     - Each device: an device entry;
     - Each entry: Device type, address, state(not work, idle/valid, or busy)
  2. A wait queue for each device
  3. When an interrupt occurs, OS indexes into I/O device table to determine device status and to modify table entry to reflect the occurrence of interrupt
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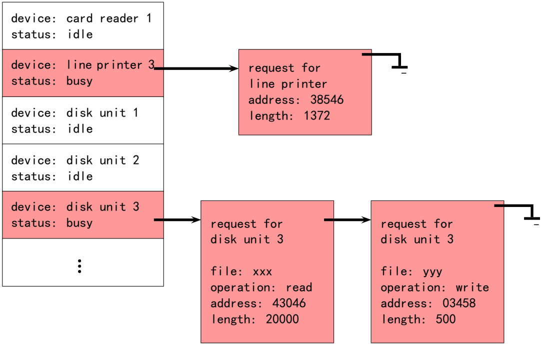

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Outline

Direct Memory Access (DMA)

Example1: 9600-baud terminal

- 2us(ISR) per 1000us
- It’s ok!

Example2: hard disk

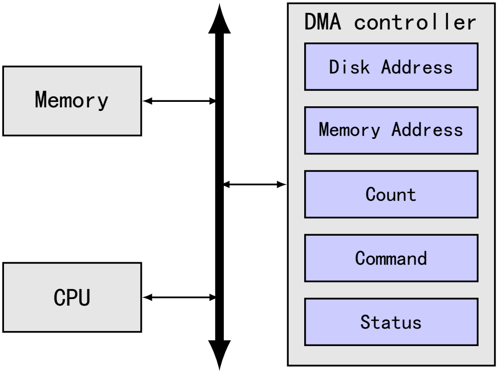
- 2us(ISR) per 4us
- The overhead (per byte) is relatively costly!

DMA (Direct Memory Access, 直接内存访问)

- Used for high-speed I/O devices able to transmit information at close to memory speeds.

DMA structure

One interrupt / block of data



CPU:

fetch instruction
decode
fetch operand
operate

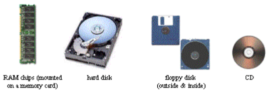
Device controller

- transfers between buffer and main memory directly, without CPU intervention.
- Memory cycle stealing

Outline

Storage structure

- Von Neumann architecture VS. Harvard architecture
  - Separated data & code in different memory???
- Main memory (RAM) is the only large storage media that the CPU can access directly
  - Small, Volatile
- Secondary storage is an extension of main memory that provides large nonvolatile storage capacity
  - Magnetic disk, 磁盘
  - Optical disk, 光盘
  - Magnetic tape, 磁带



Memory vs. registers

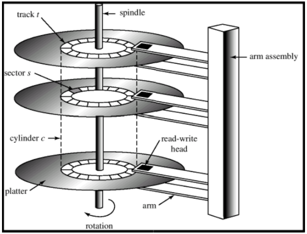
Memory VS. registers

- Same: Access directly for CPU
  - Register name
  - Memory address
- Different: access speed
  - Register, one cycle of the CPU clock
  - Memory, Many cycles (2 or more)
- Disadvantage:
  - CPU needs to stall frequently & this is intolerable
- Remedy : cache, 高速缓存

Magnetic disks

- Magnetic disks – rigid metal or glass platters covered with magnetic recording material
  - Disk surface is logically divided into tracks(磁道), which are subdivided into sectors(扇区).
  - The disk controller determines the logical interaction between the device and the computer.

- Position(定位) time T_p
- Transfer(传输) time T_T
- T_T VS. T_p
  - Please Store data closely



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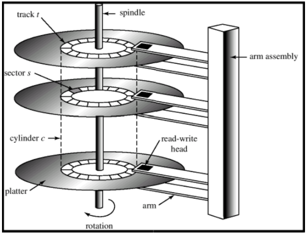
- Position(定位) time T_p
  - $T_p \approx T_s + T_R \approx$ mms
  - Seek time T_s
  - Rotational latency T_R
- Transfer(传输) time T_T
- T_T VS. T_p
  - Please Store data closely



