Microdrive: High Capacity Storage for the Handheld Revolution

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IBM Mobile Storage Development
Fujisawa, Japan

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San Jose, CA
Recent History

Autumn 1998
Technology
Introduction

June 1999
Gen 1 Product

June 2000
Gen 2 Product
CompactFlash Type II Form Factor

- CompactFlash type I already established as leading storage form factor for cameras, hand-held PCs
- Type II (introduced by CFA 12/98) is identical to Type I except height increased from 3.3 mm to 5 mm
- Microdrive brings high capacity HDD storage to hand-held devices
# Microdrive: Selected Specs

<table>
<thead>
<tr>
<th>Specification</th>
<th>Gen 1 (340 MB)</th>
<th>Gen 2 (1.0 GB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dimensions</td>
<td>42.8 x 36.4 x 5.0 mm</td>
<td>42.8 x 36.4 x 5.0 mm</td>
</tr>
<tr>
<td>Capacity</td>
<td>340 / 170 MB</td>
<td>340 / 512 MB/ 1.0 GB</td>
</tr>
<tr>
<td>Disk diameter</td>
<td>27.4 mm</td>
<td>27.4 mm</td>
</tr>
<tr>
<td>Areal Density (Gb/sq.in.)</td>
<td>5.04 (Max)</td>
<td>15.2 (Max)</td>
</tr>
<tr>
<td>Avg Seek Time</td>
<td>15ms</td>
<td>12ms</td>
</tr>
<tr>
<td>Data Rate (MB/s)</td>
<td>3.2 (Max)</td>
<td>4.2 (Max)</td>
</tr>
<tr>
<td>Rotational Speed (RPM)</td>
<td>4500</td>
<td>3600</td>
</tr>
<tr>
<td>Power Requirements</td>
<td>+3.3 v, 5.0 v +/- 5%</td>
<td>+3.3 v, 5.0 v +/- 5%</td>
</tr>
<tr>
<td>- Spin Up</td>
<td>260mA</td>
<td>260mA</td>
</tr>
<tr>
<td>- Read/Write</td>
<td>300mA</td>
<td>250mA</td>
</tr>
<tr>
<td>- Idle</td>
<td>220mA</td>
<td>140mA</td>
</tr>
<tr>
<td>- Standby</td>
<td>65mA</td>
<td>20mA</td>
</tr>
<tr>
<td>Shock: - Non-OP</td>
<td>1000 G</td>
<td>1500 G</td>
</tr>
<tr>
<td>- Operating</td>
<td>150 G</td>
<td>175 G</td>
</tr>
<tr>
<td>Weight</td>
<td>16g</td>
<td>16 g</td>
</tr>
<tr>
<td>Interface</td>
<td>CF (ATA)</td>
<td>CF (ATA)</td>
</tr>
</tbody>
</table>
Microdrive Technology
Are micromechanics required to make a microdrive?

- Microdrive project started with goal of using MEMS to make a disk drive....

(L.S. Fan)
Microdrive: Intelligently Scaled Conventional Design

- Properly scaled conventional designs turned out to be a cheaper and better approach.

- MEMS technology is not ready to replace most components yet:
  - bearings (lubrication and life)
  - motors (available torque)
  - expense (too high)
Electronics Card

- Total card area: 10 cm²
- double sided (most on one side)
- 6X smaller than 2.5" HDD card, with all the same functions
- All modules: direct chip attach (no package, no wire bonding)
- One of the most compact electronics cards in industry today
- card thickness: 0.4 mm (4 layer)
- component height: 0.9 mm

![Image of electronics card with marked components: RAM, CONTROLLER, SPIN/VCM, CHANNEL.]
Spindle Motor

- rotating mass dominated by spindle rotor, not disk (unlike most drives)
- oversize (not scaled) bearings (for manufacturability, shock resistance)
- reduced mass (increased resistance to linear shock)
- reduced rotational inertia (spin up time ~ 0.5 sec)
- reduced tilt inertia (increased resistance to rotational shock)
- increased Kt (more room for windings)
- 12-pole 9-slot design; $K_t = 0.0025 \text{ Nm/A}$
- future: fluid dynamic bearing (higher track dens, better acoustics, better shock)
Actuator

- transfer function clean out to ~ 7 kHz
- similar to moving-suspension secondary actuators in larger drives
- may achieve dual-stage performance without second stage

- 127 turn coil
- overmolded plastic carriage
- integrated lead suspension
- $K_t \sim 0.002 \text{ Nm/A}$
- $I \sim 0.1 \text{ g cm}^2$
Air Bearing

Can a conventional ABS work in a microdrive?

