CompactFlash Series 5

Endurance Report for Industrial CompactFlash Card

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Endurance

Overview

Endurance encompasses the x-factor list in SSDs that determines the effective service life of an SSD and defines the amount of written data an SSD's ability of retentiveness before coming to the end of its rated life. There is no absolute one-to-one relationship between the number of host writes and the actual writes performed to the NAND, and not every NAND block reaches to the end of it's life (rated maximum number of erases) concurrently. Since SSD endurance relies on the maximum erases for any of the blocks on the NAND, both the write amplification and wear leveling efficiency must be accounted for in determining an expected endurance rating.

SSD Endurance Impact List

Several factors impact the resulting SSD endurance including the efficiency of the wear leveling algorithms, the write efficiency (as write amplification), the cycling capability of the NAND components, and the nature of the applied workload.

Wear Leveling Efficiency

Wear leveling efficiency is defined as the ration of the average number of erases on all blocks across the entire SSD to the maximum erases on any block on the NAND. Hence, a formula concluded as below.

$$WearLevelingEfficiency = \frac{AverageErasesAcrossAllBlocks}{MaximumErasesOnAnyBlock}$$

Write Amplification

The amount of data written to the NAND components is usually greater than the amount of data written by the host. A number of different factors contribute to the amount of data written to the NAND exceeding the amount written by the host including such NAND management functions as wear leveling.

Write amplification is defined as the amount of data written to the NAND divided by the amount of data written by the host for a given host input stimulus such as below.

$$WriteAmp = \frac{TotalDataWrittenToNAND}{TotalDataWrittenByHost}$$

NAND Cycling Capability

At SSD level, the NAND cycling capability will be a combination of the component rating and the SSD controller error correction capabilities.

SSD Capacity

SSD capacity is the size of the pool of blocks over which the wear is applied. The capacity is typically larger than the reported capacity of the SSD and smaller than the total physical NAND capacity. The capacity should be de-rated by the number of defective blocks at the end of SSD's life.

SSD Endurance Measurement

The SSD endurance measurement is based on the fundamental relationship describing the number of cycles that are put on the most-cycled block in an SSD for a given workload. This relationship is described as below.

$$NANDCycles = \frac{(HostWrites) \times (WriteAmplificationFactor)}{(SSDCapacity) \times (WearLevelingEfficiency)}$$

Because NAND cycles may not be helpful to conveniently express expected endurance, the fundamental cycling equation is re-factored as below.

$$HostWrites = \frac{(NANDCycles) \times (SSDCapacity) \times (WearLevelingEfficiency)}{(WriteAmplificationFactor)}$$

SSD Endurance Measurement Example

Assume a particular SSD has the following characteristics as measured using the methods described in the earlier sections of this paper:

- SSD Capacity = 8GB
- NAND max cycles = 60,000
- Write Amplification Factor = 11.7
- Wear Leveling Efficiency = 0.89
- Rated life = 5 years

In the equation for host writes yields the following:

$$HostWrites = \frac{(60000cycles)x(8GB)x(0.89)}{11.7}$$

$$HostWrites = 36512.82 \text{ GB}$$

$$TBW = 36.51 \text{ TB}$$

The SSD endurance is expressed as maximum average host writes per day for the rated life of the drive. Therefore, for a drive with a rated life of 5 years:

$$Endurance = \frac{(HostWrites)}{(RatedLifeYears)x(365)}$$

$$Endurance = \frac{(36512.82GB)}{(5)x(365)} = 20GB/Day$$

The hypothetical SSD in the example above has an endurance metric of 20GB writes per day for its rated life-span of 5 years with a workload representative of that used to measure the core SSD endurance parameters.

Apacer CF5 endurance estimate results

Below endurance estimate results can be applied on CF5 SLC series

Write Amplification Factor*1	11.7
Wear Leveling Efficiency*2	0.89

Capacity	Flash Amount	NAND max cycle*3	TBW (TB) *4	Assumed Client Daily Workload	Lifetime (YEARS)
128 MB	1	60K	0.58	1 GB	1.6
256 MB	2	60K	1.16		3.2
512 MB	2	60K	2.33		6.4
1 GB	2	60K	4.56		12.5
2 GB	2	60K	9.12		25
4 GB	2	60K	18.25		50.01
8 GB	2	60K	36.51		100.03
16 GB	2	60K	73.02		200.07
32 GB	2	60K	146.05		400.14
64 GB	4	60K	292.1		800.28

*1.2 - The Lifetime values of this report were estimated by same WAF/WLE, rough values for reference. In real condition, WAF/WLE will vary with writing behavior on each platform.
*3 - Flash vendor guaranteed SLC P/E cycle: Toshiba - 60K; Micron – 60K.
*4 - 1 Terabyte = 1000 GB

Revision History

Revision	Date	Description	Remark
1.0	07/03/2012	Official released	
1.1	08/02/2013	Update NAND max cycle Phase in Toshiba 43nm 60K to replace Samsung 42nm 100K for 128MB~8GB capacity	

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