BUCKNELL UNIVERSITY
Computer Science

CSCI 315 Operating Systems Design

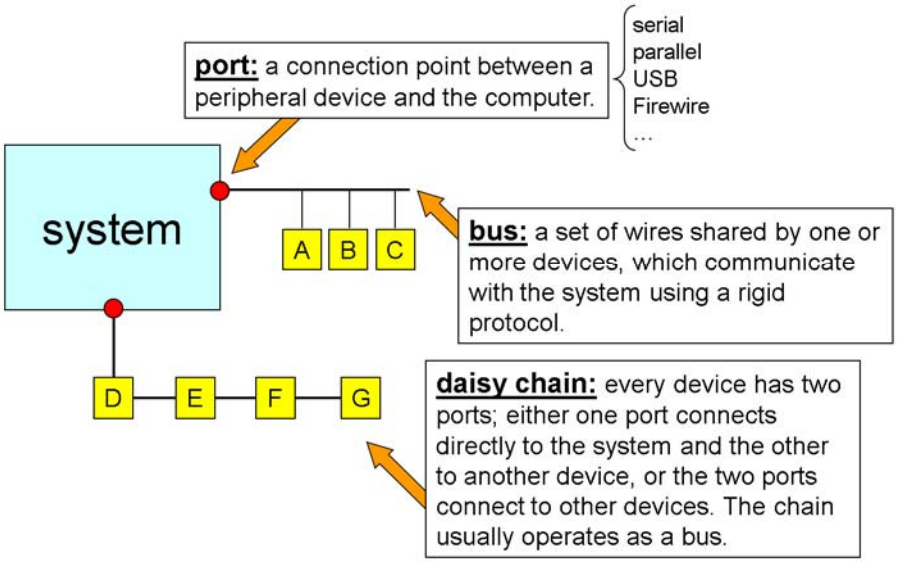
I/O Systems

Notice: The slides for this lecture have been largely based on those accompanying an earlier edition of the course text *Operating Systems Concepts with Java*, by Silberschatz, Galvin, and Gagne. Many, if not all, of the illustrations contained in this presentation come from this source.

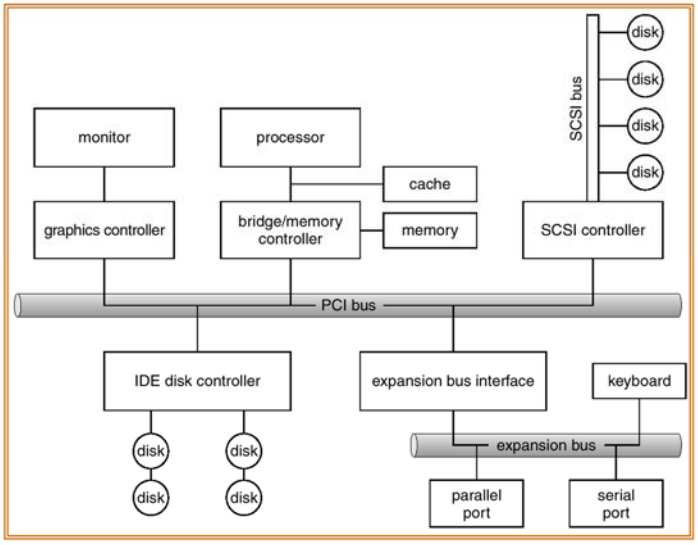
I/O Hardware

- Incredible variety of I/O devices.
- Common concepts:
  - Port,
  - Bus (daisy chain or shared direct access),
  - Controller (host adapter).
- I/O instructions control devices.
- Devices have addresses, used by
  - Direct I/O instructions,
  - Memory-mapped I/O.