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- Position(定位) time T_p
- Transfer(传输) time T_T
  - $T_T \approx \text{data size} \times \text{Transfer rate}$
  - $\text{Transfer rate} \approx (n\,M/s)^{-1} \approx (n \text{ Byte}/us)^{-1} \approx 1/n \text{ us}/\text{Byte}$
- T_T VS. T_p
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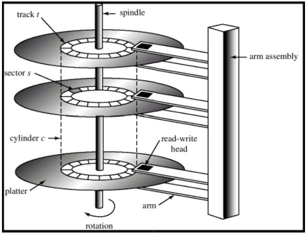

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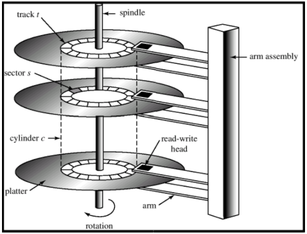
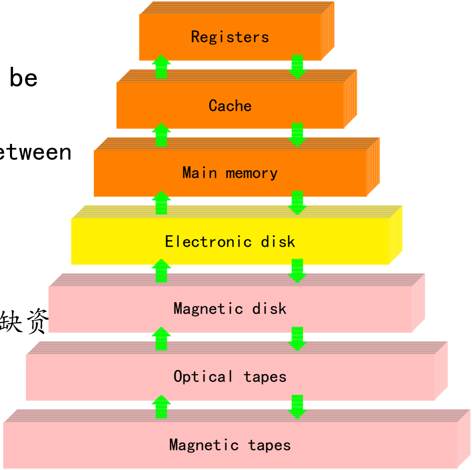


Outline

Storage hierarchy, 存储的层次

- Storage systems in a CS can be organized in a hierarchy.
  1. The contradiction(矛盾) between COST, SPEED, and CAPACITY.
  2. COST per bit.
  3. Volatility (易失性) VS. persistence (持久性).
- MM is a scarce resource (稀缺资源).



Caching

- Caching (高速缓存技术)
  - Copying information into faster storage system
  - When accessing, first check in the cache,
    - if In: use it directly
    - Not in: get from upper storage system, and leave a copy in the cache
- Using of caching
  - Registers provide a high-speed cache for main memory
  - Instruction cache & data cache
  - Main memory can be viewed as a fast cache for secondary storage
  - ...

Cache management

- Design problem
  - Hardware or software?
  - Cache size & Replacement policy is important
  - Hit rate $\approx$ 80%~99% is OK!

Memory Wall

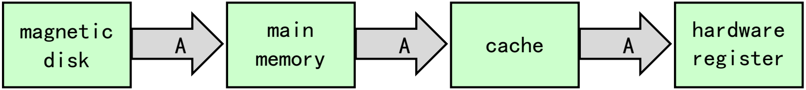
Memory Wall, 内存墙

- the growing disparity of speed between CPU and memory outside the CPU chip[1].
  - From 1986 to 2000, CPU speed improved at an annual rate of 55% while memory speed only improved at 10%.
  - Trend: memory latency would become an overwhelming bottleneck in computer performance

[1] From Wikipedia: Random-access memory

Coherency and consistency

- Multitasking environments must be careful to use most recent value, no matter where it is stored in the storage hierarchy
- Migration of Integer A from Disk to Register



- The same data may appear in different level of the storage system
- When
  - Simple batch system, no problem
  - Multitasking, always obtain the most recently updated value
  - Multiprocessor, cache coherency (always implicit to OS)
  - Distributed system?

Performance of Various Levels of Storage

- Movement between levels of storage hierarchy can be explicit or implicit

Level	1	2	3	4
Name	registers	cache	main memory	disk storage
Typical size	<1KB	>16MB	>16GB	>100GB
Implementation technology	custom memory with multiple ports, CMOS	on-chip or off-chip CMOS SRAM	CMOS DRAM	magnetic disk
Access time (ns)	0.25 - 0.5	0.5 - 25	80 - 250	5,000.000
Bandwidth (MB/sec)	20,000 - 100,000	5000 - 10,000	1000 - 5000	20 - 150
Managed by	compiler	hardware	OS	OS
Backed by	cache	main memory	disk	CD or tape

