Fundamental of Hard Disk Drive Technology (6)

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Outline

- Servo Techniques
  - Wedge Servo
  - Dedicated Servo
  - Embedded Servo
- Spindle Motor
  - Spindle Motor
    - Ball Bearing (BB)
    - Fluid-Dynamic Bearing (FDB)

Servo Techniques and Operation

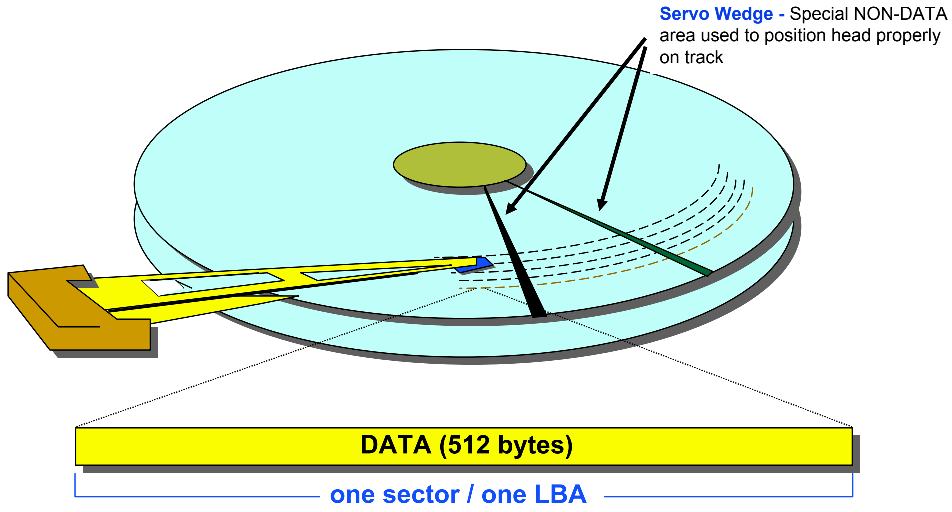
- A voice coil actuator is used to position the heads on the surface of the disk.
  - Actuator ⇒ a servo system (a type of closed-loop feedback system)
- A key element of any closed-loop feedback system is a measuring device to provide the feedback.
  - HDD ⇒ the read/write head

- **Special codes** are written on the disk to let the hard disk know where the heads are when the actuator moves.
  - Typically called **servo codes**
    - Read by the heads and fed back to the actuator control logic to guide the actuator to the correct track.
  - By putting different codes on each track of the disk, the actuator can always figure out which track it is looking at.

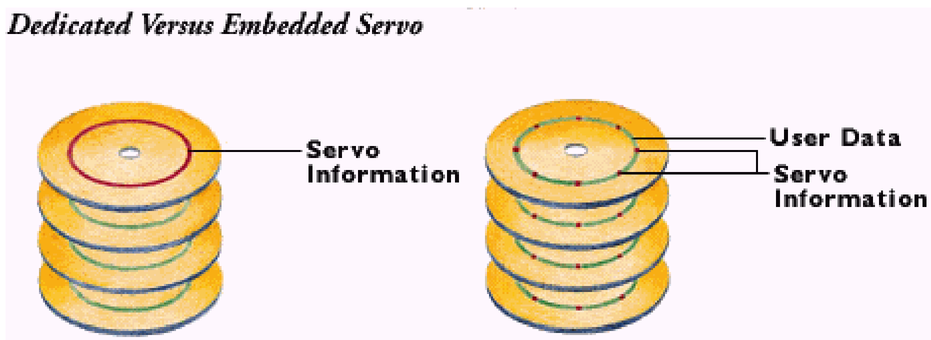
- Three ways to implement the servo mechanism:
  - Wedge Servo
  - Dedicated Servo
  - Embedded Servo

- **Wedge Servo**: (no longer used)
  - The servo information is recorded in a "wedge" of each platter
    - Located in only one location on the disk
  - Drawback
    - To position the heads, a lot of waiting must be done for the servo wedge to rotate around to where the heads are.

