Optimal Flash Storage Solutions for Applications Requiring Frequent Writes

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Agenda

- TBW & DWPD Formula
- High DWPD testing
- Compare other solutions

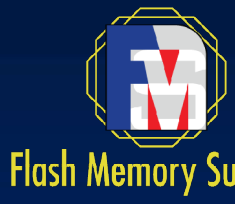
TBW & DWPD Formula

- General Formula
  - TBW (Total Byte Write) = $\frac{\text{NAND\_Size(TB)} \times \text{PE\_Cycle}}{\text{WAF} \times \text{Wear\_Level\_Factor}}$
  - DWPD = $\frac{\text{TBW}}{\text{SSD\_Capacity(GB)} \times \text{Warranty\_day}}$
  - NAND_SIZE(TB) = $\text{SSD\_Capacity(TB)} \times (1+\text{OP}(\%))$
  - DWPD = $\frac{\text{P/E\_cycle} \times (1 + \text{OP}(\%))}{\text{Warranty\_day} \times \text{WAF} \times \text{Wear\_Level\_Factor}}$

- If use SLC cache, how calculate P/E cycle?

SLC cache

- Static SLC cache
  - pros: around 30K P/E cycle
  - cons: only 1/3 capacity of TLC, need OP
- Dynamic SLC cache
  - pros: can change to TLC, don't need OP
  - cons: WAF = 3, TLC endurance
- Disable SLC cache
  - pros: WAF = 1, don't need OP, stable performance
  - cons: low peak performance, data loss in SPOR



Erase Count & Wear Leveling Factor

- The SSD controller must be provided with the following information
  - Erase count: average erase count must remove the bad block.
  - $WAF = \frac{NAND\_Program\_Size(TB)}{Host\_Write\_Size(TB)} = \frac{Erase\_cnt \times Block\_Size(TB)}{Host\_Write\_Size(TB)}$
  - WL_THR: Wear Level threshold
    - if((Max_Erase_cnt – Avg_Erase_Cnt) > WL_THR) turn on Wear_Leveling
  - Wear Level Factor Formula:
    - $WLF = \frac{P/E\_Cycle}{P/E\_Cycle - WL\_THR}$

High DWPD Testing

- Use JESD219 Endurance Workload
  - Enterprise Workload
- 2TBytes Toshiba Bics3 NAND + 100% Over Provisioning
  - Low WAF in high OP setting
- Disable SLC cache
- NAND P/E cycle = 3000
- WLF = 1.05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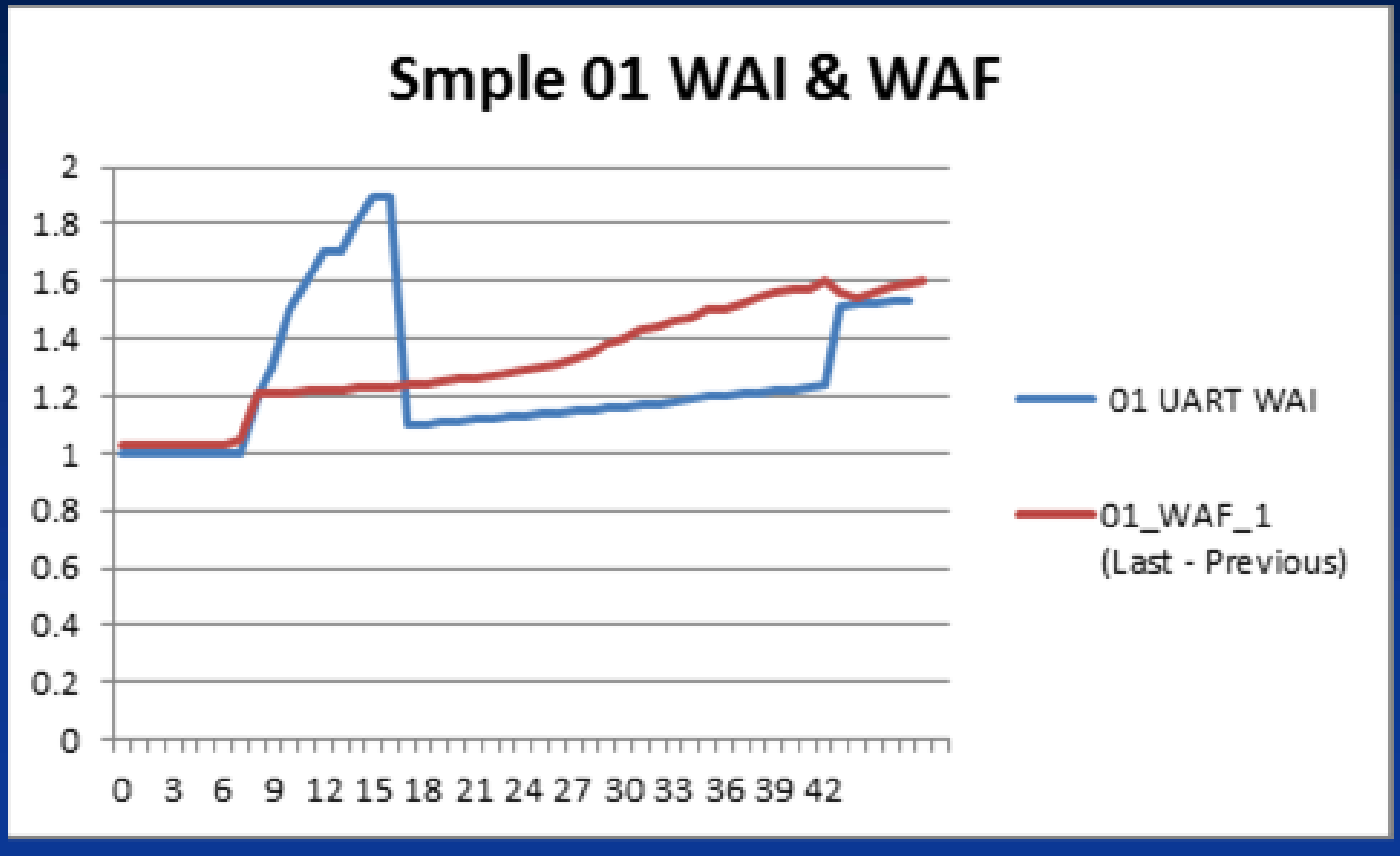
Test result


Smple 01 WAI & WAF
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0 3 6 9 12 15 18 21 24 27 30 33 36 39 42
01 UART WAI
01_WAF_1
(Last - Previous)

High DWPD Testing result

- WAF = 1.6
- TBW = 2TB x 3000 / 1.6 / 1.05 = 3600 TBW
- DWPD = 3600 / (365days x 5years) / 1TB = 2 DWPD

Compare with other solutions

- Enterprise TLC NAND
  - High capacity
  - Low sustain random write IOPS
    - No OP => more GC => high WAF, low tPROG
  - Low DWPD/Cost ratio (2.3 / 2)
    - DWPD: 7K/3K => 2.3 times, Cost: 2 times
- Pseudo SLC mode
  - Low capacity
  - Medium sustain random write IOPS
    - No OP => more GC => high WAF, high tPROG
  - High DWPD/Cost ratio (10 / 3)
    - DWPD: 30K/3K => 10 times, Cost: 3 times

Compare with other solutions

- 100% Over Provisioning
  - Medium capacity
  - High sustain random write IOPS
    - 100% OP => low GC => low WAF, high tPROG
  - High DWPD/Cost ratio (6 / 2)
    - Reduced WAF by 3 times
    - 100% OP => 2 times
    - DWPD: 3x2=6 times, Cost: 2 times

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