Requirements:
- 2.2 - 4.2 m/sec linear velocity
- sub 1 microinch FH
- good tolerances

nano ABS from early prototype

ILS suspension with pico slider

pico subambient pad ABS used in product
Load/Unload

SPINDLE TORQUE TOO LOW FOR CONTACT START-STOP

- limited coil winding space
- CompactFlash requires 3.3 V operation, limits $K_t$
- oversize bearing (not scaled) results in disproportionately high drag

OTHER ADVANTAGES OF L/UL

- increased nonoperating shock resistance (eliminates head slap)
- elimination of stiction/wear failures
- reduced power consumption (unlimited start/stops for aggressive power savings)
- increased areal density (smooth disk for low noise, low flying height)
- ease of assembly (no head merge operation)
Design Considerations for SHOCK

- Microdrive has 1500 G nonop shock spec (industry best)

- Contributing factors:
  - Load/Unload (eliminate head slap)
  - Oversize spindle and actuator bearings (higher brineling threshold)
  - Suspension limiters (prevent gimbal damage, slider-slider contact)
  - Inertia latch (keep actuator reliably parked)
  - "True Track" super-harmonic servo (allows for some disk slip)

For "throw it against the wall" durability:

Compact shock mounting system from Edapting Solutions
Microdrive Applications
Microdrive Opportunity

Information Appliances

removable storage

subnotebook PCs

PC cards

printers

communications: PC, cellular, pager

voice recognition

MPEG4 video players

MP3 audio players

dictionaries

digital still cameras

digital video cameras

GPS

games

Consumer Electronics
even a small percentage penetration into these markets represents significant volume
Digital Cameras

- most popular use of Microdrive

- image capacity for 1 GB:
  - Casio QV3000 camera (3.3 Mpel)
  - compressed:
    - 710 images @ 2048 x 1530 pel
    - 2750 images @ 1024 x 768 pel
  - uncompressed:
    - 100 images @ 2048 x 1530 pel

- uncompressed images:
  - superior quality
  - better for subsequent editing
  - 10 MB per image @ 3.3 MP
  - only practical with Microdrive
MP3 Audio Players

- MPEG-1 audio layer 3
- compressed audio (16X smaller than CD)
- data rate 128 kb/sec (16 KB/sec, ~1 MB/min)
- competition uses solid state flash memory (typically 32-128 MB)
- flash is not a very good solution (too expensive)
- high capacity of Microdrive is ideal

Microdrive-based MP3 Player designed by e.Digital (coming to market soon)
Mythical Problem: Microdrive Power Consumption

- Flash memory card
  - 35 mA @ 3.3 V
- IBM Microdrive
  - 300 mA @ 3.3 V
- MP3 player electronics
  - 70 mA @ 3.3 V

- Total 105 mA @ 3.3 V

There is a better way...

- Total 370 mA @ 3.3 V
  - 3.6 X more current
  - more than 5X shorter battery life
Solution: Add a Data Buffer

- MP3 data rate: 16 KB/sec
- Microdrive minimum sustained data rate: 1.8 MB/sec
- Microdrive is > 100X too fast!

- Microdrive consumes only 15% of total power
- negligible effect on battery life vs. flash memory
- 10-20 hrs battery life with pair of AA batteries
Digital Video Players
Enterprise to Entertainment

MPEG4 Video with 8 MB buffer

<table>
<thead>
<tr>
<th>Data Rate</th>
<th>Duty Cycle*</th>
<th>Ave. Current</th>
</tr>
</thead>
<tbody>
<tr>
<td>300 kb/s</td>
<td>3.3%</td>
<td>8 mA</td>
</tr>
<tr>
<td>1 Mb/s</td>
<td>10%</td>
<td>25 mA</td>
</tr>
<tr>
<td>1.6 Mb/s</td>
<td>15%</td>
<td>38 mA</td>
</tr>
</tbody>
</table>

Assumptions:
- 2 MB/sec sustained data rate
- 2 seconds overhead per buffer cycle

Negligible effect on battery life vs flash memory
1 inch today => 1 cm tomorrow?

Price trends for storage

Microdrive market occupies widening gap between flash and larger HDDs
Fixed costs of HDDs needs to be reduced before further downward scaling in size (Flash scales down better)
Microdrive: Summary

- World's smallest, lightest HDD
- World's lowest power HDD
- World's most shock resistant HDD
- Based on intelligently scaled conventional design
- Most important applications:
  - digital cameras
  - MP3 audio players
  - MPEG4 video players
- Achieves excellent battery life in sequential access applications (audio, video)