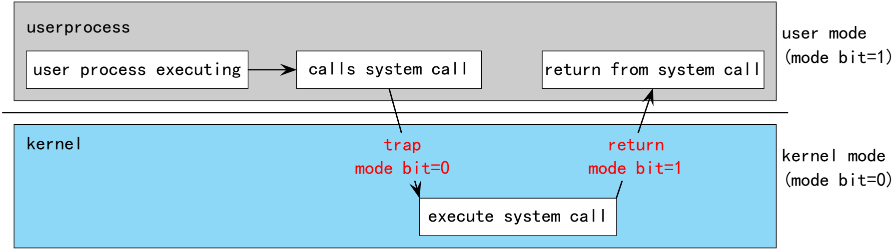
Outline

Hardware protection

- A properly designed OS must ensure that an incorrect (or malicious) program cannot cause other programs to execute incorrectly.
  1. When in dead loop
  2. When sharing recourses
  3. When one erroneous program might modify the program or data of another program, or even the OS
- Hardware must provide protection
  1. Dual-Mode Operation
  2. I/O protection
  3. Memory protection
  4. CPU protection

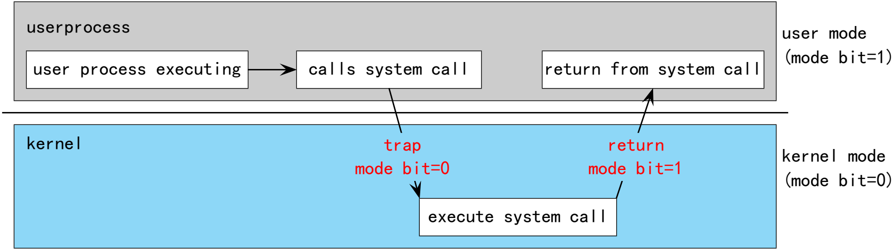
Hardware protection 1: Dual-Mode Operation（双操作模式）

- Using mode bit to provide different modes of execution
  - mode bit=1≡User mode（用户模式）: execution done on behalf of user
  - mode bit=0≡privileged mode（特权模式）, also called monitor mode（监督程序模式）/supervisor mode（管理模式）/system mode（系统模式）: execution done on behalf of OS
    - Privileged instructions



Hardware protection 1: Dual-Mode Operation（双操作模式）

- User program VS. OS (or Kernel)
  - Switch between user mode (1) and privileged mode(0)
    - Boot: from privileged mode.
    - User program: user mode.
    - Interrupt (include system call): switch to privileged mode.
    - OS: privileged mode



- Example: i386
  - 4 modes (2 mode bits)
  - Linux uses 2 mode (00b & 11b)

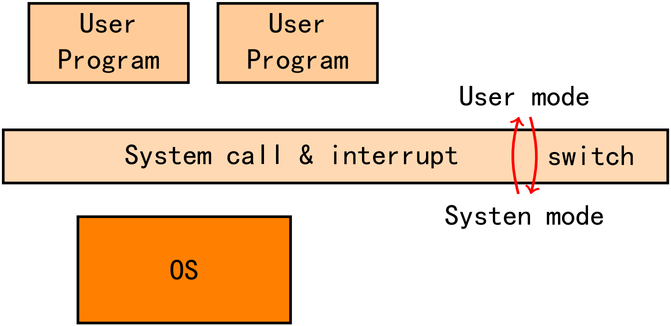
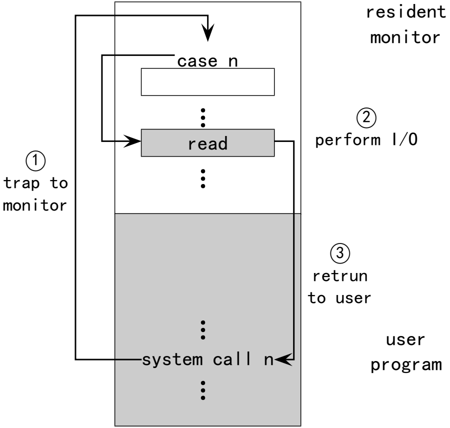


Figure: Linux uses two modes

Hardware protection 2: I/O protection

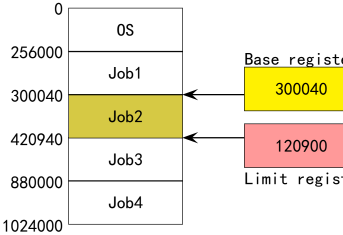
- Preventing the users from issuing illegal I/O instructions
- All I/O instructions are privileged instructions
  - instead of performing I/O operation directly, user program must make a system call
  - OS, executing in monitor mode, checks validity of request and does the I/O
  - input is returned to the program by the OS
- Smart hacker may···
  - Stores in the interrupt vector a new address, which points to a malicious routine
  - The I/O protection is compromised
  - We need some more protection···

