Technical Note

Client SATA SSD SMART Attribute Reference

Introduction

This technical note describes the self-monitoring, analysis, and reporting technology (SMART) feature set available for Micron's client SSDs. The SMART attributes are used to protect user data and minimize the likelihood of unscheduled system downtime that may be caused by predictable degradation and/or fault of the device.

This document describes the SMART parameters available on the following client SSD products:

- M500 (MU03 firmware and later)
- M510
- M550
- MX100
- M600
- MX200
- 1100
- MX300

SMART Attribute Definitions

Table 1: SMART Attribute Definitions

ID (Dec)	ID (Hex)	Description
1	01h	Raw read error rate
5	05h	Reallocated NAND block count
9	09h	Power-on hours count
12	0Ch	Power cycle count
171	ABh	Program fail count
172	ACh	Erase fail count
173	ADh	Average block erase count
174	AEh	Unexpected power-loss count
180	B4h	Unused reserve (spare) NAND blocks
183	B7h	SATA interface downshift
184	B8h	Error correction count
187	BBh	Reported uncorrectable errors
194	C2h	Enclosure temperature
196	C4h	Reallocation event count
197	C5h	Current pending ECC count
198	C6h	SMART offline scan uncorrectable error count
199	C7h	Ultra-DMA CRC error count
202	CAh	Percent lifetime remaining
206	CEh	Write error rate
210	D2h	Successful RAIN recovery count
246	F6h	Cumulative host sectors written
247	F7h	Number of NAND pages of data written by the host
248	F8h	Number of NAND pages written by the FTL

SMART Attribute Threshold Description

The SMART attributes that use non-zero threshold values in some of Micron's client SSDs are described in this section.

Table 2: SMART Attribute ID 5: Reallocated NAND Block Count

Applicable Products	Applicable Firmware Revisions	Threshold[1]	Advisory/Warranty
M600 SSD	MU02 and later	0Ah	Advisory
MX200 SSD	MU02 and later	0Ah	Advisory
1100 SSD	All	0Ah	Advisory
MX300 SSD	All	0Ah	Advisory

Note: 1. A threshold trip can occur when the SSD is approaching design tolerances for reallocation events. If reallocation event tolerances are reached, the device may enter a read-only mode.

Table 3: SMART Attribute ID 202: Percent Lifetime Remaining

Applicable Products	Applicable Firmware Revisions	Threshold[1]	Advisory/Warranty
M600 SSD	MU02 and later	01h	Advisory
MX200 SSD	MU02 and later	01h	Advisory
1100 SSD	All	01h	Advisory
MX300 SSD	All	01h	Advisory

Note: 1. A threshold trip can occur when the SSD has reached the end of its designed media endurance. The device may continue to function beyond this point, but data retention specifications may no longer apply.

SMART ID 1 (01h): Raw Read Error Rate

Current Value (8 bits)

This value is the total number of correctable and uncorrectable ECC error events divided by the total host pages read over the life of the drive.

$$V_C = 100 - \left(\frac{E_C + E_U}{H_P}\right) 100$$

Where:
E_C = Total number of correctable errors
E_U = Total number of uncorrectable errors
H_P = Total number of NAND pages read by the host

ECC errors occurring while reading non-user data will still contribute to this rate.

Worst Value (8 bits)

The worst value of this field is the lowest value of the Current Value field calculated over the life of the drive, always between 1% and 100% (01h to 64h).

Raw Data (48 bits)

This data field holds the raw sum of correctable and uncorrectable ECC error events over the life of the drive. This value will saturate at FFFFFFFFh.

SMART ID 5 (05h): Reallocated NAND Block Count

Current Value (8 bits)

This value is calculated as:

$$V_C = 100 - \left(\frac{B_R}{B_T}\right)100$$

Where:
B_R = Number of all retired blocks
B_T = The bad block threshold to enter WP mode

Worst Value (8 bits)

This field contains the value of the Current Value field.

Raw Data (48 bits)

Represents the total number of reallocated NAND blocks due to grown bad blocks.

SMART ID 9 (09h): Power-On Hours Count

Current Value (8 bits)

This value is hard-coded to 100% (64h).

Worst Value (8 bits)

This value is hard-coded to 100% (64h).

Raw Data (48 bits)

This value gives the raw number of hours that the drive has been under power (online) over its lifetime.

This attribute shall increment for each hour in the following link power state:

- SATA PHYRDY (Link Active)

This attribute may not increment for each hour in the following link power states:

- SATA Partial
- SATA Slumber
- SATA Device Sleep

SMART ID 12 (0Ch): Power Cycle Count

Current Value (8 bits)

This value is hard-coded to 100% (64h).

Worst Value (8 bits)

This value is hard-coded to 100% (64h).

Raw Data (48 bits)

This value gives the raw number of power-cycle events experienced over the life of the drive.

SMART ID 171 (ABh): Program Fail Count

Current Value (8 bits)

This value is calculated as:

$$V_C = 100 - \left(\frac{F_P}{F_P + B_R}\right)100$$

Where:
F_P = Total number of program fails
B_R = Number of reserved blocks remaining

Worst Value (8 bits)

This value is the lowest Current Value recorded over the life of the drive.

Raw Data (48 bits)

This value contains the raw number of program failure events over the life of the drive.

SMART ID 172 (ACh): Erase Fail Count

Current Value (8 bits)

This value is calculated as:

$$V_C = 100 - \left(\frac{E_F}{E_F + B_R}\right)100$$

Where:
E_F = Total number of erase failures
B_R = Current number of reserved blocks

Worst Value (8 bits)

This value is the lowest current value recorded over the life of the drive.

