Session: Hardware
Topic: Disks

Daniel Chang
Basic Components

Disks
- Considered I/O devices
- Used to hold data and programs before they are loaded to memory and used
- Data is stored as bits
- Have magnetic (hard) disks and optical disks

Issues
- Performance - Response Time (latency) and Throughput (bandwidth)
- Supported formats
Magnetic Disks (Hard)

- Store bits as magnetic direction

- Platters (1-15 per disk)
- Tracks (1000-5000 per platter surface)
- Sectors (64 to 200 per track) containing
  1. Sector Number
  2. Gap
  3. Data for sector
  4. Gap

- Platters are dual-sided (information on top and bottom)
- A Sector is the smallest unit of data that can be read or written
- Sector Data may contain error correction codes (e.g. CRC)
- Hard disks rotate at 3600 to 7200 RPM (also 10,000)
- Traditionally the same amount of information is stored in each track (so inner tracks are "denser")
- Newer disks with intelligent interfaces (SCSI) can allow for constant bit density (resulting in more data on outer tracks)
• Disk Read/Write Heads all connected to a single boom (actuator arm), and move together
• "Cylinder" indicates all the tracks on all surfaces under the heads at any one time
Disk Access Factors

Seek Time
- The time to move the arm to the desired track
- Often reported as "Average Seek Time" (of all possible seeks)
- Will actually be less due to locality in disk references
- Sequential data is often stored within the same Cylinder to minimize seeks
- Seek time is also not linear, as there is lift off, slow down, and stop vibration phases (moving 10 tracks <> 10 * moving 1 track)

Rotational Delay (Rotational Latency)
- The time for requested sector to rotate under the head
- The Average time would be halfway around the disk
- Example: for a 3600 RPM disk

\[
\text{Avg Latency} = \frac{0.5 \text{ revolutions}}{3600 \text{ RPM}} \\
= \frac{0.5 \text{ revolutions}}{60 \text{ RPS}} \\
= 0.0083 \text{ sec} = 8.3 \text{ ms}
\]

- Disks have been getting "smaller" as information density increases
- This reduces costs (less material), as well as reduces power requirements
- This also increases speed as smaller disks can be rotated faster, and more bits per second move under the head

Transfer Time (Transfer Rate*)
- The time to transfer data (a Sector) under the head
- Can be determined using bytes transferred, rotational speed, and bit density
Controller Time (Controller Overhead)

- Overhead time Disk Controller requires to process an I/O access
- Essentially the time needed to setup the disk access
- The Disk Controller is a specialized processor
- This time is usually a small percentage of overall access time since the actions are not mechanical
Average Access Time Example

- Consider a drive with 512-byte Sectors, rotating at 5400 RPM.
- The Average Seek Time is 12 ms, the Transfer Rate is 5 MB/s, and the Controller Overhead is 2 ms

\[
\text{AverageAccessTime} = \text{AverageSeekTime} + \text{AverageRotationalLatency} + \text{TransferTime} + \text{ControllerOverhead}
\]

\[
\text{AverageRotationalLatency} = \frac{0.5 \text{ revolutions}}{5400 \text{ RPM}} = \frac{0.5 \text{ revolutions}}{90 \text{ RPS}} = 0.00556 \text{ s} \approx 5.6 \text{ ms}
\]

\[
\text{TransferTime} = \frac{0.5 \text{ KB}}{5.0 \text{ MB/s}} = \frac{2^9 \text{ bytes}}{5 \times 2^{20} \text{ bytes/s}} = \frac{1 \text{ byte}}{5 \times 2^{11} \text{ bytes/s}} = 0.0000976 \text{ s} \approx 0.1 \text{ ms}
\]

\[
\text{AverageAccessTime} = 12 \text{ ms} + 5.6 \text{ ms} + 0.1 \text{ ms} + 2 \text{ ms} = 19.7 \text{ ms}
\]

Access Time

- Seek Time is the slowest component, followed by Rotational Latency
- However, Seek Time may often be 0 due to locality
- There can be additional delays if the disk is responding to other requests

Caches

- Modern disks include disk caches (within the disk drive itself)
- These caches contain data for sectors recently accessed or data for sectors following ones recently accessed
Interface
- Refers to the connection from the hard disk to the processor/computer
- Vary in maximum transfer rate possible from drive to system

ATA
- Many versions (also know as IDE, Parallel ATA, PATA)
- Ultra-ATA (also Ultra-DMA, ATA-33, DMA-33) supports up to 33 MB/s transfer rate
- ATA/66 supports up to 66 MB/s
- ATA/100 supports up to 100 MB/s
- ATA/133 supports up to 133 MB/s