Data and Servo Wedge Recording



- **Dedicated Servo** (through the mid-1990s)
  - An entire surface of one disk platter is "dedicated" just for servo information.
  - One head is constantly reading servo information
    - Allow very fast servo feedback
      - Separated heads for reading data and servo information
    - Eliminate the delays associated with wedge servo designs
  - Drawback
    - An entire surface of the disk is wasted
    - Thermal recalibration is required
      - The head where data is recorded may not line up exactly with the head that is reading the servo information.

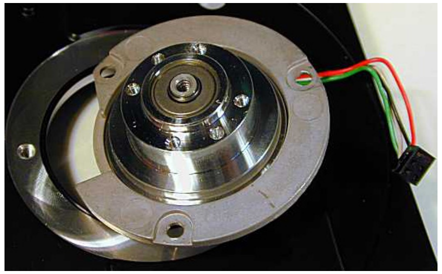


- **Embedded Servo**: (used in modern drives)
  - Intersperse servo information with data across the entire disk
  - The servo information and data are read by the same head
  - The need for thermal recalibration is greatly reduced
    - The servo information and data are the same distance from the center of the disk and will expand or contract together

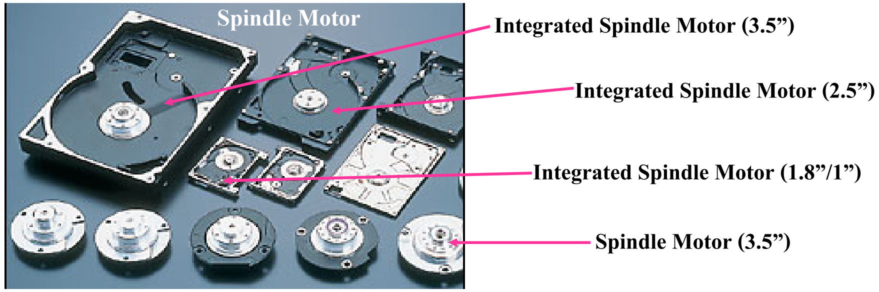
- The servo codes are written to the disk surfaces at the time the hard disk is manufactured.
- Special, complex and expensive equipment is employed to record this information ⇒ **a servo-writer**
- The servo codes
  - Put in place for the life of the drive
  - Cannot be rewritten without returning the drive to the factory
- The heads are locked out at the hardware level by the drive's controller from writing data to the areas where servo information is written.

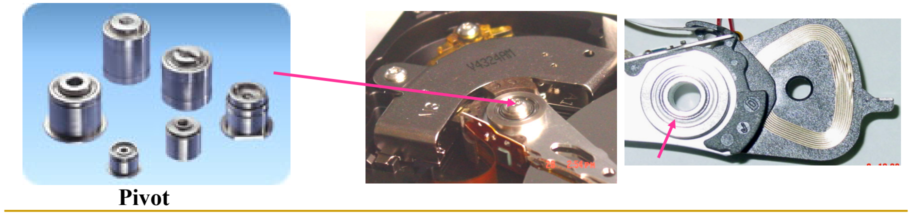
Spindle Motor

- The spindle motor (a spindle shaft) is responsible for turning the hard disk platters.
- For many years hard disks all spun at the same speed.
  - The higher the speed, the faster the read/write capability.
  - However, these higher-speed spindles often have issues related to the amount of heat and vibration they generate.



