Apacer

Endurance

White Paper

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1. Introduction

This whitepaper outlines a method to determine a rated endurance metric for SSDs. The manufacturer's test described here for deriving SSD endurance may be supplemented by a corresponding customer's test for validating the manufacturer's claims.

Endurance is a key metric in SSDs that determines the effective service life of an SSD and defines the amount of writing an SSD can sustain before reaching the end of its rated life. In SSDs there isn't a one-to-one relationship between the number of host writes and the actual writes performed to the NAND, and not all NAND blocks reach their end of life at the same time.

Since SSD endurance depends 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.

This whitepaper defines:

- The factors that determine SSD endurance.
- Measurement techniques for determining an SSD endurance rating.

Refer to the JEDEC - JESD218A, JESD219 documents for workloads to be used for characterizing SSD endurance.

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2. 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.

2.1 Wear Leveling Efficiency

Wear leveling efficiency is defined as the ratio of the average number of erases on all blocks across the entire SSD to the maximum erases on any block on the NAND. This formula can be expressed as:

$$WearLevelingEfficiency = \frac{AverageEraseseAcross\,AllBlocks}{MaximumEraseOnAnyBlock}$$

2.2 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.

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

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2.3 NAND Cycling Capability

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

2.4 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.

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3. 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.

$$NANDCycle = \frac{(HostWrites) * (WriteAmplificationFactor)}{(SSDCapacity) * (WearLevelingEfficiency)}$$

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

$$TeraBytes\ Written = \frac{(NANDCycle) * (SSDCapacity) * (WearLevelingEfficiency)}{(WriteAmplificationFactor)}$$

Drive Writes Per Day (DWPD) is calculated as the number of times that user can overwrite the entire capacity of an SSD per day of its lifetime during the warranty period.

$$Drive\ Write\ Per\ Day = \frac{(TBW)}{(Capacity) * (Warranty) * 365}$$

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4. 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 = 240GB
- NAND max cycles = 3,000
- Write Amplification Factor = 1.21
- Wear Leveling Efficiency ≒ 1
- Endurance Measurement : A. Daily Work Load = 480GB
  B. Rated life = 2 years
  C. 3D NAND TLC warranty = 2 years

In the equation for host writes yields the following:

$$TeraBytes\ Written = \frac{(3000cycle) * (240GB) * (1.00)}{1.21} = 595041.32(GB) = 581.10(TB) => TBW$$

If daily work load is 480GB:

$$LifeTime = \frac{(TBW)}{(DailyWorkLoad) * 365} = \frac{(595041.32GB)}{(480) * 365} = 3.40(years)$$

The SSD endurance is expressed as maximum average host writes per day for the rated life of the drive. If the drive with a rated life of 2 years:

$$HostWrite\ /\ day = \frac{(TBW)}{(RatedLifeYears) * 365} = \frac{(595041.32GB)}{(2) * 365} = 815.13GB/day$$

The warranty of the SSD is 2 years:

$$Drive\ Write\ Per\ Day = \frac{(TBW)}{(Capacity) * (Warranty) * 365} = \frac{(595041.32GB)}{(240GB) * (2) * 365} = 3.4(\text{times})$$

The hypothetical SSD in the examples above has a maximum average writes of 815.13GB per day for its rated life-span of 2 years with a workload representative of that used to measure the core SSD endurance parameters.

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Revision History

Revision	Description	Date
1.0	Official release	8/3/2011
1.1	- Added DWPD to 3. SSD Endurance Measurement - Updated 4. SSD Endurance Measurement Example	8/13/2018
1.2	Textual and grammatical revisions.	12/28/2018

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