Serial ATA
- Technically have not even saturated ATA/100 transfer rates
- Supports up to 150 MB/s
- Operates using less voltage, better power consumption
- Somewhat easier configuration and installation

<table>
<thead>
<tr>
<th>Parallel ATA</th>
<th>Serial ATA</th>
<th>SATA Advantage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to 133 MB/tes/sec</td>
<td>Up to 150 MB/tes/sec (1.5 Gbits/sec)</td>
<td>Faster, and room for expansion</td>
</tr>
<tr>
<td>Tiny jumpers</td>
<td>No master/slave, point to point</td>
<td>Ease of use</td>
</tr>
<tr>
<td>Eighteen-inch cable</td>
<td>Up to 39-inch (1-meter) cable</td>
<td>Ease of integration</td>
</tr>
<tr>
<td>Two inch wide ribbon cable</td>
<td>Thin cable (1/4 inch)</td>
<td>Improved system airflow</td>
</tr>
<tr>
<td>80 conductor</td>
<td>7 wire differential (noise canceling)</td>
<td>Eliminates data integrity problems</td>
</tr>
<tr>
<td>40 pin and socket</td>
<td>Blade and beam connector (snap-in)</td>
<td>Ease of use</td>
</tr>
<tr>
<td>Two-inch-wide data connector</td>
<td>1/2-inch-wide data connector</td>
<td>Ease of integration</td>
</tr>
<tr>
<td>Onboard DMA controller</td>
<td>First-party DMA support</td>
<td>Performance enhancement</td>
</tr>
<tr>
<td>High 5V tolerance for legacy drives</td>
<td>1.8V voltage (.25V) tolerance</td>
<td>Design improvement</td>
</tr>
<tr>
<td>Limited (legacy command queuing)</td>
<td>Intelligent Data Handling</td>
<td>Performance enhancement</td>
</tr>
<tr>
<td>—</td>
<td>Hot Swap</td>
<td>Ease of integration/upgrade</td>
</tr>
<tr>
<td>CRC on data only</td>
<td>CRC on data, command, status</td>
<td>Enhanced data protection</td>
</tr>
</tbody>
</table>

Reference: Seagate Technology
ATA Configuration

- Have "channels" in a system (typically two or four)
- Each channel can have up to two (2) drives, connected with a single cable
- Must also connect power cable to drive

Ultra ATA data cable (ribbon)

Jumper Settings

- On a single channel with two (2) drives, one must be the "Master" and one must be the "Slave"
- Drives must have "jumpers" set to indicate channel status (Single, Master, Slave)
- "Cable Select" sets drive status based on where the drive connects to the cable
Serial ATA Configuration
• Just plug it in
• Thinner cables and smaller connectors

Hard Drive Vendors
• Maxtor
• Seagate
• Western Digital
• Fujitsu
• Samsung
• Many Others
# Seagate Barracuda 7200.8 Series - Data Sheet

<table>
<thead>
<tr>
<th>Specifications</th>
<th>400GB</th>
<th>300GB</th>
<th>250GB</th>
<th>200GB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model Number</td>
<td>ST3400832AS</td>
<td>ST3300831AS</td>
<td>ST3250833AS</td>
<td>ST3200826AS</td>
</tr>
<tr>
<td>Interface/External Transfer Rate (MB/s)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(MB/s/sec)</td>
<td>SAA/50 NCQ</td>
<td>SAA/150 NCQ</td>
<td>SAA/150 NCQ</td>
<td>SAA/150 NCQ</td>
</tr>
<tr>
<td>Maximum Internal (MB/s)</td>
<td>95</td>
<td>95</td>
<td>95</td>
<td>95</td>
</tr>
<tr>
<td>Maximum External (MB/s)</td>
<td>126/100</td>
<td>136/100</td>
<td>136/100</td>
<td>136/100</td>
</tr>
<tr>
<td>Sustained Transfer Rate (KB/s)</td>
<td>65</td>
<td>65</td>
<td>65</td>
<td>65</td>
</tr>
<tr>
<td>Cache, Multi-segmented (MB)</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Average Seek (msec)</td>
<td>4.16</td>
<td>4.16</td>
<td>4.16</td>
<td>4.16</td>
</tr>
<tr>
<td>Average Latency (msec)</td>
<td>7200</td>
<td>7200</td>
<td>7200</td>
<td>7200</td>
</tr>
<tr>
<td>Spindle Speed (RPM)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

## Configuration/Organization
- **Available Sectors**: 781,422,768
- **Bytes per Sector**: 512
- **Logical Cylinders**: 16,383/63
- **Recording Method**: EPROM/16/17

## Reliability/Data Integrity
- **Contact Start-Stop**: 50,000
- **Non-recoverable Read Errors per 8K Read**: 1 per 10^8
- **Limited Warranty (years)**: 5

