Computer Architecture

Chapter 6. Inputs and Outputs

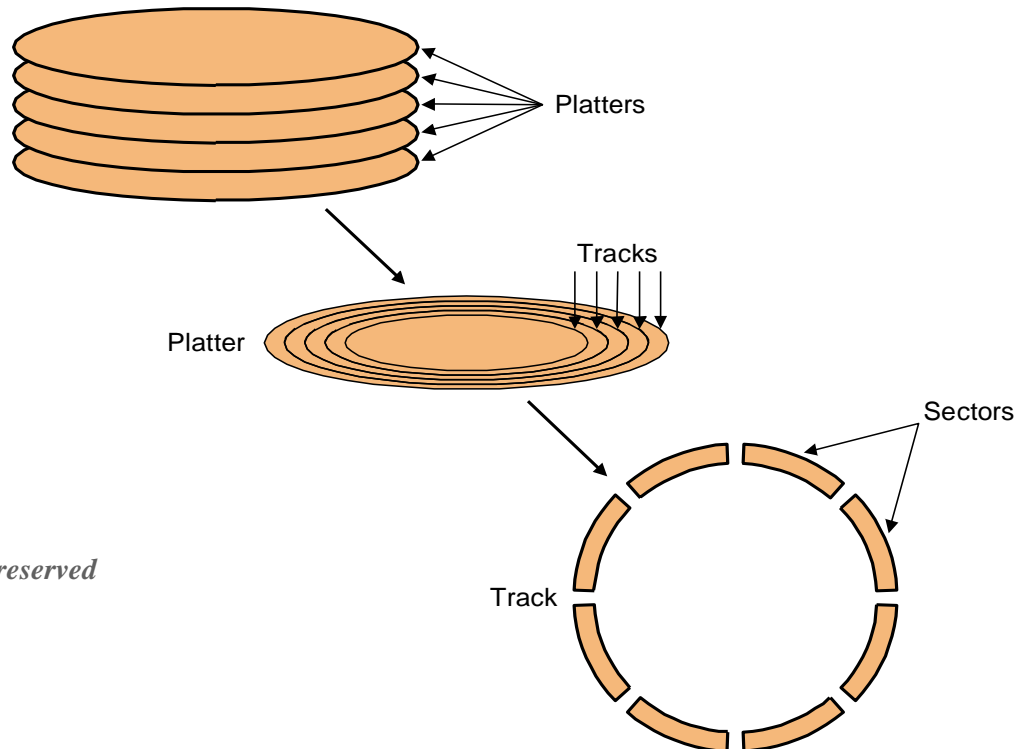**Lynn Choi**
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Magnetic Disk

- **A magnetic disk consists of a collection of platters, each of which has two recordable surfaces.**
  - The stack of flatters rotate at 5400 RPM to 15000 RPM
  - The diameter of this aluminum platter is from 3 ~ 12 cm

Platters

Tracks

Platter

Sectors

Track

Magnetic Disk

- **Organization**
  - ▶ Read/write heads
    - ◆ To read or write, the read/write heads must be moved so that they are over the correct location
    - ◆ Disk heads for each surface are connected together and move in conjunction
  - ▶ Cylinder: a set of tracks at a given radial position
    - ◆ All the tracks under the heads at a given point on all surfaces
  - ▶ Track: each surface is divided into concentric circles
    - ◆ 10,000 to 50,000 tracks per surface
    - ◆ ZBR (Zone Bit Recording)
      - ✦ The number of sectors per track increases in outer zones
  - ▶ Sector - track is divided into fixed size sectors (100 ~ 500 sectors/track)
    - ◆ Preamble - allows head to be synchronized before r/w
    - ◆ Data - 512B - 4KB
    - ◆ Error correcting code (ECC)
      - ✦ Hamming code
      - ✦ Reed-Solomon code
    - ◆ Inter-sector gap
    - ◆ Formatted capacity does not count preamble/ecc/gap

Magnetic Disk

- **Performance**
  - Seek time
    - To move to the right radial position (cylinder/track)
    - 3 ~ 14ms, consecutive tracks less than 1 ms
  - Rotational latency
    - To rotate the desired sector under the head
    - 5400 ~ 16200 rpm (90 ~ 270 rotations/s), 2 ~ 6ms avg.
  - Transfer time
    - Depends on the rotation speed and data density
    - 30 ~ 40MB/s, 1 512B sector takes 12 ~ 16us
- **Disk Controller**
  - Accept commands from CPU
    - read, write, format (write preambles), control the arm motion, detect/correct errors, convert byte to a serial bit pattern, buffering/caching, remapping bad sectors

