Technical Note

SMART Attribute: Calculating the Write Amplification Factor

Introduction

This technical note describes how to calculate the write amplification factor (WAF) for Micron's client SSDs using the Self-Monitoring, Analysis, and Reporting Technology (SMART) feature set. WAF is an indicator of wear acceleration as a function of any given workload. The SMART attributes are used to monitor the current "health" of an SSD and minimize the likelihood of unscheduled system downtime that can be caused by predictable degradation of the device. Refer to Micron's technical notes TN-FD-21 and TN-FD-22 (available at micron.com) for details on Micron's implementation of SMART in client SSDs.

For questions relating to this topic, contact your Micron Technical Sales Representative.

Write Amplification

Write amplification (WA) is an SSD phenomenon that occurs when the actual amount of written physical data is more than the amount of logical data that is written by the host computer. There are two main factors that cause this difference: First, every storage device that uses NAND Flash memory is made of elements that must be erased before they can be rewritten. Second, while NAND Flash devices can be written a single page at a time (a page is typically 4KiB–16KiB), NAND Flash devices can only be erased one block at a time; and a block (also known as a "NAND block" or an "erase block") can contain hundreds of pages. This requires the internal movement of saved user data in background operations to free up adjacent pages of data that are eligible to be erased, and therefore available for new data written by the host computer. Consequently, the total number of actual writes to an SSD is typically more than the number of writes intended to be written by the host computer.

WAF is the mathematical representation of this phenomenon and it describes the ratio of physical writes to logical writes. Depending on the nature of the data stream (or workload) from the host computer, write amplification can vary significantly. Generally, small-block random writes will result in a higher WAF and more wear than large-block sequential writes. Also, full drives will experience a higher WAF compared to partially-full drives.

Optimizing workload to minimize WAF can maximize the lifetime of an SSD. Micron recommends contacting an SSD support representative for more information on the factors that can affect WA.

Calculating the Write Amplification Factor

WAF is an attribute that tracks the multiplicative effect of additional writes that result from WA. WAF is the ratio of total writes to the NAND divided by the total writes intended by the host computer. An ideal WAF would be exactly 1.0. A WAF that maximizes the lifetime of an SSD would asymptotically approach 1.0.

Table 1 describes the SMART attributes used to calculate WAF. Attribute 247 is the total number of NAND page program operations initiated by the host computer. Attribute 248 is the number of NAND page program operations initiated by the SSD's Flash Translation Layer (FTL) and are in addition to the operations programmed by the host.

Table 1: SMART IDs and Descriptions

ID (DEC)	ID (HEX)	Description
247	F7	Host program page count
248	F8	Background program page count

The WAF is calculated using the following equation:

$$WAF = 1 + \left(\frac{\text{Attrib 248}}{\text{Attrib 247}}\right)$$

Attributes 247 and 248 are cumulative over the lifetime of the SSD and cannot be reset. However, it is valid to calculate WAF over experimental time periods using the following equation:

$$WAF = 1 + \left(\frac{\Delta\,\text{Attrib 248}}{\Delta\,\text{Attrib 247}}\right)$$

The deltas indicate the difference of the attributes between any two points in time. Therefore, recording the values of the two attributes at the beginning of a test, running the test, recording the attribute values at the end of the test, and then using the deltas in the equation is a valid way to calculate WAF under specific experimental conditions.

Unrealistic results are possible if WAF is measured with small amounts of data. Micron recommends a SECURITY ERASE and a precondition period that transitions the SSD into the desired fill state before every WAF evaluation experiment. Then, at least several times the total native capacity of the SSD should be written before a WAF calculation is made. Micron also recommends a precondition period that transitions the SSD into the desired fill state.

Your Micron Technical Sales Representative can help you set up experiments that will measure WAF in your computing environment.

Revision History

Rev. B – 12/2014

- Made generic to client SSDs.

Rev. A – 02/2014

- Initial release

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This data sheet contains minimum and maximum limits specified over the power supply and temperature range set forth herein.
Although considered final, these specifications are subject to change, as further product development and data characterization sometimes occur.