Example – Spindle Motor & Pivot

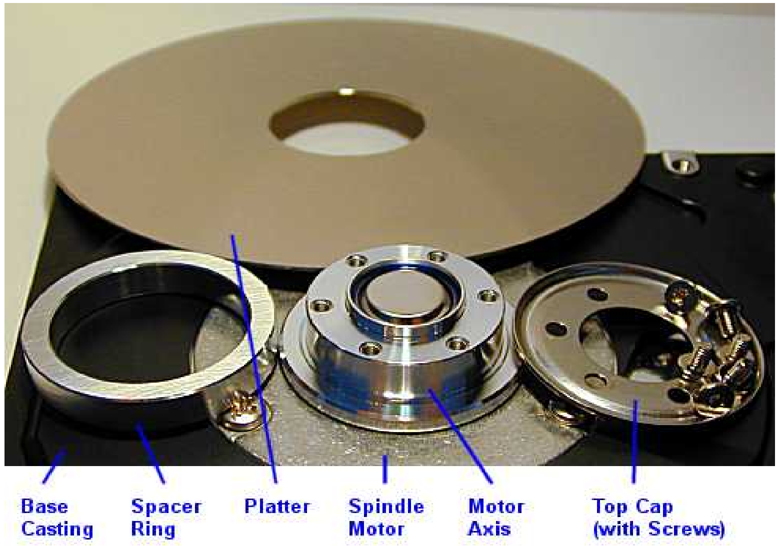




Spindle Motor Operation

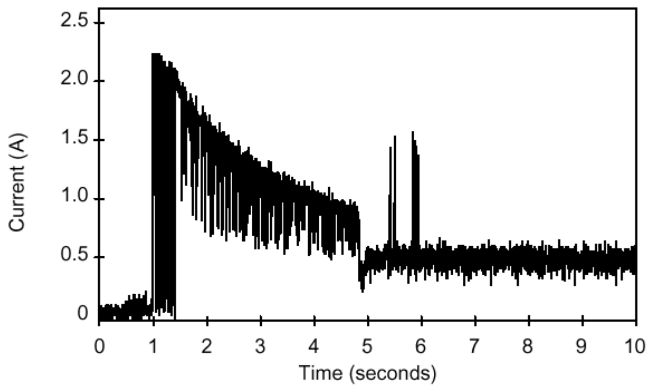
- Normally causes noise, heat, and vibration
- Good spindle motor:
  - **High quality**: Must be able to run for thousands of hours, and tolerate thousands of start and stop cycles (4000 – 10000 RPM), without failing
  - **High stability**: Must run smoothly and with a minimum of vibration
  - **Low noise & heat**: Must not generate excessive amounts of heat or noise.
  - **Low power supply**: Should not draw too much power

- To achieve these demands ⇒ Use a servo-controlled DC spindle motor
  - Same technology as is used in a voice coil actuator
- Platters:
  - Are machined with a hole the exact size of the spindle
  - Are placed onto the spindle with separator rings (spacers) between them to maintain the correct distance and provide room for the head arms



Spindle Speed (RPM)	Average Latency (Half Rotation) (ms)	Typical Current Applications
3,600	8.3	Former standard, now obsolete
4,200	7.1	Laptops
4,500	6.7	IBM Microdrive, laptops
4,900	6.1	Laptops
5,200	5.8	Obsolete
5,400	5.6	Low-end IDE/ATA, laptops
7,200	4.2	High-end IDE/ATA, Low-end SCSI
10,000	3.0	High-end SCSI
12,000	2.5	High-end SCSI
15,000	2.0	Top-of-the-line SCSI

Continuous Power vs. Peak Power at Spin-Up



- 12V power profile of an IDE/ATA hard disk at startup
- Require power management systems

