Announcements

- **Program #0**
  - its due Friday

- **Reading**
  - Chapter 2
  - Chapter 3 (for Thursday)
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)**
  - ~10s Gigabyte per second
- **I/O Bus (PCI)**
  - ~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