Computer Organization and Architecture

Memory System Design

(Date: 16/03/2023 and 17/03/2023)

Magnetic Disk

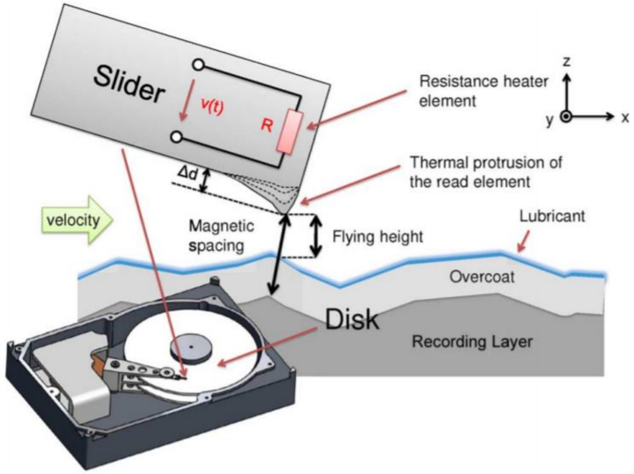
- A disk is a circular platter constructed of nonmagnetic material, called the substrate, coated with a magnetizable material
- Traditionally, the substrate used to be aluminum or aluminum alloy material
- More recently, glass substrates are introduced

The glass substrate has a number of benefits, including the following:

✓ Improvement in the uniformity of the magnetic film surface to increase disk reliability

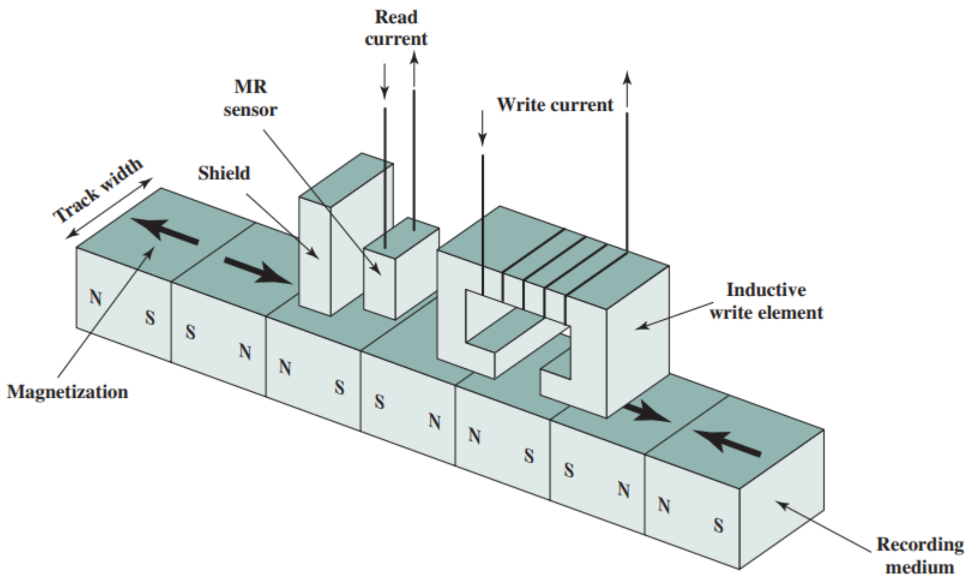
✓ A significant reduction in overall surface defects to help reduce read- write errors

✓ Ability to support lower fly heights



Ref: Computer Organization and Architecture Designing for Performance__ William Stallings
Ref: Uwe Boettcher et al., IEEE Tran. On Magnetics, 47, 7, 2011

- Data are recorded on and later retrieved from the disk via a conducting coil named the head (in many systems, there are two heads, a read head and a write head)
- During a read or write operation, the head is stationary while the platter rotates beneath it
- The write mechanism exploits the fact that electricity flowing through a coil produces a magnetic field
- Electric pulses are sent to the write head and the resulting magnetic patterns are recorded on the surface below (different patterns for positive and negative currents)
- An electric current in the wire induces a magnetic field across the gap, which in turn magnetizes a small area of the recording medium



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- The traditional read mechanism exploits the fact that a magnetic field moving relative to a coil produces an electrical current in the coil
- When the surface of the disk rotates under the head, it generates a current of the same polarity as the one already recorded
- The structure of the head for reading is in this case essentially the same as for writing and therefore the same head can be used for both
- Such single heads are used in floppy disk systems and in older rigid disk systems

✓ Contemporary rigid disk systems use **a different read mechanism, requiring a separate read head, positioned for convenience close to the write head**

✓ The read head consists of a partially shielded magnetoresistive (MR) sensor

✓ The MR material has an electrical resistance that depends on the direction of the magnetization of the medium moving under it

✓ By passing a current through the MR sensor, resistance changes are detected as voltage signals

○ The MR design allows higher- frequency operation, which equates to greater storage densities and operating speeds