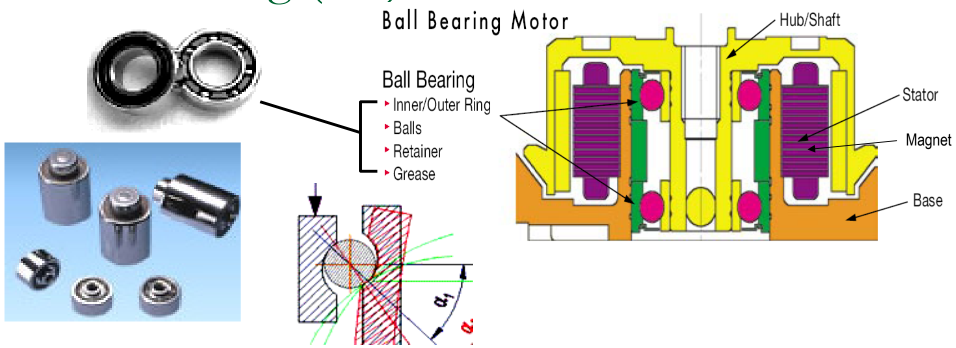
Power Management

- A set of protocols used to allow PCs to reduce the amount of power that they consume, especially when they lie idle.
- An example of power management schemes:
  - The HDD's spindle motor can be "spun down" after a certain amount of inactivity, and then can be "spun up" (reactivated) when the system needs it again.
  - Controversy ⇒ How much energy is really saved?
- Laptop users need power management
  - All laptop HDDs support power management via BIOS settings and/or operating system controls

Spindle Motor Bearing

- A critical component of the HDD's spindle motor is the set of spindle motor bearings.
- Bearing are precision components that are placed around the shaft of the motor
  - To support them and ensure that the spindle turns smoothly with no wobbling or vibration
- Increasing spindle motor speed requires many design challenges to keep vibration and heat under control.
- Two spindle motor bearings depending on mechanical design, i.e., ball bearing and fluid-dynamic bearing.

Ball Bearing (BB)



- Used in HDDs for many years
- Small metal balls are placed in a ring around the spindle motor shaft

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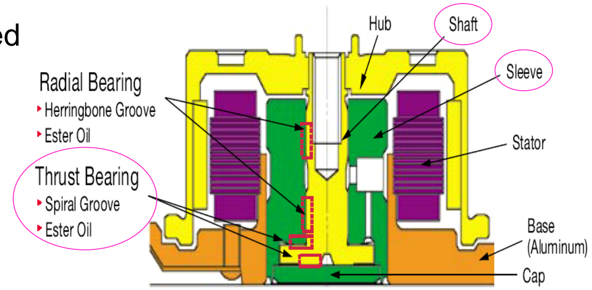
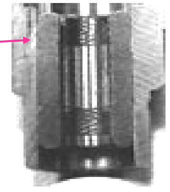
- Non-Repeatable Runout (NRRO) ⇒ any runout of the bearing that does not repeat when the appropriate ring, inner ring or outer ring, is rotated one complete revolution.
  - Cause Track Mis-Registration
  - Impact HDD performance
- BB motors produce large NRRO due to the mechanical contact (metal balls).
- There is an upper limit at which the BB design can no longer overcome the NRRO problem at the higher areal densities.
  - Ball Bearings ⇒ NRRO has settled in the 0.1 micro-inch range

Fluid-Dynamic Bearing (FDB)

- Metal balls are replaced with a thick oil
  - Reduce noise greatly
- Increase bearing life





- FDB generates less NRRO due to the higher viscosity of lubrication oil between the sleeve and stator.
  - Expect to limit NRRO in the range of 0.01 micro-inch.
- Properties of the FDB design
  - Higher damping
  - Reduced frequency resonance
  - Better non-operational shock resistance
  - Greater speed control
  - Improved acoustics.
- Non-operational shock improvement is a result of a much larger area of surface-to-surface contact.
  - Lubricant film provides additional damping to shock.

Performance Comparison

- FDB motor is better than BB motor:
  - Storage capacity
    - Support higher areal density
  - Acoustics (noise) $\Rightarrow$ due to dynamic motion of the disk and spindle motor components
    - Has lower acoustics due to having lubricant film and no metal-to-metal contact
  - Non-operation shock
    - More resistant to non-operational shock
  - Rotational speed
    - Achieve higher spinning speed