**Input/Output**

- Plates of magnetic material, organized in cylinders, divided in tracks, divided in sectors. Sectors go up to several hundreds. Heads vary from 1 to 16
- Some have little electronics, IDE drives have a microcontroller in the disk itself
- Controller: some can do overlapped seeks that is, while waiting for one seek to complete on one disk it can start another one on another disk

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**Disks**

**Example of the numbers**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>IBM 360K floppy</th>
<th>WD 18300 HD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of cylinders</td>
<td>20</td>
<td>9</td>
</tr>
<tr>
<td>Tracks per cylinder</td>
<td>12</td>
<td>9</td>
</tr>
<tr>
<td>Sectors per track</td>
<td>180</td>
<td>35</td>
</tr>
<tr>
<td>Sectors per disk</td>
<td>3.6k</td>
<td>512</td>
</tr>
<tr>
<td>Rotation speed</td>
<td>15500 rpm</td>
<td>1800rpm</td>
</tr>
<tr>
<td>Time per sector</td>
<td>0.8ms</td>
<td>6ms</td>
</tr>
<tr>
<td>Motor start/stop</td>
<td>20ms</td>
<td>6.9ms</td>
</tr>
<tr>
<td>Disk capacity</td>
<td>360Kb</td>
<td>18.3G</td>
</tr>
<tr>
<td>Bytes per sector</td>
<td>512</td>
<td>35742000</td>
</tr>
<tr>
<td>Sectors per disk</td>
<td>281</td>
<td>720</td>
</tr>
<tr>
<td>Tracks per cylinder</td>
<td>140</td>
<td>122</td>
</tr>
<tr>
<td>Number of cylinders</td>
<td>9</td>
<td>1060</td>
</tr>
</tbody>
</table>

**Organization of the disk**

- To simplify searching for sectors on the disk most disk presents:
  - A virtual organization in (c, t, s) that are mapped to the physical one
  - The number of sector per track changes as we move along the disk (minimum size of the magnetic site)
- On modern disks there's something called LBA (logical block addressing) where sectors are numbered sequentially without considering cylinder, track, or sector

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**Disk formatting**

- Cylinder skew
  - Start cylinders at different points to give the head time to jump from one to the next
- Interleaving
  - To give the controller time to transfer to main memory
- Scheduling of head movements
  - Controllers can schedule the movements of the head

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**Error handling**

- The controller can transparently take care of replacing a bad sector with a spare sector
- Bad sectors are due to wear and tear of the magnetic medium or construction defects (technology is always pushed to the extreme)
**Crash recovery**

- Two identical disks
  - Probability of same block spontaneously going bad on two disks is negligible
- Stable read:
  - Write block on disk 1, read it back (re-read until it works up to N times). This would eventually work. Write on disk 2. Same procedure. In absence of CPU crashes the block is written twice
- Stable write:
  - Read from block 1. Read up to N times. If disk 1 went bad for any reason, read from disk 2. Since a stable write always succeeds also the read succeeds.
- Crash recovery:
  - See next slide

The recovery program scans both disks.

If a pair is good nothing is done, if one has an error (ECC) copy the good one into the bad one. If a pair has both block good but different, write 1 onto 2.

**CD technology**

- Pits and lands:
  - Pit: depression in the plastic
  - Land: unburned area
- Different reflectance of the pits
  - It can be identified as a 1 or 0
- Recording follows a spiral
- Various materials for CD-R and CD-RW
- Improvement for DVD (also changed the laser wavelength)

**Clocks**

- Preventing one process to monopolize the CPU
- Maintaining the time of the day
- Accounting for CPU usage
- Handling ALARM signals
  - A device driver considers all the events (e.g. alarms) within the system (not a timer for every process/thread)
- Providing watchdog timers for part of the OS
  - e.g. timeouts – stop rotation of disk if not used
- Doing profiling, monitoring, statistics

**Soft timers**

- Handling an interrupt at each clock time would be too much
  - Interrupts involve delays
  - Can only be serviced with certain rates
- Idea! Why not calling the timer handling whenever in kernel mode
  - Occurrence of system calls, TLB misses, page faults, I/O interrupts, CPU idle, etc.
- Experimentally
  - Going in kernel mode on average between 2 and 18μs
- Combine soft timer with a lower frequency one
More...

- Terminals
  - Character oriented
  - Over a serial line
- GUIs
  - MS Windows (GUI into the kernel)
  - X-Windows (GUI as a user process, native networking)
    - X-server: does the display
    - X-client: an application
- In practice the controller is seen by the OS as a buffer (the video buffer) mapped in memory

Last but not least

- Since batteries are big, expensive, and not particularly efficient
- Need to save power
- Power management (on laptops)...
- …but also on desktop computers
  - For fun. Each desktop has 200W power supply, 85% efficient. 100000 PCs consume 20MW equivalent to 20 average-size nuclear power plants