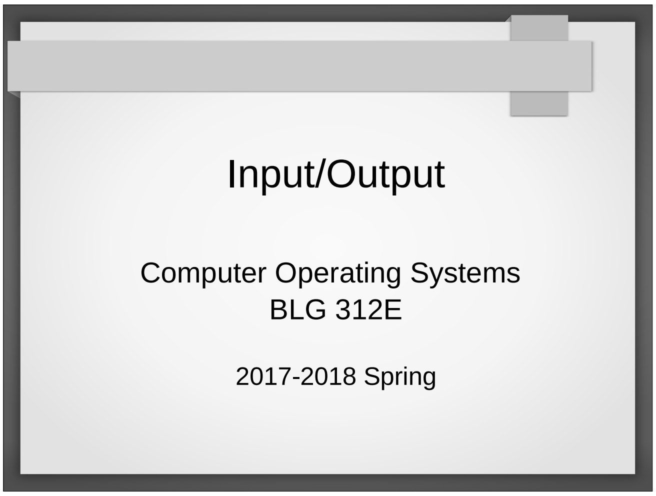
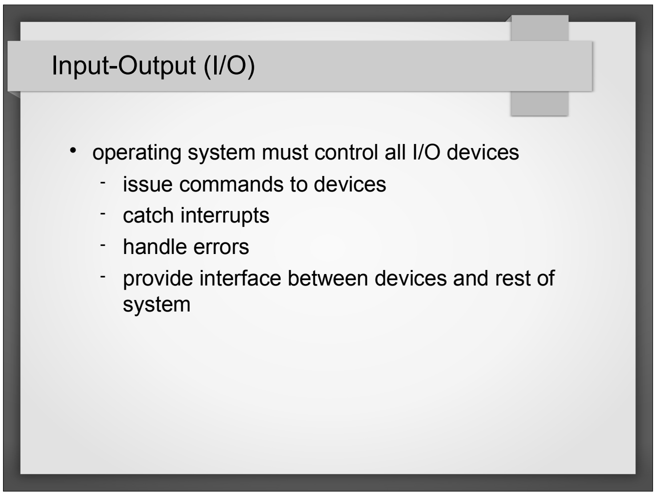


Input/Output

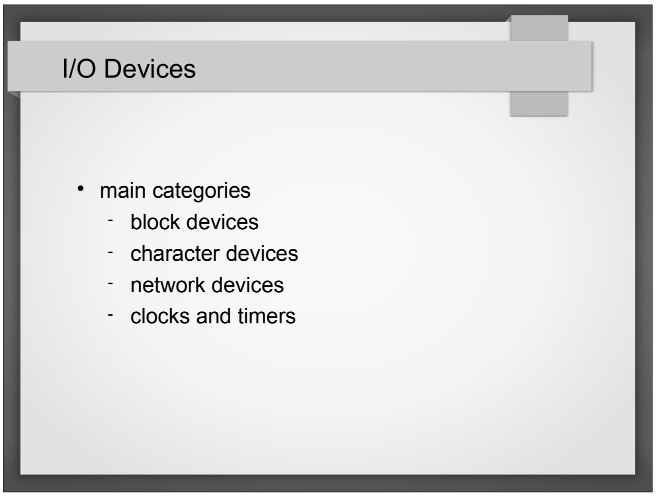
Computer Operating Systems
BLG 312E

2017-2018 Spring



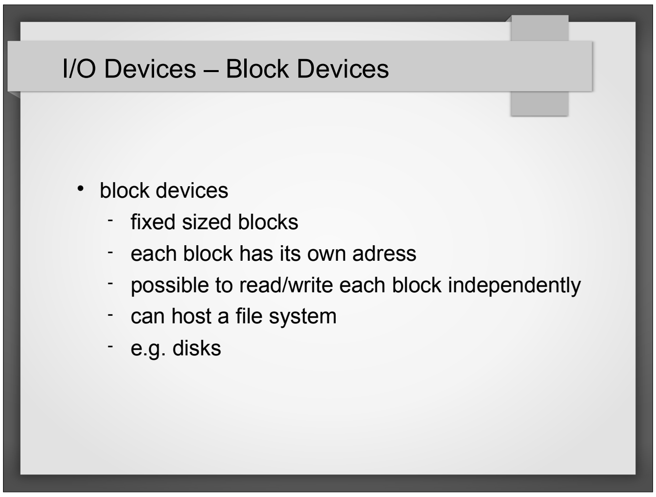
Input-Output (I/O)