Disk Access Time

- **Disk access time =**
  - ▶ Seek time + rotational latency + transfer time + controller overhead
- **For example,**
  - ▶ HDD with the following characteristics
    - ◆ 10,000 RPM
    - ◆ Average seek time 6ms
    - ◆ Transfer rate 50MB/s
    - ◆ Controller overhead 0.2ms
    - ◆ No disk idle time
  - ▶ Average time for a 512B sector =
    - ◆ 6ms + 0.5 rotation / 10000RPM + 0.5KB/50MB/s + 0.2ms = 6 + 3 + 0.01 + 0.2 = 9.2ms
    - ◆ Usually seek time is only 25% ~ 33% of the advertised number due to locality of disk references
    - ◆ Most disk controllers have a built-in cache and transfer rates from the cache are typically much higher and up to 320MB/s

Disk Drive Types

- **Removable disk drives**
  - Floppy disks (diskettes) - HD 3.5" 1.44MB, 2 heads, 80 tracks, 18 sectors/track, 300 RPM, 500 Kbps
  - ZIP disks

- **Fixed disk drives**
  - ATA (Advanced Technology Attachment)
    - Standard interface connecting storage devices such as HDD, CD-ROM
    - IDE (Integrated Drive Electronics) disks, 1986
      - BIOS calling convention - 4b head, 6b sector, 10b cylinder (written in 8088 assembly) - limited to 504MB
    - Enhanced IDE disks, 1994
      - LBA (Logical Block Addressing) - up to 2^{24} sectors
      - Control 4 drives (> 2), higher transfer rate, CD-ROM, DMA
    - Serial ATA disks, 2003
      - 7-pin cables rather than 40/80-pin connectors, hot swap
  - SCSI (Small Computer System Interface) disks
    - SCSI (1986), SCSI-2 (1994), fast/wide SCSI-2, SCSI-3
    - Bus (8b or 16b bus, 5 or 10 MHz), 7 devices and 1 used for host adapter
    - Higher transfer (160MB/s), multiple active devices at a time
    - For servers

CD-ROM/ DVD

- **Capacity**
  - 650MB, 74 minutes of music

- **Performance**
  - Single-speed CD-ROM - 75 sectors/s, 150KB/s
  - 32X CD-ROM - 4.8MB/s (still slower than magnetic disks)

- **DVD (Digital Versatile Disk)**
  - A DVD can hold a minimum of 4.7 GB, enough for a full-length movie
    - Smaller pit size, tighter track spacing, and multiple layers enables 4.7GB space
  - MPEG-2 is used to compress video data for storage on a DVD
  - DVD drives are backward-compatible and can play CD-ROMs.
  - 4 DVD construction formats
    - Single-sided, single-layered: 4.7GB
    - Single-sided, dual-layered: 8.5GB
    - Double-sided, single-layered: 9.4GB
    - Double-sided, dual-layered: 17GB
  - DVD application formats
    - DVD-Video, DVD-Audio, DVD-ROM
    - Recordable DVDs

	DVD	CD-ROM
Thickness	0.6 mm	1.2 mm
Track Pitch	0.74 nm	1.6 nm
Min Pit Len.	0.40 nm	0.834 nm
Data Capacity	4.7 GB	.68 GB
Data Rate	1.1 MB/sec	.176 MB/sec
Layers	1,2,4	1

Input Devices

- **Keyboard**
  - When a key is depressed, it closes a circuit or induces a current through magnet, creating an interrupt to CPU
  - OS keyboard interrupt handler reads a hardware register inside keyboard controller to get the key number
- **Mouse**
  - Mechanical - measure distance moved in each direction
  - Optical - for laptops, plastic pad containing grid of lines
    - photodetector senses light changes from LED
  - Mouse sends 3B every time it moves a minimum distance
    - 1st B - x direction, 2nd B - y direction, 3rd B - state
  - Mouse driver converts this relative movement sent by mouse to an absolute position, then displays the position on the screen

