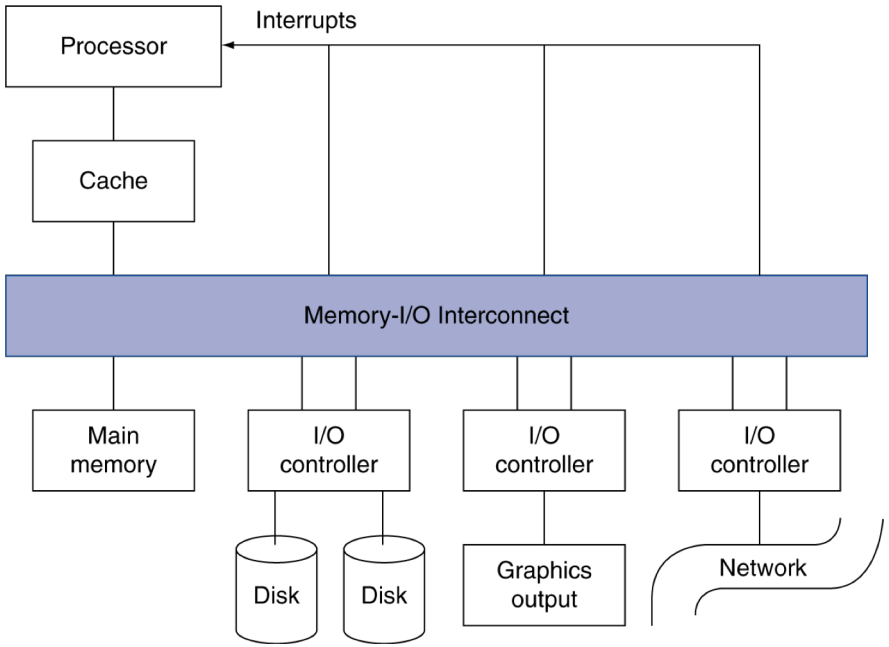
# Topic 13

## I/Os and Their Interfaces

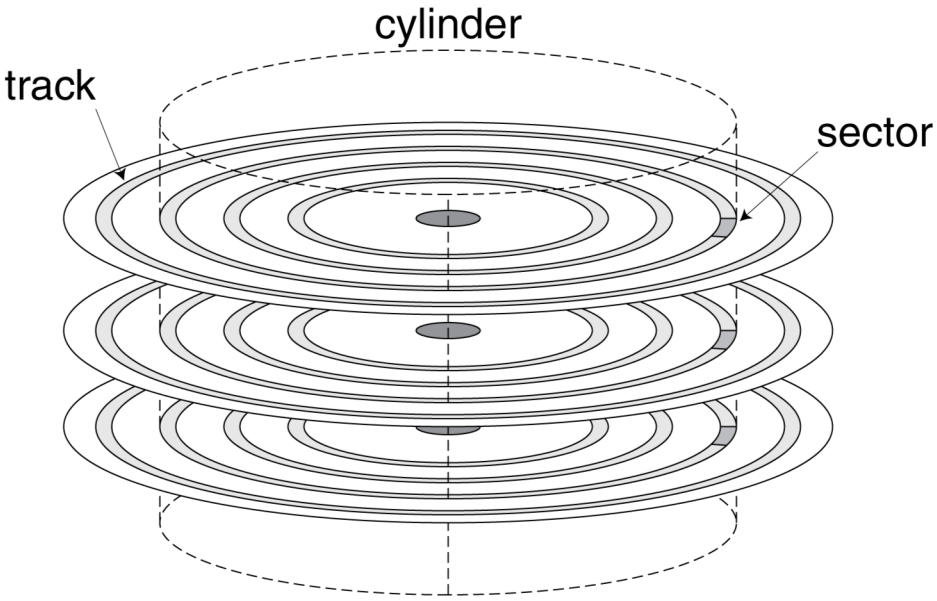
# Introduction

- I/O devices can be characterized by
  - Behavior: input, output, storage
  - Partner: human or machine
  - Data rate: bytes/sec, transfers/sec
- I/O bus connections