Concepts

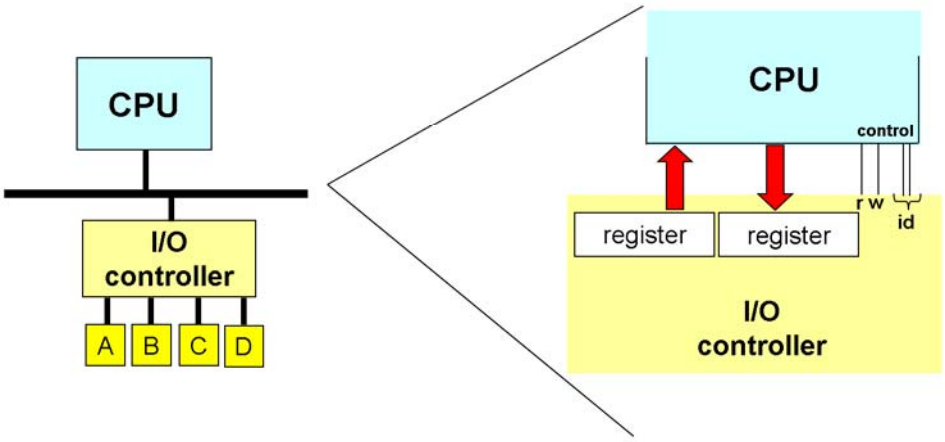

port: a connection point between a peripheral device and the computer.
serial
parallel
USB
Firewire
…
system
A
B
C
bus: a set of wires shared by one or more devices, which communicate with the system using a rigid protocol.
D
E
F
G
daisy chain: every device has two ports; either one port connects directly to the system and the other to another device, or the two ports connect to other devices. The chain usually operates as a bus.

A Typical PC Bus Structure



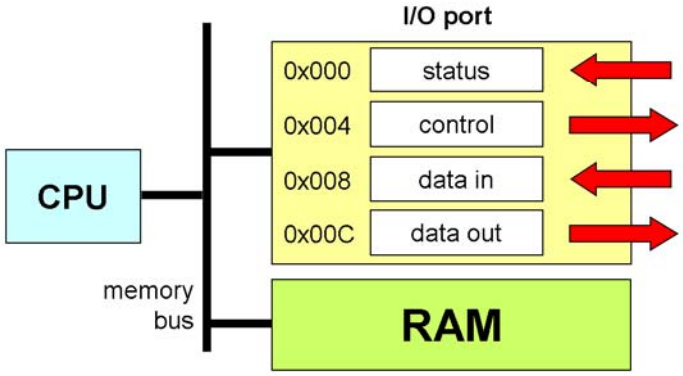
CPU and I/O Controllers

The processor transfers data to and from an I/O controller to effect I/O operations on devices.



Memory-Mapped I/O

The processor reads and writes data to address in its memory space, which are associated with the registers and control lines of I/O controllers.



Device I/O Port Locations on PCs (partial)

I/O address range (hexadecimal)	device
000-00F	DMA controller
020-021	interrupt controller
040-043	timer
200-20F	game controller
2F8-2FF	serial port (secondary)
320-32F	hard-disk controller
378-37F	parallel port
3D0-3DF	graphics controller
3F0-3F7	diskette-drive controller
3F8-3FF	serial port (primary)

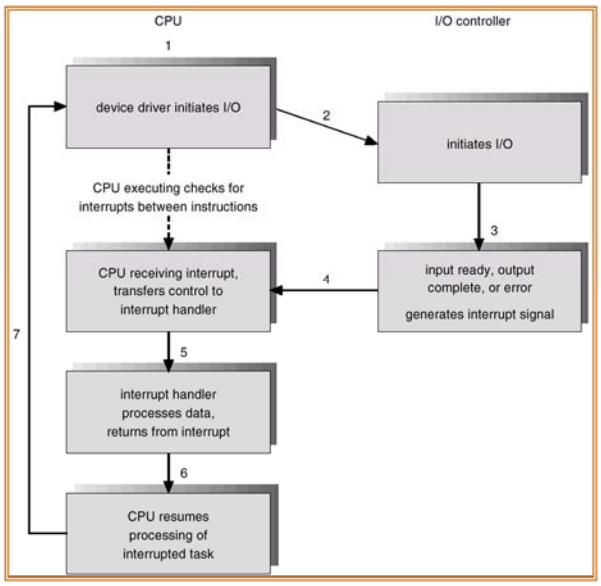
Polling

- Determines state of device:
  - command-ready,
  - busy,
  - error.
- Busy-wait cycle to wait for I/O from device: the CPU is involved in periodically checking the status of the operation.

Interrupts

- CPU Interrupt request line triggered by I/O device.
- Interrupt handler receives interrupts.
- Maskable to ignore or delay some interrupts.
- Interrupt vector used to dispatch interrupt to correct handler:
  - Based on priority.
  - Some unmaskable.
- Interrupt mechanism also used for exceptions.

Interrupt-Driven I/O Cycle



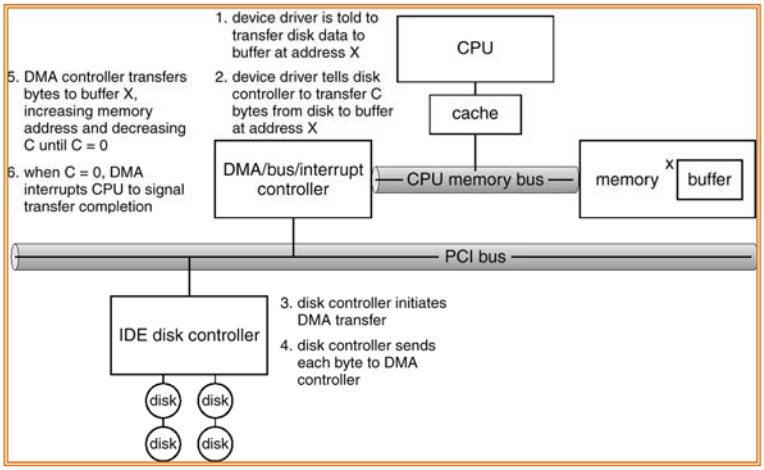
Intel Pentium Processor Event-Vector Table

