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)
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 multi-programming**
  - preemptive means that a process can be forced off the processor by the OS
  - provides processor protection
Process State Transitions

- **new**
- **ready**
- **running**
- **waiting**
- **terminated**

State Transitions:
- New → Ready: admitted
- Ready → Running: dispatch
- Ready → Waiting: I/O request or event wait
- Running → Waiting: I/O request or event wait
- Running → Ready: interrupt
- Waiting → Ready: I/O request or event wait done
- Terminated
  - Kill
  - Exit