# Disk Storage

- Nonvolatile, rotating magnetic storage



# Disk Sectors and Access

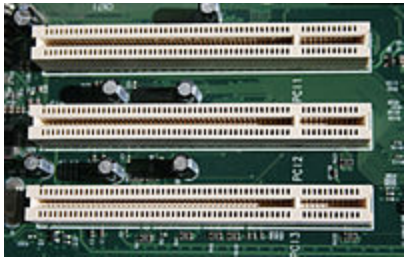
- Each sector records
  - Sector ID
  - Data (512 bytes)
  - Error correcting code (ECC)
    - Used to hide defects and recording errors
  - Synchronization fields and gaps
- Access to a sector involves
  - Queuing delay if other accesses are pending
  - Seek: move the heads
  - Rotational latency
  - Data transfer
  - Controller overhead

# Disk Performance Issues

- Has smart disk controller to create simpler interface
  - With microprocessor inside
  - Present logical sector interface to host
  - Various controller interfaces:
    - SCSI – small computer system interface
    - ATA – AT (Advanced Tech) attachment
    - SATA – Serial ATA
    - PCI – peripheral controller interface
    - PCI x – eXtended, PCI Express
    - LPC – low pin count bus
- Disk controllers include caches
  - Write through
  - Pre-fetch sectors in anticipation of access
  - Avoid seek and rotational delay

SCSI connector

ATA connector



PCI socket

# Interconnecting Components

- Need interconnections between
  - CPU, memory, and I/O controllers
  - Using buses
- Bus: shared communication channel
- Parallel set of wires for data and synchronization of data transfer
  - Advantages:
    - Versatility – various functions, easy to be added or removed
    - Low cost
  - Concerns: performance limited by physical factors
    - Bus speed – can become a communication bottleneck
    - Wire length, number of connections
- More recent alternative: high-speed serial connections

# Bus Types

- Processor-Memory buses (North bridge)
  - Short, high speed
  - Designed to match memory organization
- I/O-Memory buses (South bridge)
  - Longer, allowing multiple connections
  - Specified by standards for interoperability
  - Connected through a north bridge then to memory

