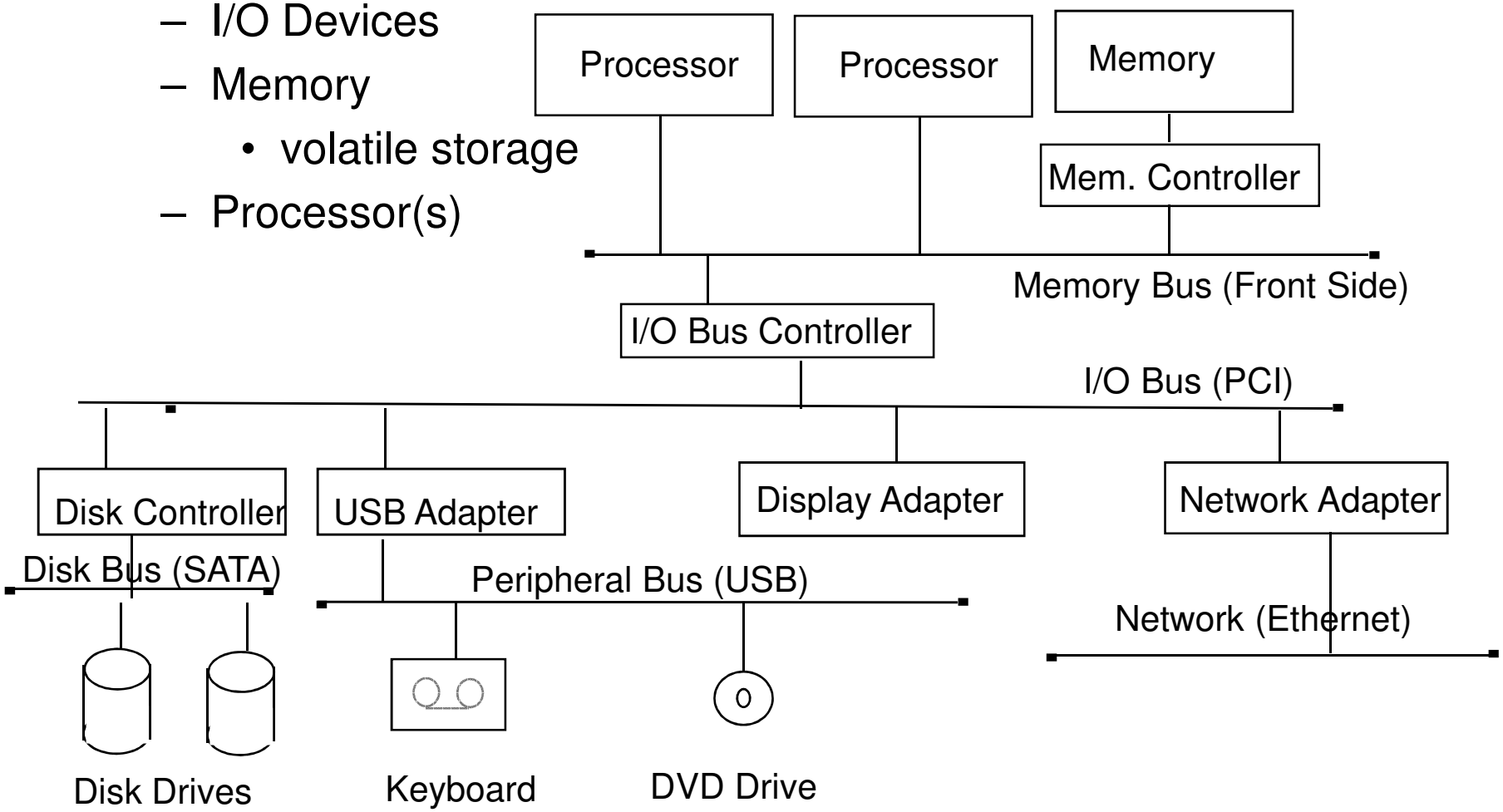
Announcements

- Program #0
  - Due on Wed
  - Limit should return 0 when called with correct parameters
  - Calling limit resets the counter, so a Limit(0,4) will be killed on the 5th system call after Limit.