## Power Management
- **+12VDC ±10% (amps peak)**: 2.8
- **Power Management (watts)**: 1.2
- **Operating Avg**: 12.8
- **Idle Avg**: 1.2
- **Standby Avg (SATA/PW)**: 1.4/0.8

## Environmental
- **Temperature, Operating (°C)**: 0°C to 60°C
- **Temperature, Nonoperating (°C)**: -40 to 70°C
- **Shock, Operating (2 m/sec², 0.5 s)**: 125
- **Shock, Nonoperating (2 m/sec², 0.5 s)**: 150
- **Acoustics (idle—sound power)**: 2.8
- **Quiet Seek (idle—sound power)**: 3.2

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# Maxtor DiamondMax 10 Series - Data Sheet

## ORDER INFORMATION

<table>
<thead>
<tr>
<th>Capacity</th>
<th>80GB</th>
<th>120GB</th>
<th>160GB</th>
<th>200GB</th>
<th>250GB</th>
<th>300GB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Serial ATA/150 8 MB buffer</td>
<td>6B00M0</td>
<td>6B12M0</td>
<td>6B16M0</td>
<td>6B20M0</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Model</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Serial ATA/150 16 MB buffer</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>6B250S0</td>
<td>6B300S0</td>
</tr>
<tr>
<td>Model</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ATA/133 8MB buffer</td>
<td>—</td>
<td>—</td>
<td>6B16P0</td>
<td>6B20P0</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Model</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ATA/133 16MB buffer</td>
<td>—</td>
<td>—</td>
<td>6B250R0</td>
<td>6B300R0</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

## RoHS Compliant Version

| Model             |      |       |       |       |       |       |
| Serial ATA/150 8 MB buffer | 6L080M0 | 6L120M0 | 6L160M0 | 6L200M0 | —     | —     |
| Model             |      |       |       |       |       |       |
| Serial ATA/150 16 MB buffer | —     | —     | —     | —     | 6L250S0 | 6L300S0 |
| Model             |      |       |       |       |       |       |
| ATA/133 8MB buffer | 6L080P0 | 6L120P0 | 6L160P0 | 6L200P0 | —     | —     |
| Model             |      |       |       |       |       |       |
| ATA/133 16MB buffer | —     | —     | —     | —     | 6L250R0 | 6L300R0 |

## SPECIFICATIONS

### Performance Specifications

- **Rotational Speed**: 7200 RPM
- **Buffer Size**: 80GB, 120GB, 160GB, 200GB: 8MB, 250GB, 300GB: 16MB
- **External Data Transfer Rate (MB/sec)**
  - **Serial ATA**: 150
  - **Parallel ATA**: 133
- **Average Seek (ms)**: <5.0
- **Average Latency (ms)**: 4.17

### Reliability Specifications

- **Start/Stop Cycles (min)**: >50,000
- **Component Design Life (min)**: 5 years
- **Annualized Return Rate (ARR)**: <1%

### Environmental Limits

- **Temperature**
  - **Operating (°C)**: 0 to 60
  - **Non-operating (°C)**: -40 to 71
- **Shock**
  - **Operating Mechanical Shock 2ms (G)**: 60
  - **Non-operating Mechanical Shock 2ms (G)**: 300

### Physical Dimensions

- **Width (max mm)**: 101.8
- **Length (typical mm)**: 147
- **Height (max mm)**: 28.1
- **Weight max (LB)**: 1.39

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Optical Storage
- CD and DVD store bits using reflective medium
- Reflection of laser indicates a 0. A hole (pit) will not reflect, indicating a 1

Operations
- Optical drives can support various levels of reading and writing

<table>
<thead>
<tr>
<th>Term</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ROM</td>
<td>Can only read media</td>
</tr>
<tr>
<td>R</td>
<td>Can read media and write media once</td>
</tr>
<tr>
<td>RW</td>
<td>Can read media, write media, and then erase and rewrite media</td>
</tr>
</tbody>
</table>
DVD Formats
- DVD supports multiple "R" and "RW" formats
- Each has a "Plus" (+) and "Dash" (-) format
- For DVD video (or DVD players that support playing MP3 files or AVI/DIVX video files), player must also support format
- Generally (+) is a newer format, (-) is more compatible with older DVD players
- Buy a drive and DVD player that supports all formats ("Combo Drive")