- operating system must control all I/O devices
  - issue commands to devices
  - catch interrupts
  - handle errors
  - provide interface between devices and rest of system



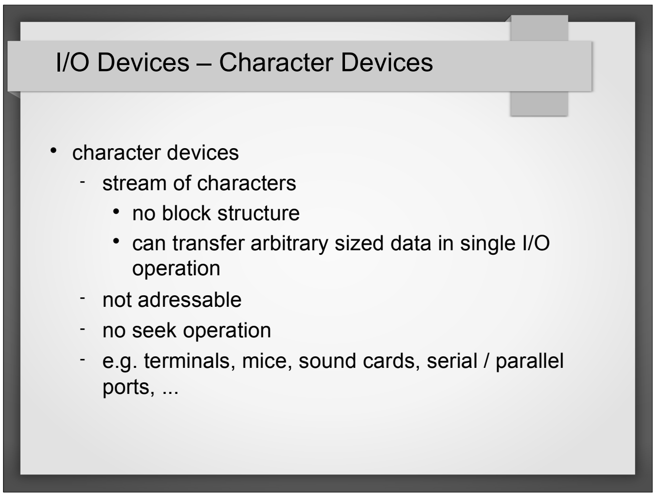
I/O Devices

- main categories
  - block devices
  - character devices
  - network devices
  - clocks and timers



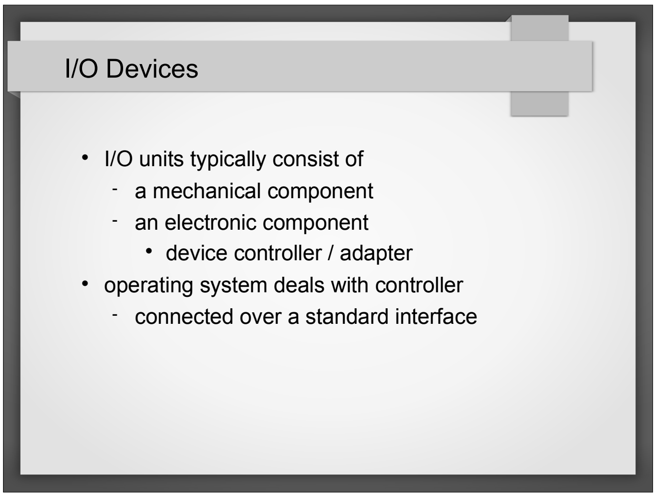
I/O Devices – Block Devices

- block devices
  - fixed sized blocks
  - each block has its own adress
  - possible to read/write each block independently
  - can host a file system
  - e.g. disks



I/O Devices – Character Devices

- character devices
  - stream of characters
    - no block structure
    - can transfer arbitrary sized data in single I/O operation
  - not adressable
  - no seek operation
  - e.g. terminals, mice, sound cards, serial / parallel ports, ...



I/O Devices

- I/O units typically consist of
  - a mechanical component
  - an electronic component
    - device controller / adapter
- operating system deals with controller
  - connected over a standard interface

Device Controllers

- controllers have registers to communicate with CPU
  - control register
    - send command to device
  - status register
    - read state of device
  - input / output register

Memory Mapped I/O

- registers part of regular memory adress space
  - e.g. 680x0 family
  - directly mapped
    - preserve part of memory address space for I/O locations
    - disable virtual memory management
    - not frequently used
  - software mapped
    - virtual memory management available

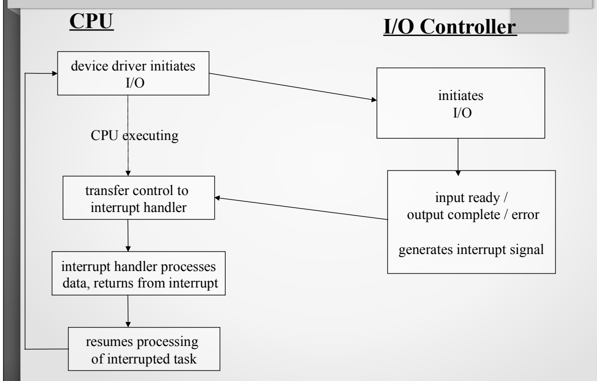
I/O Ports

- use a special adress space for I/O
  - controllers have I/O adresses and interrupt vectors
  - separate read/write lines for I/O ports
  - special instructions

