Outline
- Hard Disk Drive (HDD)
- Key Technological Firsts
- Important HDD Characteristics
- HDD Structure
- Platters
- Media Materials

Hard Disk Drive (HDD)
- HDD is the most important of permanent storage devices (e.g., floppy disks, CD-ROMs, DVD, tapes, etc.)
- HDD differs from the others primarily in two ways:
  - Size (usually larger)
  - Speed (usually faster)
- HDD is as amazing as microprocessors in terms of the technology:
  - Significantly change in capacity, speed, and price

Key Technological Firsts
- First Hard Disk (1956): IBM's RAMAC 305
  - 5 MB stored on 50 24" disks
- First Air Bearing Heads (1962): IBM's model 1301
  - 28 MB, flying height = 250 microinches
- First Removable Disk Drive (1965): IBM's model 2310
- First Ferrite Heads (1966): IBM's model 2314
- First Modern Hard Disk Design (1973): IBM's model 3340 or "Winchester"
  - 60 MB with several key technologies
  - Recognized as the ancestor of the modern disk drive
First Thin Film Heads (1979): IBM's model 3370
First 8" Form Factor Disk (1979): IBM's model 3310
  - 8" platters, greatly reduced in size from the 14"
First 5.25" Form Factor Disk (1980): Seagate's ST-506
First 3.5" Form Factor Disk Drive (1983)
  - Rodime introduces the RO352
First Voice Coil Actuator 3.5" Drive (1986)
  - Conner Peripherals introduces the CP340
First 2.5" Form Factor Disk Drive (1988)

First Drive to use Magnetoresistive Heads and PRML Data Decoding (1990)
  - IBM's model 681 (Redwing)
First Thin Film Disks (1991): IBM's "Pacifica"
  - Replace oxide media with thin film media
First 1.8" Form Factor Disk Drive (1991)
  - Integral Peripherals' 1820
First 1" Form Factor Disk Drive (1999)
  - IBM's Microdrive to fit inside a CF Type II slot
First 0.85" Form Factor Disk Drive (2004)
  - Toshiba announced this form factor in January 2004

Important HDD Characteristics
- Areal Density = TPI x BPI
- Capacity
- Spindle Speed
  - Increasing the spindle speed improves both random-access and sequential performance
  - E.g., 7200 RPM for IDE/ATA drives, 15,000 RPM for SCSI drive
- Form Factor (5.25", 3.5", 2.5", etc.) ⇒ "shrinking trend"
  - Enhanced rigidity of smaller platters
  - Reduction of mass to enable faster spin speeds
  - Improved reliability

Performance
- Improve both positioning and transfer performance factors
Reliability
- Improve slowly as manufacturers refine their processes and add new reliability-enhancing features
RAID (Redundant Array of Independent Disks)
  - For high-end servers, the use of multiple disk arrays to improve performance and reliability is becoming increasingly common.
  - Standards for interfacing between different HDDs
Interfaces (IDE/ATA, SCSI, USB, IEEE-1394, etc.)
  - Continuously create new and improved standards with higher maximum transfer rates, to match the increase in performance of the HDDs.
RAID

Most of the reliability features and issues discussed in this part of the site relate to making drives themselves more reliable. However, there is only so much you can do to improve the reliability of a single drive without the cost becoming exorbitant. Furthermore, since most people aren't willing to pay for ultra-reliable drives, manufacturers have little incentive to develop them. For those applications where reliability is paramount, the quality of no single-drive solution is sufficient. For these situations, many businesses and power users are increasingly turning to the use of multiple drives in a redundant or partially-redundant array configuration. The common term that refers to this technology is Redundant Arrays of Inexpensive (or Independent) Disks, abbreviated RAID.

The principle behind RAID is "belt and suspenders": if you store redundant information across multiple disks, then you insulate yourself from disaster in the event that one of the disks fails. If done properly, you also improve performance—sometimes in a substantial way—by allowing the drives to be accessed in parallel. And you can make it so bad drives can be replaced without the system even being taken down.

RAID is a big topic unto itself; there are many different ways that RAID can be implemented; various hardware and software considerations; and many tradeoffs to be considered when implementing a system. I have therefore created a separate area that discusses RAID in detail. Check it out if the subject interests you. RAID is rapidly increasing in popularity, and I believe it will only be a few years before it starts showing up even in high-end home systems.

HDD Structure

HDD uses round, flat disks called platters, coated on both sides with a special media material.

The platters are mounted by cutting a hole in the center and stacking them onto a spindle, and rotated at high speed, driven by a spindle motor.

Special electromagnetic read/write devices called heads are mounted onto sliders, used to read/write data.

The sliders are mounted onto arms, all are mechanically connected into a single assembly and positioned over the surface of the disk by a device called an actuator.

A logic board (known as PCB) controls the activity of the other components and communicates with PC.
Mechanical Parts of Drive [WD]

- Magnetic Disk (glass / aluminum substrate)
- Dual magnet VCM
- “Spoiler” Suppressor comb
- Flex
  - Preamp
  - Flex circuit
  - P2 connector
- Inertial Latch (locking latch) to prevent HSA from coming off ramp due to shock
- Re-circulation filter
- Disk Clamp
- Ramp L/UL

Mechanical Parts of HSA [WD]

- Actuator Arm
- HGA
- Base Casting
- HSA
- Slider / Heads
- Actuator – Unamount spacer
- Bracket / Connector
- Voice Coil (moulded)
- Voice Coil (non-moulded)
- Latch Tang
- Pivot
- Flex Circuit
- Preamp: Mounted on flex at actuator body

Mechanical Parts of HGA & Slider [WD]

- Read / Write head
- Slider
- Slider Pad
- Slider ABS (facing disk)
- Wafer and Bar level
- HGA

Size Does Matter: HGA

- TSA: Trace-Suspension Assembly
- Lift Tab
- Actuator – Unamount design
- 3.5”
- 2.5”

3.5”

2.5”
PCB Components

PCBA Diagram

Moving the Heads to the Right Track

- The HSA is moved by applying a current to the wires wound around a loop at its back end.
- This coil forms an electromagnet.
- The amount of current used is calculated by servo electronics.
- By varying the current, very precise acceleration and deceleration can be programmed, increasing performance and servo head positioning accuracy.