<table>
<thead>
<tr>
<th></th>
<th>Standard</th>
<th>Write</th>
<th>Write/Rewrite</th>
</tr>
</thead>
<tbody>
<tr>
<td>CD</td>
<td>CD, CD-ROM</td>
<td>CD-R</td>
<td>CD-RW</td>
</tr>
<tr>
<td>DVD</td>
<td>DVD</td>
<td>DVD-R</td>
<td>DVD-RW</td>
</tr>
<tr>
<td></td>
<td></td>
<td>DVD+R</td>
<td>DVD+RW</td>
</tr>
<tr>
<td></td>
<td></td>
<td>DVD+R DL</td>
<td></td>
</tr>
</tbody>
</table>

General Compatibility
- Drives can sometimes read unsupported formats
- Drives are less likely to read unsupported formats of different symbol type (+, -)
- Drives can **never** write unsupported format
- Generally RW drives can write R drives of same symbol
Optical Media
- Disc used must also be able to support attempted operation
- For example, to write data at least an "R" or "RW" disc must be used

Storage Sizes

<table>
<thead>
<tr>
<th>Type</th>
<th>Maximum Storage</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>CD</td>
<td>700 MB (80 min if creating audio CD)</td>
<td>$33 for 100 ($0.33 ea)</td>
</tr>
<tr>
<td>DVD</td>
<td>4.7 GB (120 min if creating video DVD)</td>
<td>$18 for 50 ($0.36 ea)</td>
</tr>
<tr>
<td>DVD-DL</td>
<td>8.5 GB (&quot;Dual-Layer&quot;)</td>
<td>$30 for 15 ($2.00 ea)</td>
</tr>
</tbody>
</table>

Speeds
- Given in "x" (number of times faster than standard read speed)
- Read speeds are generally faster than write speeds
- Drives have maximum speed, but media also has a speed
- CD write speeds: 32x - 52x
- DVD write speeds: 8x - 16x
- DVD-DL write speeds: 2.4x

Installation
- Optical drives are ATA devices, installed like an ATA hard drive
- Have jumpers for setting "Master" or "Slave" status
- Some optical drives perform better with DRM encoded material than others
Samples

NEC Black IDE DVD Burner (ND-3540A)
- $39 (October 2005 - www.newegg.com)

<table>
<thead>
<tr>
<th></th>
<th>Standard</th>
<th>Write</th>
<th>Write/Rewrite</th>
</tr>
</thead>
<tbody>
<tr>
<td>CD</td>
<td>48x CD-ROM</td>
<td>48x CD-R</td>
<td>32x CD-RW</td>
</tr>
<tr>
<td>DVD</td>
<td>16x DVD</td>
<td>16x DVD-R</td>
<td>6x DVD-RW</td>
</tr>
<tr>
<td></td>
<td></td>
<td>16x DVD+R</td>
<td>8x DVD+RW</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>8x DVD+R DL</td>
</tr>
</tbody>
</table>

- Other brands: Lite-On

Sony Progressive Scan DVD Player (DVPNS50P/S)
- $80 (October 2005 - www.bestbuy.com)
- JPEG viewer, MP3 playback
- Progressive scan output
- Supports:

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<th>Write</th>
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<td>DVD</td>
<td>DVD-R</td>
<td>DVD-RW</td>
</tr>
<tr>
<td></td>
<td></td>
<td>DVD+R</td>
<td>DVD+RW</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>DVD+R DL</td>
</tr>
</tbody>
</table>

Sony 50-Pack 8x DVD+R (50DPR47LS2)
- $80 (On sale this week - Best Buy)
Examples

DVD Drive supports CD, DVD, DVD+R
  • Can read CD, DVD, and DVD+R
  • Maybe can read DVD+RW
  • Less likely to read DVD-R, DVD-RW
  • Cannot write (or rewrite) DVD-R, DVD-RW

DVD Drive supports 32x CD-R, 16x DVD, 8x DVD+R
  • Can write 32x CD-R media at 32x
  • Can write 24x CD-R media at 24x (may cause errors if use maximum possible speed)
  • Can write 16x DVD+R media at 8x (only)
Future Directions

RAID
- Redundant Array of Inexpensive Disks
- Uses Striping and Independent Access to increase throughput
- Allows for automatic data recovery

Optical Storage
- DVD+R DL (Dual Layer) offers 8.5 GB Capacity (Sony DRU-710A $130)
- Blu-ray Disc technology uses blue-violet laser (short λ) technology to achieve 27 GB storage on DVD-size disc

Holographic Storage
- Data is stored through full volume of medium
- Data is recorded using the interference of a reference beam and a signal beam (which is varied to represent bit data using a Spatial Light Modulator) within a light sensitive storage medium
- Varying the reference beam angle, wavelength, or the media position allows for multiple holograms to be recorded in the same volume of material
- Data is read by directing the reference beam through the material, and projecting the resulting reconstructed hologram onto a detector that reads the data in parallel