- Reading
  - Today: Processes - Chapter 3 (ch 4, 6th Ed)
  - Thursday: Threads - Chapter 4 (ch 5, 6th Ed)

Computer Systems

- Computers have many different devices
  - I/O Devices
  - Memory
    - volatile storage
  - Processor(s)



I/O Systems

- Many different types of devices
  - disks
  - networks
  - displays
  - mouse
  - keyboard
  - tapes
- Each have a different expectation for performance
  - bandwidth
    - rate at which data can be moved
  - latency
    - time from request to first data back

Different Requirements lead to Multiple Buses

- Processor Bus (on chip)
  - Many Gigabytes/sec
- Memory Bus (on processor board)
  - Up to 100 Gigabyte per second
- I/O Bus (PCI & PCI-E)
  - ~1s gigabytes per second
  - buses are more complex than we saw in class
    - show PCI spec.
- Device Bus (SCSI, USB)
  - tens of megabytes per second

Issues In Busses

- Performance
  - increase the data bus width
  - have separate address and data busses
  - block transfers
    - move multiple words in a single request
- Who controls the bus?
  - one or more bus masters
    - a bus master is a device that can initiate a bus request
  - need to arbitrate who is the bus master
    - assign priority to different devices
    - use a protocol to select the highest priority item
      - daisy chained
      - central control

Disks

- Several types:
  - Hard Disks - rigid surface with magnetic coating
  - Floppy disks - flexible surface with magnetic coating
  - Optical (CDs and DVDs) - read only, write once, multi-write
  - Solid State (Flash) – fast seek times, limited number of writes
- Hard Disk Drives:
  - collection of platters
  - platters contain concentric rings called tracks
  - tracks are divided into fixed sized units called sectors
  - a cylinder is a collection of all tracks equal distant from the center of disk
  - Current Performance:
    - capacity: gigabytes to terabytes
    - throughput: sustained < 20 megabytes/sec
    - latency: mili-seconds

I/O Interfaces

- Need to adapt Devices to CPU speeds
- Moving the data
  - Programmed I/O
    - Special instructions for I/O
  - Mapped I/O
    - looks like memory only slower
  - DMA (direct memory access)
    - device controller can write to memory
    - processor is not required to be involved
    - can grab bus bandwidth which can slow the processor down

I/O Interrupts

- Interrupt defined
  - indication of an event
  - can be caused by hardware devices
    - indicates data present or hardware free
  - can be caused by software
    - system call (or trap)
  - CPU stops what it is doing and executes a handler function
    - saves state about what was happening
    - returns where it left off when the interrupt is done
- Need to know what device interrupted
  - could ask each device (slow!)
  - instead use an interrupt vector
    - array of pointers to functions to handle a specific interrupt

Hardware Protection

- Need to protect programs from each other
- Processor has modes
  - user mode and supervisor (monitor, privileged)
  - operations permitted in user mode are a subset of supervisor mode
- Memory Protection
  - control access to memory
  - only part of the memory is available
    - can be done with base/bound registers
- I/O Protection
  - I/O devices can only be accessed in supervisor mode
- Processor Protection
  - Periodic timer returns processor to supervisor mode

Operating System Structure

- Simple Structure (or no structure)
  - any part of the system may use the functionality of the rest of the system
  - MS-DOS (user programs can call low level I/O routines)
- Layered Structure
  - layer n can only see the functionality that layer n-1 exports
  - provides good abstraction from the lower level details
    - new hardware can be added if it provides the interface required of a particular layer
  - system call interface is an example of layering
  - can be slow if there are too many layers
- Hybrid Approach
  - most real systems fall somewhere in the middle

Policy vs. Mechanism

- Policy - what to do
  - users should not be able to read other users files
- Mechanism- how to accomplish the goal
  - file protection properties are checked on open system call
- Want to be able to change policy without having to change mechanism
  - change default file protection
- Extreme examples of each:
  - micro-kernel OS - all mechanism, no policy
  - MACOS - policy and mechanism are bound together

Multi-programming

- Systems that permit more than one process at once
  - virtually all computers today
- Permits more efficient use of resources
  - while one process is waiting another can run
- Provides natural abstraction of different activities
  - windowing system
  - editor
  - mail daemon
- Preemptive vs. non-preemptive muti-programming
  - preemptive means that a process can be forced off the processor by the OS
  - provides processor protection

Process State Transitions