I/O Devices

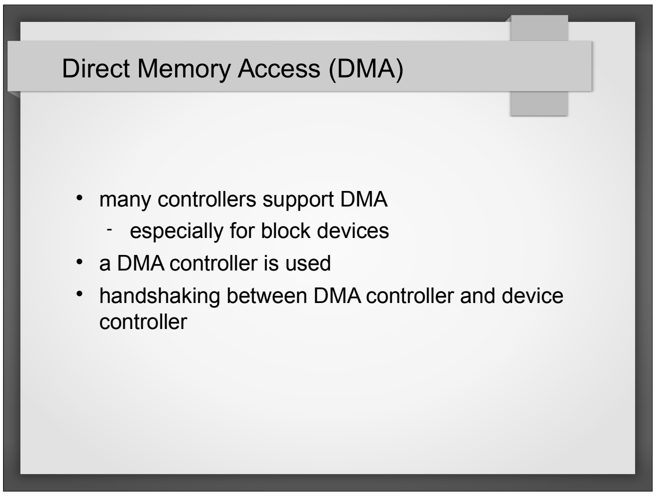
- protocol for interaction between host and controller
  - polling (via handshaking)
    - uses controller status register
  - interrupt driven

Interrupt-Driven I/O Cycle


CPU
I/O Controller
device driver initiates I/O
CPU executing
initiates I/O
transfer control to interrupt handler
input ready / output complete / error
generates interrupt signal
interrupt handler processes data, returns from interrupt
resumes processing of interrupted task

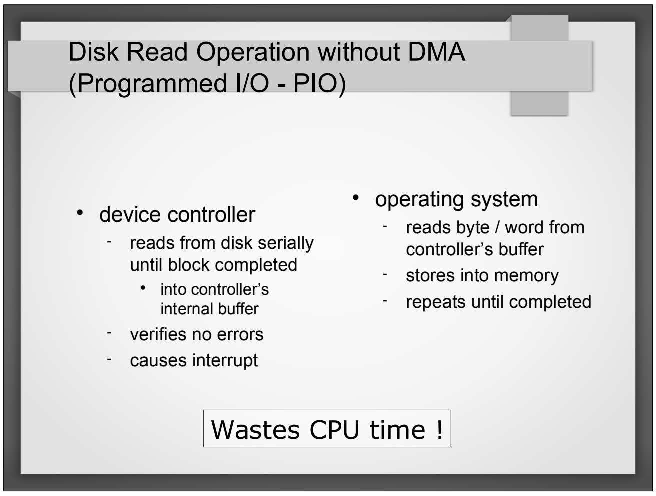
Device Controllers

- for I/O
  - CPU
    - writes command into controller registers (with parameters)
    - continues with other work
  - controller
    - accepts and executes command
    - causes an interrupt on conclusion
  - CPU
    - gets results and device status from controller registers



Direct Memory Access (DMA)

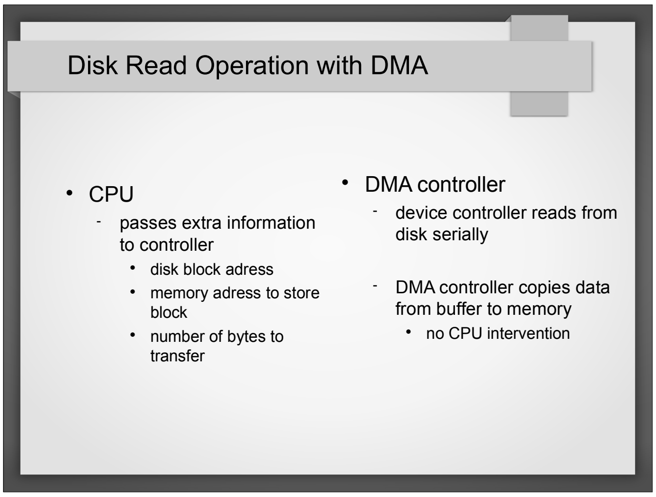
- many controllers support DMA
  - especially for block devices
- a DMA controller is used
- handshaking between DMA controller and device controller



Disk Read Operation without DMA (Programmed I/O - PIO)

