The Write Endurance of SSDs –
Is MLC NAND Fit for Data Centers?

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Agenda

☐ MLC vs. SLC NAND
☐ What does endurance really mean?
☐ How much endurance is really needed?
☐ How to make MLC fit for enterprise?
### MLC vs. SLC NAND

<table>
<thead>
<tr>
<th></th>
<th>SLC</th>
<th>MLC</th>
<th>Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>$/GB*</td>
<td>$6.75</td>
<td>$1.41</td>
<td>X4.8</td>
</tr>
<tr>
<td>Endurance</td>
<td>50K-100K</td>
<td>3K</td>
<td>X20+</td>
</tr>
<tr>
<td>Failure Rate</td>
<td>100 PPM</td>
<td>5000 PPM</td>
<td>X50</td>
</tr>
</tbody>
</table>


#### Diagram

![Graph showing MLC vs. SLC NAND performance on a cost-effectiveness vs. reliability axis.](image-url)
What Does Endurance Really Mean?

- **Flash Endurance:**
  - The number of times each flash cell can be programmed and erased before it is unusable
  - Specified in Program/Erase cycles

- **Drive Endurance:**
  - The number of times the full media can be written, before it is unusable
  - Can be specified in media cycles/day for 5 year
How to Translate Flash Endurance to Drive Endurance
Write Amplification

- Write Amplification:
- Why Write Amplification?
  - The main reason: garbage collection
  - Efficient garbage collection can reduce write amplification by half

Amount of data written to the drive

Amount of data written by the user

Unused (over provision)

Initial state

Intermediate state

After copy and refill block

Copy

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Over Provisioning

- Over Provisioning: \[ \frac{\text{Spare flash size}}{\text{Usable media size}} \]

- High over provisioning \(\rightarrow\)
  - Larger average number of punches per block \(\rightarrow\)
  - Less pages to copy \(\rightarrow\)
  - Lower write amplification (higher efficiency)
Methods To Reduce Write Amplification

- Increase Over Provisioning

- Compression
  - The Benefit
    - Less data to write
    - The gained capacity is used for overprovision
  - The Downside - Data Dependent Pattern
    - Will not work when data is encrypted at application level
    - Will not work when most of the data is compressed (e.g. MS Windows)

- TRIM Command
  - In order to improve the overprovisioning, OS is requested to notify the drive which LBA are not used
  - Very basic TRIM support is implemented in Win 7, eMMC4.4 & Server 2008 R2
Drive Endurance vs. NAND Endurance

- Calculated for fully random, non-compressible data
- Assuming efficient garbage collection
How Much Endurance Is Really Needed?

Matching NAND and Application:
How to Make MLC Fit for Enterprise
"Enterprise MLC"

- High endurance MLC process
- Methods:
  - Screening parts, based on in-process variations
  - Reduced program performance
- Downside:
  - Requires special process handling
    - Enterprise SSD market is forecasted at 6% of the NAND market (~$2B out of ~$30B in 2015)
    - Will the NAND vendors commit a special process for this market size?
  - Reduced program performance
MSPTM – Memory Signal Processing

Over 60 patent applications

Error Reduction

- Compensates for process and array impairments
  Cross coupling, Read disturbs, Program disturbs, Data retention impairments, Endurance impairments

Error Correction

- Advanced ECC with improved error correction capabilities
MLC + MSP – The "Holy Grail"

- Endurance: ~50K
- Reliability: ~100PPM
- No special process handling: use consumer MLC
Impact on the Industry

Impact of Flash Signal Processing on SSD Market

*Source: Forward Insights, August 2010
About Anobit

- Founded in 2006
- Based in Israel
- Subsidiaries in the US and Korea
- 130 Employees
Thank You