Hard Drive Average Access Time

This is the amount of time it typically takes to Read or Write the requested data between disk and host.

\[ \text{Avg. Access Time} = \text{Seek Time} + \text{Latency} + \text{Transfer Time} + \text{Controller Overhead} \]

- **Seek Time**: Time required to move the heads a desired distance. Typically specified at 1/3 the radius of the platter.
- **Latency**: Amount of time the drive must wait before data is under the read/write head.
- **Transfer Time**: Amount of time required to transfer data to or from the host.
- **Controller Overhead**: How long it takes the drive to decode a command from the host.
Platter

- Two main substances:
  - **A magnetic media coating** (a very thin media layer)
    - Hold the magnetic impulses that represent the data
  - **A substrate material** (support the media layer)
    - Give it structure and rigidity
- Information recorded in concentric circles called **tracks**.
  - Each track is broken down into smaller pieces called **sectors**, each of which holds 512 bytes of information.
- The quality of the platters and their media are **critical**.
  - HDD is assembled in a **clean room** to reduce the chances of any dirt or contamination.

Platter Size

- Determine the overall physical dimensions
  - Generally called the drive's **form factor** (e.g., 3.5”, 2.5”, etc.)
- Reasons for going to smaller platters
  - **Enhanced Rigidity**
    - Stiff platters are **more resistant** to shock and vibration
    - Reducing the platter's diameter by a factor of two approximately quadruples its rigidity.
  - **Manufacturing Ease**
    - The flatness and uniformity of a platter is **critical** to its quality.
    - Smaller platters are easier to make than larger ones.

- **Mass Reduction**
  - Smaller platters are **easier to spin** and require **less-powerful motors**
- **Power Conservation**
  - Smaller drives generally **use less power** than larger ones
- **Noise and Heat Reduction**
- **Improved Seek Performance**
  - Reducing the size of the platters **reduces the distance** that the head actuator must move the heads side-to-side to perform random seeks
  - This **improves seek time** and makes random reads and writes faster.

- Practically, using a smaller platter size is **more efficient**, **simpler** and **less wasteful** than a large platter.
  - The hard disk platter size of 1” in diameter by IBM
Number of Platters

- Normally, the platter has two surfaces, each has its own read/write head.
  - Older drives use one surface for holding servo information.
  - Newer drives don't need to spend a surface on servo information, but sometimes leave a surface unused for marketing reasons.
    - E.g., to create a drive of a particular capacity in a family of drives.
- Drives with many platters are more difficult to engineer
  - The need to perfectly align all the drives
  - The greater difficulty in keeping noise and vibration under control
- Trend ⇒ Drives with fewer head arms and platters.

Platter Substrate Materials

- The bulk of the material of the platter is called the **substrate**
  - Support the media layer
- Generally, a **substrate material** must be
  - Rigid
  - Easy to work with
  - Lightweight
  - Stable
  - Magnetically inert
  - Inexpensive
  - Readily available

Because the platters spin with the read/write heads floating just above them, the platters must be **extremely smooth and flat**.

Possible materials for making platters are
- Aluminum alloy ⇒ old drives
- Glass ⇒ modern drives
- Glass composites
- Magnesium alloys

Glass platter has several advantages
- Better Quality
  - Much smoother and flatter than aluminum

- Improved Rigidity
  - More rigid than aluminum for the same weight of material
  - Improved rigidity ⇒ smaller platter ⇒ reducing noise and vibration when spinning at high speed
- Thinner Platters
  - Allow more platters to be packed into the same drive dimensions
- Thermal Stability
  - When heated, glass expands much less than aluminum does.

Disadvantage of using glass platters
- Fragility, especially when made very thin
Magnetic Media

- The media layer is a very thin coating of magnetic material
  - Store data
  - Only a few millionths of an inch in thickness
- Old HDDs use oxide media
  - Inexpensive, but
  - Easily damaged from contact by a read/write head
  - Only useful for relatively low-density storage
  - Oxide particles became too large for the small magnetic fields of modern HDDs
- Today’s HDDs use thin film media

Thin film media consists of a very thin layer of magnetic material applied to the surface of the platters.

Techniques to deposit the media material on the platters:

- **Electroplating**
  - Similar to a process used in electroplating jewelry
- **Sputtering**
  - Use a vapor-deposition process
  - More uniform and flat surface than plating
  - Used in new HDDs, despite its higher cost

Compared to oxide media, thin film media is

- Much more uniform and smooth
- Hold much more data in the same amount of space
- Much harder and more durable material
- Much less susceptible to damage
Disk Media Basics

- Hard disk media is made up of several layers of material
- Base material used for media are:
  - Aluminum for 3.5" HDD
  - Glass for 2.5" HDD
- Goal is to be strong and very smooth / flat

Most important layer is magnetic layer that actually records the user data.

Carbon layer
- Increase mechanical durability of the disk
- Slow down corrosion of the magnetic layer
- Provide low friction
- A thin layer of lubricant on the top is used to minimize the wear of the carbon layer.

Normally, the heads fall down to the surface of the disk when the disk's motor is stopped
- A special track for the heads to be placed for takeoffs and landing

New technique ⇒ load/unload technology (IBM)
- The heads are lifted completely off the surface of the disk while the drive is still spinning, using a special ramp.