Direct Memory Access

- **DMA procedure**
  - IO device(eg. disk controller) requests DMA (8237 DMA controller) by asserting DREQ
  - DMA requests system bus control by asserting HOLD to CPU
  - CPU complete current bus cycle and responds to DMA by asserting HLDA (hold acknowledge) and releasing bus
  - DMA will assert DACK (DMA acknowledge) to IO
  - DMA transfers data between memory and IO by
    - Putting address, memory read/write & IO write/read
    - Decrement counter, increment address
    - Until the count reaches zero
  - DMA deactivate HRQ, releasing bus to CPU
- **To transfer a byte from memory to IO**
  - 8088 takes 39 clocks while DMA takes only 4 clocks

DMA

- **8237 DMA controller chip**
  - 4 *channels*, 8b data transfer
    - Each channel can transfer data for a separate IO device such as floppy disk, hard disk, etc.
    - Each channel is programmed separately by setting base address and count for the data transfer
    - Each channel contains 16b base address register and 16b count register
  - In PC XT (8088), channel 0 is used for refresh, channel 1 for network, channel 2 for floppy disk
  - 286, 386, 486, Pentium use two 8237s for 16b data transfer and allows 7 channels
- **Two DMA transfer modes**
  - Third-party DMA
    - DMA controllers on the motherboard coordinate the DMA transfers
    - Old and very slow--basically unchanged since the earliest days of PC
  - First-party DMA
    - Peripheral device itself does the work of transferring data to and from memory, with no external DMA controller involved.
    - Requires bus mastering, because when such transfers are occurring the device becomes the "master of the bus"
    - Modern IDE/ATA hard disks use *first-party* DMA transfers

Serial Interface

- **One bit at a time, for a long distance data transfer**
- **Parallel-in-serial-out shift register**
- **Asynchronous transfer (National UART 8250)**
  - 1 byte at a time
  - Framing - each byte packed between start and stop bits
  - Disadvantage - high overhead
  - National 8250 UART (Universal Asynchronous Receiver Transmitter)
- **Synchronous transfer (Intel USART 8251)**
  - Hundred bytes (block) at a time
  - BISYNC protocol or SDLC protocol
  - Synchronous characters (start and stop of block) and checksum for error detection and correction
- **Data transfer rate**
  - *Baud rate* - number of signal changes per second
    - A single signal change can transfer multiple bits of data
 - *Bit rate* - number of bits per second

Parallel Interface

- **8 bits or more at a time, for a short distance**
- **Used for printers, scanners, and external drives**
- **Parallel port types**
  - SPP (Standard Parallel Port)
    - Unidirectional, 8 bit data
    - Designed to send data from PC to printer
  - PS/2 - bidirectional data bus
  - EPP (enhanced parallel port)
    - Similar to PS/2, but hardware handshaking
    - Faster transfer (512KB/s ~ 2MB/s) for external storage devices
  - ECP (extended capability port)
    - EPP + DMA+compression capability
    - Used for laser printers and scanners
- **IEEE 1284 standard includes EPP and ECP**

# BIOS (Basic Input Output System)

- **The lowest level of OS code that interfaces hardware directly and resides on motherboard (as a ROM or FLASH)**

- **A kind of firmware**
  - Software that is permanently stored on a chip
  - Instructions for hardware
  - Interface between higher-level software and hardware

- **Contains all the routines required to control I/O functions**
  - Keyboard
  - Display
  - Disk drives
  - Serial communications
  - A number of miscellaneous function
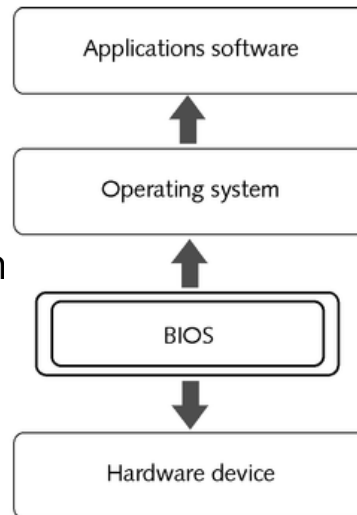
BIOS must be compatible with both hardware and software
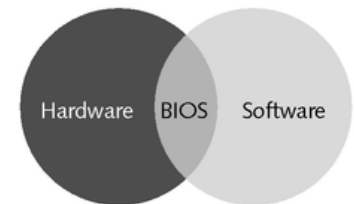
Figure 3-15 BIOS can serve as the hardware/software interface