Use of a system all to perform I/O



Hardware protection 3: Memory protection

- At least for interrupt vector and the ISR
- Base register protection scheme
  - Base register+Limit register
  - Memory outside is protected
  - OS has unrestricted access to both monitor and user's memory
  - Load instructions for the base/limit regis



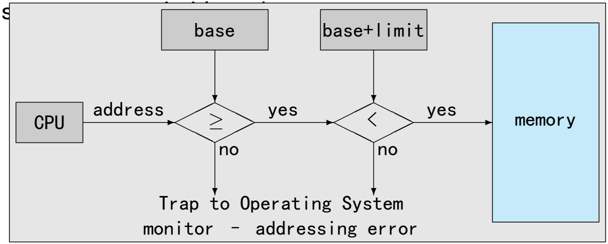


Figure: Hardware address protection with base and limit registers

Hardware protection 4: CPU protection

- OS should be always take control of everything
  - What if a user program is in dead loop?
- Timer
  - Interrupts computer after specified period
  - Periodically or one-shot
  - Load-timer is also a privileged instruction
- Usage
  - Time sharing
  - Compute current time
  - Alarm or timer

Timer to prevent infinite loop / process hogging resources

- Set interrupt after specific period
- Operating system decrements counter
- When counter zero generate an interrupt
- Set up before scheduling process to regain control or terminate program that exceeds allotted time

Outline

General system architecture

- multiprogramming
- time sharing
- OS: in kernel (privileged) mode
  - control hardware & software resource
  - execute privileged instruction
  - system call

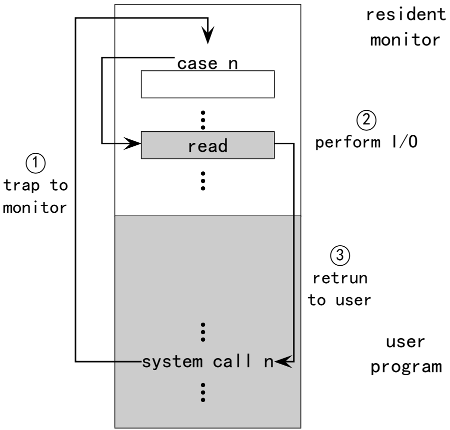
Outline

system call

System call—like a common function call, but totally different!

- Trap to a specific location in interrupt vector
  - int (i386)
  - trap (SUN SPARC)
  - syscall (MIPS R2000)
- Control passes to a service routine in the OS, and the mode bit is set to monitor mode
- The kernel
  - Verifies that the parameters are correct and legal
  - Executes the request
  - Returns control to the instruction following the system call

Use of a system all to perform I/O

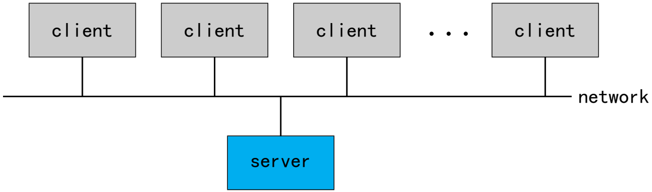


Computing Environments

- Traditional computer
  - 随计算机的发展而变化
  - Office environment
    - PCs connected to a network, terminals attached to mainframe or minicomputers providing batch and timesharing
    - Now portals allowing networked and remote systems access to same resources
  - Home networks
    - Used to be single system, then modems
    - Now firewalled, networked

Computing Environments

- Client-Server Computing
  - Dumb terminals supplanted by smart PCs
  - Many systems now servers, responding to requests generated by clients
    - Compute-server provides an interface to client to request services (i.e. database)
    - File-server provides interface for clients to store and retrieve files



Computing Environments

- 其他
  - Peer-to-Peer Computing
  - Web-Based Computing
  - Grid Computing
  - Cloud Computing
  - 普适计算Pervasive/Ubiquitous Computing

小结

- Computer System Operation
  - A modern computer system
  - System boot
  - Interrupt
- I/O Structure
  - I/O Structure
  - I/O operation
  - DMA
- Storage Structure and Storage Hierarchy
  - Storage Structure
  - Storage hierarchy
- Hardware Protection
  - Hardware Protection
- General System Architecture
  - General System Architecture
  - system call
- Computing Environments
- 小结和作业

谢谢！