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- The head is a relatively small device capable of reading from or writing to a portion of the platter rotating beneath it
- This gives rise to the organization of data on the platter in a concentric set of rings, called tracks
- Each track is the same width as the head
- There are thousands of tracks per surface
- Adjacent tracks are separated by intertrack gaps
- This prevents, or at least minimizes, errors due to misalignment of the head or simply interference of magnetic fields
- Data are transferred to and from the disk in sectors

✓ There are typically hundreds of sectors per track, and these may be of either fixed or variable length

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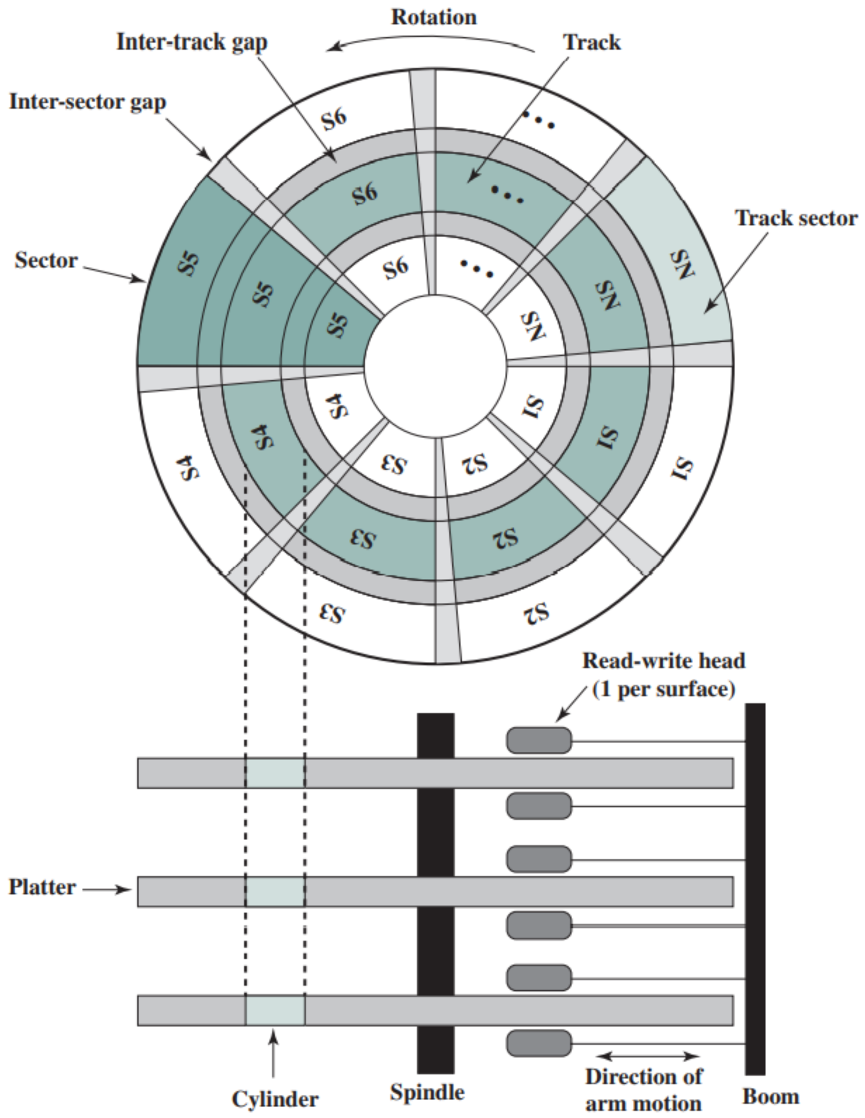


Disk Data Layout

- In most contemporary systems, fixed-length sectors are used, with 512 bytes being the nearly universal sector size

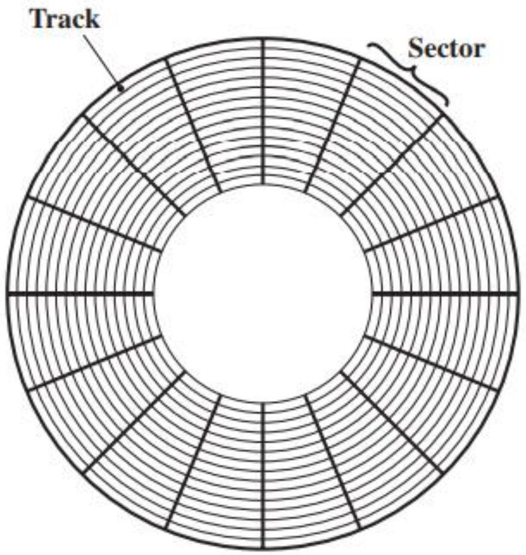
- To avoid imposing unreasonable precision requirements on the system, adjacent sectors are separated by intersector gaps

- A bit near the center of a rotating disk travels past a fixed point (such as a read– write head) with a different speed compared to that of a bit on the outside