BIOS Functions

- ## Performs POST (Power-On Self Test)
  - **Perform diagnostics and initialize system components**
  - **Identify and display system configuration**
    - Video card information, BIOS version, count memory and system configuration
      - processor, FDD, display type, memory size
      - HDD type, serial/parallel ports, cache size, etc.
  - **POST errors**
    - DRAM refresh failure, parity failure, memory failure within 64KB, system timer failure, processor failure, virtual mode failure, ROM BIOS checksum failure, CMOS memory, external cache failure
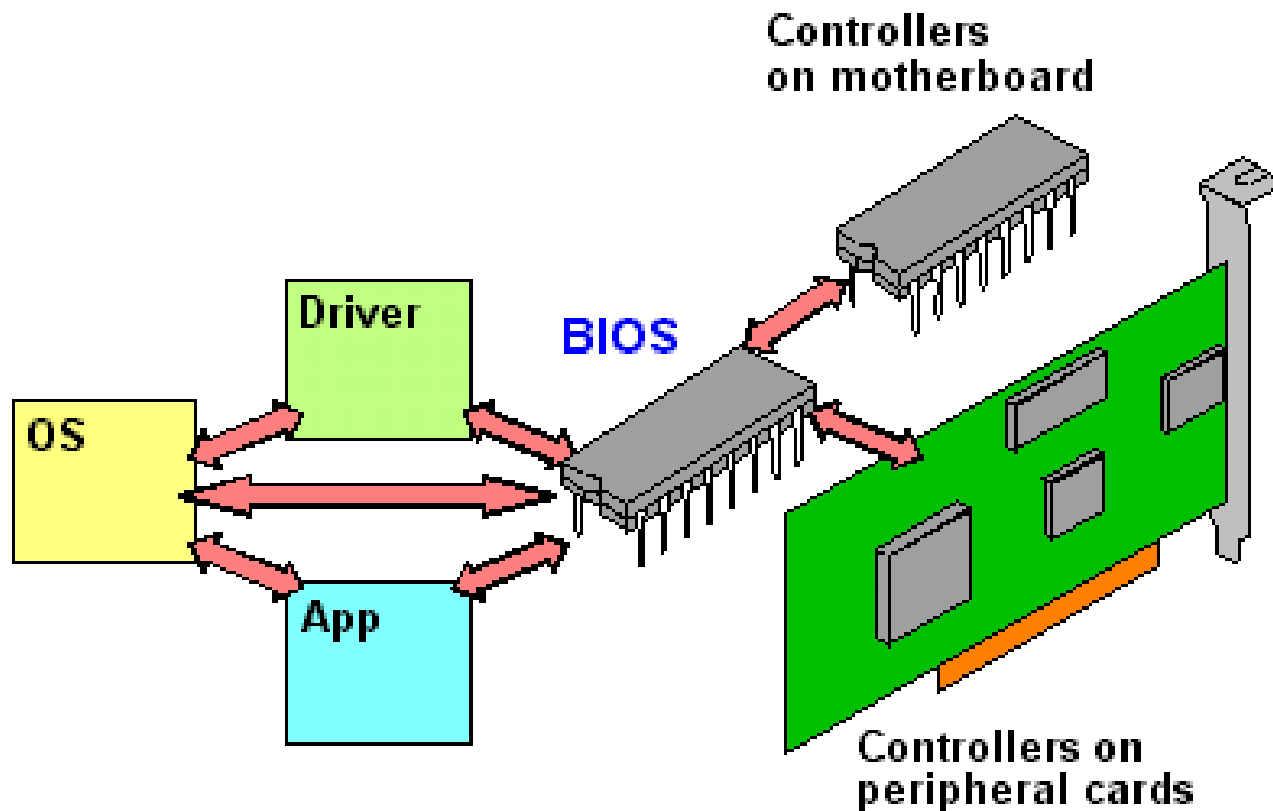
- ## Boot OS from FDD or HDD

- ## Provides HW interface to the OS in the form of a library of interrupt handlers
  - **A new device requires a BIOS or a device driver for the OS to use it**

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Asynchronous serial transfer

Keyboard Microcontroller

Keyboard cable

Motherboard

8255 PPI
8259 PIC
BIOS

Start bit (0)
8b scan code
Odd parity bit
Stop bit (1)

When a key is pressed, the keyboard
controller identifies the key and sends
its scan code serially to the motherboard.
Key press (*make*) and release (*break*) are
represented by two different scan codes

Motherboard get rids of frame bits
and makes one byte with shift register
and present the scan code to 8255
and activates IRQ1(INT 09) of 8259
ISR residing in BIOS is invoked
ISR reads the scan code and write into
the keyboard buffer

8255 PPI (Programmable Peripheral Interface)
8259 PIC (Programmable Interrupt Controller)