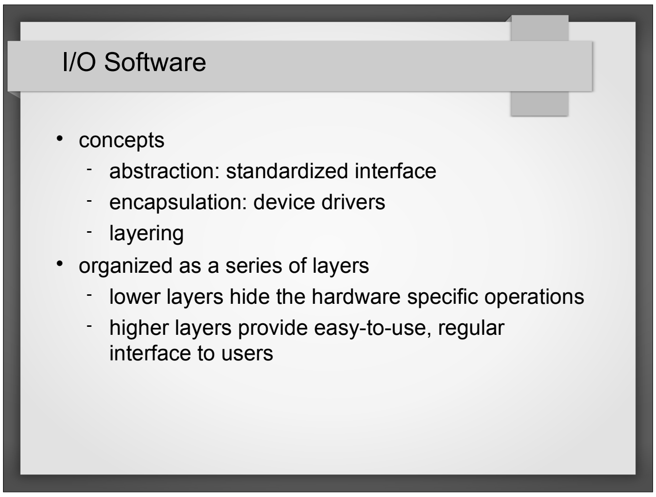
- device controller
  - reads from disk serially until block completed
    - into controller's internal buffer
  - verifies no errors
  - causes interrupt
- operating system
  - reads byte / word from controller's buffer
  - stores into memory
  - repeats until completed

Wastes CPU time !



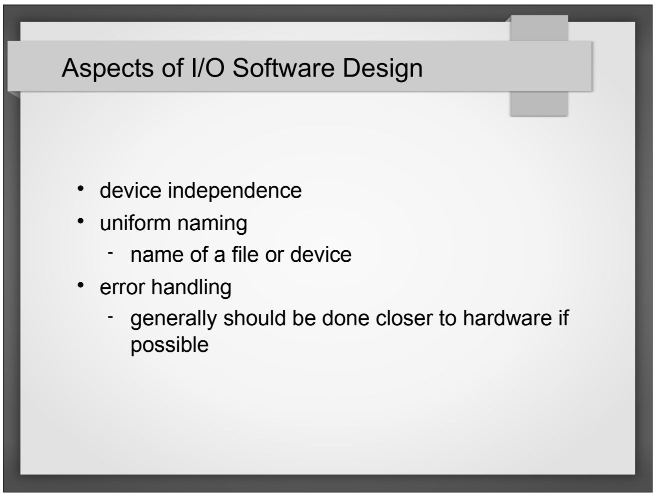
Disk Read Operation with DMA

- CPU
  - passes extra information to controller
    - disk block adress
    - memory adress to store block
    - number of bytes to transfer
- DMA controller
  - device controller reads from disk serially
  - DMA controller copies data from buffer to memory
    - no CPU intervention



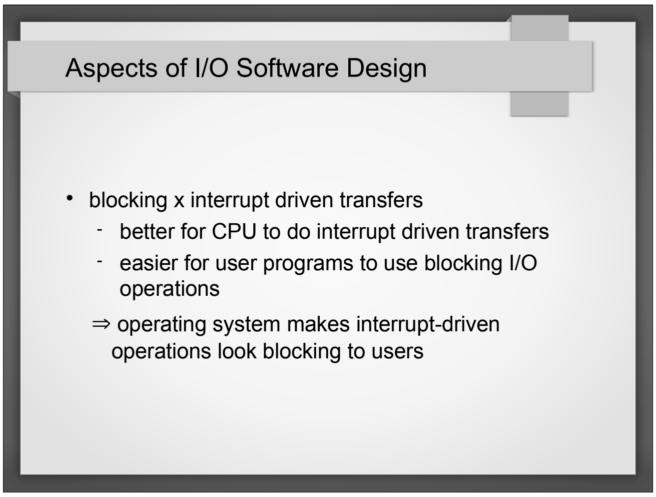
I/O Software

- concepts
  - abstraction: standardized interface
  - encapsulation: device drivers
  - layering
- organized as a series of layers
  - lower layers hide the hardware specific operations
  - higher layers provide easy-to-use, regular interface to users



Aspects of I/O Software Design

- device independence
- uniform naming
  - name of a file or device
- error handling
  - generally should be done closer to hardware if possible



Aspects of I/O Software Design

- blocking x interrupt driven transfers
  - better for CPU to do interrupt driven transfers
  - easier for user programs to use blocking I/O operations

  ⇒ operating system makes interrupt-driven operations look blocking to users

Aspects of I/O Software Design

- shared x dedicated devices
  - e.g. disks x printers

  ⇒ operating system handles the devices accordingly

Kernel I/O Subsystem

- services provided
  - I/O scheduling
    - order in which they are issued may not be the best order to execute them
    - requests are queued
    - scheduling re-arranges order in queue
    - improves efficiency