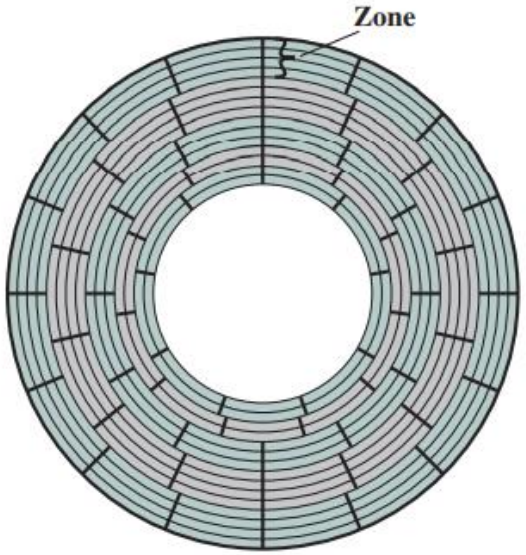
- Therefore, some way must be found to compensate for the variation in speed so that the head can read all the bits at the same rate

- This can be done by defining a variable spacing between bits of information recorded in locations on the disk, in a way that the outermost tracks have sectors with bigger spacing

✓ The information can then be scanned at the same rate by rotating the disk at a fixed speed, known as the constant angular velocity (CAV)



Constant angular velocity



Simplified MZR layout

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- ✓ The advantage of using CAV is that individual blocks of data can be directly addressed by track and sector
- ✓ To move the head from its current location to a specific address, it only takes a short movement of the head to a specific track and a short wait for the proper sector to spin under the head
- ○ The disadvantage of CAV is that the amount of data that can be stored on the long outer tracks is the only same as what can be stored on the short inner tracks
- ○ Because the density, in bits per linear inch, increases in moving from the outermost track to the innermost track, disk storage capacity in a straightforward CAV system is limited by the maximum recording density that can be achieved on the innermost track

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- ✓ Modern hard disk systems use simpler technique, which approximates equal bit density per track, known as multiple zone recording (MZR), in which the surface is divided into a number of concentric zones (16 is typical)

- ✓ **Zones far from the center contain more bits (more sectors) than zones closer to the center**

- ✓ **Zones are defined in such a way that the linear bit density is approximately the same on all tracks of the disk**

- ✓ <u>MZR allows for greater overall storage capacity at the expense of somewhat more complex circuitry</u>

- ✓ As the disk head moves from one zone to another, the length (along the track) of individual bits changes, causing a change in the timing for reads and writes

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Typical Hard Disk Drive Parameters

Characteristics	Seagate Enterprise	Seagate Barracuda XT	Seagate Cheetah NS	Seagate Laptop HDD
Application	Enterprise	Desktop	Network-attached storage, application servers	Laptop
Capacity	6 TB	3 TB	600 GB	2 TB
Average seek time	4.16 ms	N/A	3.9 ms read 4.2 ms write	13 ms
Spindle speed	7200 rpm	7200 rpm	10,075 rpm	5400 rpm
Average latency	4.16 ms	4.16 ms	2.98	5.6 ms
Maximum sustained transfer rate	216 MB/sec	149 MB/sec	97 MB/sec	300 MB/sec
Bytes per sector	512/4096	512	512	4096
Tracks per cylinder (number of platter surfaces)	8	10	8	4
Cache	128 MB	64 MB	16 MB	8 MB

- On a movable- head system, the time it takes to position the head at the track is known as seek time
- In either case, once the track is selected, the disk controller waits until the appropriate sector rotates to line up with the head
- The time it takes for the beginning of the sector to reach the head is known as rotational delay, or rotational latency
- The sum of the seek time, if any, and the rotational delay equals the access time, which is the time it takes to get into position to read or write

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Transfer time

(the time required for data the transfer)

The transfer time to or from the disk depends on the rotation speed of the disk in the following fashion:

$T = (b / rN)$

where, T = transfer time
b = number of bytes to be transferred
N = number of bytes on a track
r = rotation speed, in revolutions per second

Thus the total average read or write time T_{total} can be expressed as,

$$T_{total} = T_s + \frac{1}{2r} + \frac{b}{rN}$$

where T_s is the average seek time

- Note that on a zoned drive, the number of bytes per track is variable, complicating the calculation

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RAID (Redundant Array of Independent Disks)

➢ The rate in improvement in secondary storage performance has been considerably less than the rate for processors and main memory

➢ This mismatch has made the disk storage system perhaps the main focus of concern in improving overall computer system performance

- <u>Arrays of disks that operate independently and in para</u>llel

✓ With multiple disks, separate I/O requests can be handled in parallel, as long as the data required reside on separate disks

✓ With the use of multiple disks, there is a wide variety of ways in which the data can be organized and in which redundancy can be added to improve reliability

✓ Fortunately, industry has agreed on a standardized scheme for multiple-disk database design, known as RAID

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https://www.youtube.com/watch?v=NtPc0jI21i0