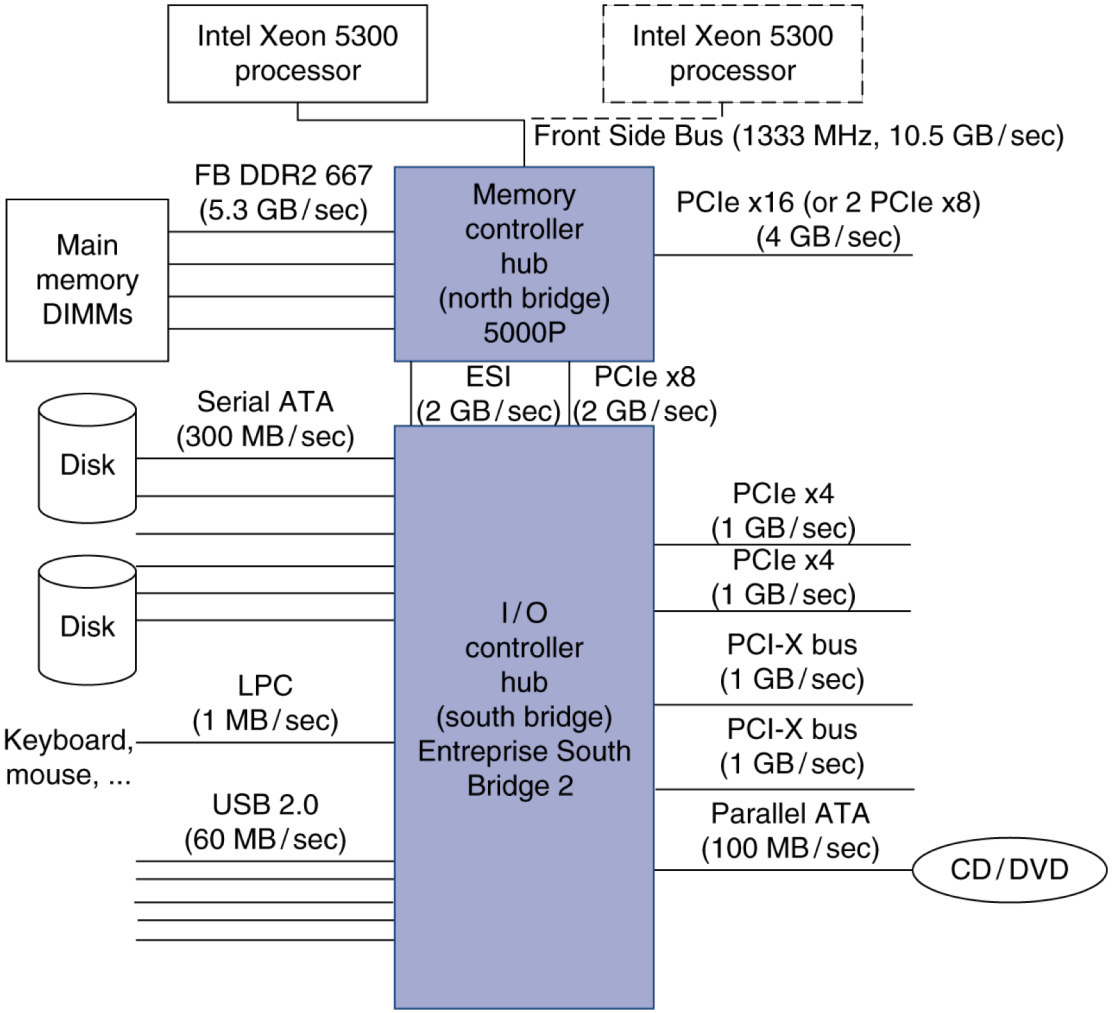
# Bus Types

- Data/Address bus
  - Carry data/address, respectively
    - Multiplexed or separate
- Control bus
  - Indicate data type, synchronize transactions
    - Synchronous – uses a separate clock line
    - Asynchronous – synchronization integrated in data
- Communication standard
  - Coordinate communications
  - Ensure compatibility
  - E.g. RS232, 802.11, 802.15.1, 802.15.4, USB…

# I/O Bus Examples

| | Firewire | USB 2.0 | USB 3.1 | PCI Express | Serial ATA | Serial Attached SCSI |
|---|---|---|---|---|---|---|
| Intended use | External | External | External | Internal | Internal | External |
| Devices per channel | 63 | 127 | 127 | 1 | 1 | 4 |
| Data width | 4 | 2 | 2 | 2/lane | 4 | 4 |
| Peak bandwidth | 50MB/s or 100MB/s | 0.2MB/s, 1.5MB/s, or 60MB/s | 1GB/s | 250MB/s/lane 1×, 2×, 4×, 8×, 16×, 32× | 300MB/s | 300MB/s |
| Hot pluggable | Yes | Yes | Yes | Depends | Yes | Yes |
| Max length | 4.5m | 5m | 3m | 0.5m | 1m | 8m |
| Standard | IEEE 1394 | USB Implementers Forum | USB Imp. Forum | PCI-SIG | SATA-IO | INCITS TC T10 |

# Typical x86 PC I/O System



# I/O Management

- I/O is managed by the Operating System (OS)
  - Multiple programs share I/O resources
    - Need protection and scheduling
    - Done by OS in supervisor mode
  - I/O causes asynchronous interrupts to communicate operation information with CPU
    - Same mechanism as exceptions
    - Interrupt service routine – part of OS
  - I/O programming is non-trivial and sophisticated
    - OS provides abstractions (interfaces) to programs
    - API – Application Programming Interface

# I/O Control Register

- I/O devices are controlled by a set of registers
  - Command, Status, Data
- Command registers
  - Cause device to do something
- Status registers
  - Indicate what the device is doing or has done and occurrence of errors
- Data registers
  - Write: transfer data to an I/O device
  - Read: transfer data from an I/O device

# OS (sw) & I/O (hw) Interface

- Memory mapped I/O
  - I/O registers are connected to memory locations
  - I/Os are accessed as regular memory locations
    - Accessible from software by virtual memory addresses
  - OS writes/reads memory to operate I/O devices
  - OS uses address translation mechanism to make them only accessible in kernel mode
    - Virtual address translation only accessible to OS
- I/O instructions
  - Separate instructions to access I/O registers
  - Can only be executed in kernel mode (by OS)