Kernel I/O Subsystem

(*services provided cntd.*)

- buffering
  - to cope with speed mismatch
    - e.g. receive file through modem to store on disk
  - to adapt between devices that have different data-transfer sizes
    - e.g. network packets
  - to support copy-semantics for application I/O

Kernel I/O Subsystem

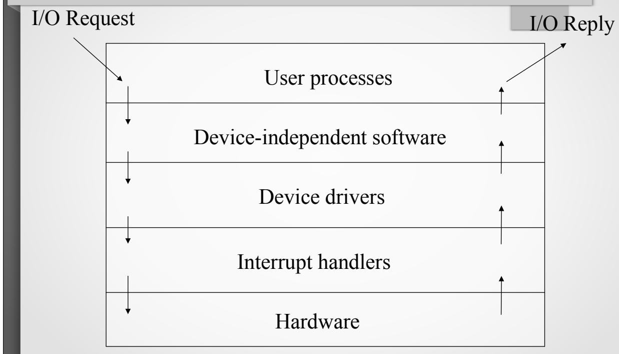
(*services provided cntd.*)

- caching
  - provides faster access
- error handling
- spooling and device reservation system

Structure of an I/O Software

- organized as 4 layers:
  - interrupt handlers
  - device drivers
  - device independent operating system software
  - user level software

I/O System



Interrupt Handlers

- interrupts hidden from rest of system
- I/O requesting process blocks until request completed
- when I/O is completed, interrupt occurs
- process is made to unblock

Device Drivers

- device dependent code
- a driver for each device type
- e.g. for a disk, driver knows
  - controller registers
  - disk info (sectors, tracks, cylinders, …)

Device Drivers

- accepts abstract requests from device-independent software
- translates request
  - decides on sequence of controller operations
    - e.g. for a disk driver
      - finds block on actual disk
      - checks drive's motor
      - positions disk arm…

Device Drivers

- issues commands to controller
- blocks until operation completed
- unblocks on interrupt
- checks for errors
- passes required info to device independent software
- returns status info to caller
- ready for next request

Device - Independent I/O Software

- performs I/O functions common to all devices
- provides uniform interface to user-level software

Functions of the Device - Independent I/O Software

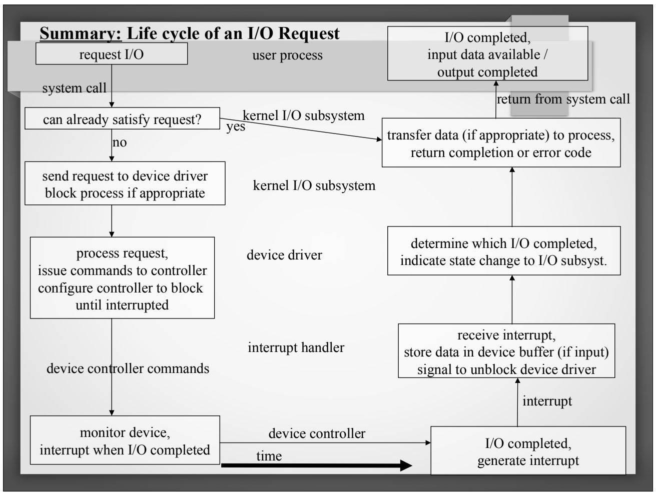
- uniform interfacing for device drivers
- device naming
- device protection
- provide device independent block sizes
- buffering
- allocating and releasing dedicated devices
- error reporting

User-Space I/O Software

- a small part of I/O software provided as libraries
  - system calls are made by library procedures

    e.g. `printf`
    - takes format string and parameters as input
    - builds an ASCII string
    - calls WRITE to output string
- library procedures run as part of user programs

Summary: Life cycle of an I/O Request



request I/O
user process
I/O completed, input data available / output completed
system call
return from system call
can already satisfy request?
yes
kernel I/O subsystem
transfer data (if appropriate) to process, return completion or error code
no
send request to device driver block process if appropriate
kernel I/O subsystem
process request, issue commands to controller configure controller to block until interrupted
device driver
determine which I/O completed, indicate state change to I/O subsyst.
interrupt handler
receive interrupt, store data in device buffer (if input) signal to unblock device driver
device controller commands
interrupt
monitor device, interrupt when I/O completed
device controller
I/O completed, generate interrupt
time