vector number	description
0	divide error
1	debug exception
2	null interrupt
3	breakpoint
4	INTO-detected overflow
5	bound range exception
6	invalid opcode
7	device not available
8	double fault
9	coprocessor segment overrun (reserved)
10	invalid task state segment
11	segment not present
12	stack fault
13	general protection
14	page fault
15	(Intel reserved, do not use)
16	floating-point error
17	alignment check
18	machine check
19Ð31	(Intel reserved, do not use)
32Ð255	maskable interrupts

Direct Memory Access (DMA)

- Used to avoid programmed I/O for large data movement.
- Requires DMA controller.
- The controller allows for data to be transferred directly between I/O device and memory without CPU intervention.

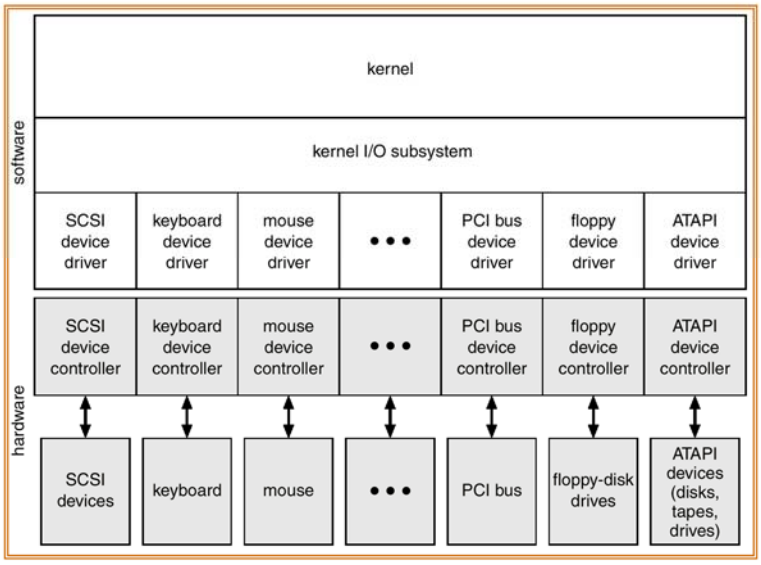
DMA Transfer



Application I/O Interface

- I/O system calls encapsulate device behaviors in generic classes.
- Device-driver layer hides differences among I/O controllers from kernel.
- Devices vary in many dimensions:
  - Character-stream or block.
  - Sequential or random-access.
  - Sharable or dedicated.
  - Speed of operation.
  - Read-write, read only, or write only.

A Kernel I/O Structure



Characteristics of I/O Devices

aspect	variation	example
data-transfer mode	character block	terminal disk
access method	sequential random	modem CD-ROM
transfer schedule	synchronous asynchronous	tape keyboard
sharing	dedicated sharable	tape keyboard
device speed	latency seek time transfer rate delay between operations	
I/O direction	read only write only readÐwrite	CD-ROM graphics controller disk

Block and Character Devices

- Block devices include disk drives.
  - Commands include read, write, seek.
  - Raw I/O or file-system access.
  - Memory-mapped file access possible.
- Character devices include keyboards, mice, serial ports.
  - Commands include `get, put.`
  - Libraries layered on top allow line editing.

Network Devices

- Different enough from block and character to have their own interface.
- Unix and Windows NT/9*x*/2000 include socket interface:
  - Separates network protocol from network operation.
  - Includes `select` functionality.
- Approaches vary widely (pipes, FIFOs, streams, queues, mailboxes).

Clocks and Timers

- Provide current time, elapsed time, timer.
- If programmable interval time used for timings, periodic interrupts.
- `ioctl` (on UNIX) covers odd aspects of I/O such as clocks and timers.

Blocking and Nonblocking I/O

- **Blocking** - process suspended until I/O completed.
  - Easy to use and understand.
  - Insufficient for some needs.
- **Nonblocking** - I/O call returns as much as available.
  - User interface, data copy (buffered I/O).
  - Implemented via multi-threading.
  - Returns quickly with count of bytes read or written.
- **Asynchronous** - process runs while I/O executes.
  - Difficult to use.
  - I/O subsystem signals process when I/O completed.