Raw Data (48 bits)

This value contains the raw number of erase failure events over the lifetime of the device.

SMART ID 173 (ADh): Average Block-Erase Count

Current Value (8 bits)

This value is calculated as:

$$V_C = 100 - \left(\frac{E_{AVG}}{B_L}\right)100$$

Where:
V_C = Current value
E_{AVG} = Average erase count
B_L = Rated life of a block (the rated erase count for the NAND used)

Worst Value (8 bits)

This value is the lowest recorded current value.

Raw Data (48 bits)

This value is the average erase count of all super blocks. One super block is defined to include all the physical blocks with the same block number of all planes.

SMART ID 174 (AEh): Unexpected Power Loss Count

Current Value (8 bits)

This value is hard-coded to 100% (64h).

Worst Value (8 bits)

This value is hard-coded to 100% (64h).

Raw Data (48 bits)

This value is the total number of times the device has been power-cycled unexpectedly.

Unexpected power loss can be avoided by preceding a power off with an ATA STBI (STANDBY IMMEDIATE) command, and allowing the SSD to properly complete this command before removing power to the SSD.

SMART ID 180 (B4h): Unused Reserve (Spare) NAND Blocks

Current Value

This value is hard-coded to zero (00h).

Worst Value

This value is hard-coded to zero (00h).

Raw Data

This value is calculated as:

$$U_{RBC} = B_T - B_G$$

Where:
U_{RBC} = Total unused reserved block count.
B_T = Total number of spare blocks when the drive left the factory. The spare block count represents the number of grown bad blocks the drive can handle in the field before it enters write protect.
B_G = Total number of grown bad blocks.

SMART ID 183 (B7h): SATA Interface Downshift

Current Value (8 bits)

This value is hard-coded to 100% (64h).

Worst Value (8 bits)

This value is hard-coded to 100% (64h).

Raw Data (48 bits)

Represents the total number of host interface speed downshifts on the SATA link. For example, the SATA link shifts to a lower-generation speed (1.5 Gb/s or 3.0 Gb/s) than what was previously negotiated (6 Gb/s).

SMART ID 184 (B8h): Error Correction Count

Current Value (8 bits)

This value is calculated as:

$$V_C = \left(\frac{100 - E_{NR} - \left(\frac{E_R}{2} \right)}{100} \right)$$

Where:
E_{NR} = Number of nonrecoverable errors
E_R = Number of recoverable errors

Worst Value (8 bits)

This value contains the lowest value of the Current Value field over the life of the drive.

Raw Data (48 bits)

This value represents the total number of end-to-end correction events, specifically errors on the write/read data path:

$$V_R = E_{NR} + E_R$$

SMART ID 187 (BBh): Reported Uncorrectable Errors

Current Value (8 bits)

This value is hard-coded to 100% (64h).

Worst Value (8 bits)

This value is hard-coded to 100% (64h).

Raw Data (48 bits)

This value represents the total number of UECC errors reported by the drive as a result of host commands (for example, READ commands).

SMART ID 194 (C2h): Enclosure Temperature

Current Value (8 bits)

This value is calculated as:

$V_C = 100 - T_C$

Where:
T_C = Current temperature in degrees Celsius

Worst Value (8 bits)

This value is calculated as:

$V_W = 100 - T_M$

Where:
T_M = Maximum temperature recorded over lifetime in degrees Celsius

Raw Data (48 bits)

The value is defined as:

Bytes					
5	4	3	2	1	0
MAX temperature		MIN temperature		Current temperature	

SMART ID 196 (C4h): Reallocation Event Count

Current Value (8 bits)

This value is hard-coded to 100% (64h).

Worst Value (8 bits)

This value is hard-coded to 100% (64h).

Raw Data (48 bits)

This value represents the total number of grown bad blocks. This value is calculated as:

$V_R = B_T - B_F$

Where:
B_T = Total number of bad blocks on the drive
B_F = Number of factory marked OTP bad blocks

SMART ID 197 (C5h): Current Pending ECC Count

Current Value (8 bits)

This value is hard-coded to 100% (64h).

Worst Value (8 bits)

This value is hard-coded to 100% (64h).

Raw Data (48 bits)

This value represents the total number of ECC events found as a result of host commands (for example, READ commands) or during background operations.

SMART ID 198 (C6h): SMART Offline Scan Uncorrectable Error Count

Current Value (8 bits)

This value is hard-coded to 100% (64h).

Worst Value (8 bits)

This value is hard-coded to 100% (64h).

Raw Data (48 bits)

This value is the cumulative number of unrecoverable read errors (UECC) found in the most recent media scan triggered by a SMART EXECUTE OFF-LINE IMMEDIATE command. At the beginning of each media scan, this value shall reset to zero. If no media scan has been previously run, this field will be zero.

SMART ID 199 (C7h): Ultra-DMA CRC Error Count

Current Value (8 bits)

This value is hard-coded to 100% (64h).

Worst Value (8 bits)

This value is hard-coded to 100% (64h).

Raw Data (48 bits)

This value represents the total number of CRC errors the drive has detected on the SATA interface over the life of the drive. A CRC error is generated when the CRC check fails on a SATA Transport Layer FIS.

SMART ID 202 (CAh): Percent Lifetime Remaining

Current Value (8 bits)

This value gives the threshold inverted value of the raw data value below. That is, if 30% of the lifetime has been used, this value will report 70%. A value of 0% indicates that 100% of the expected lifetime has been used.

This value is defined as:

$$V_C = 100 - V_R$$

Where:
V_R = Raw data value

Worst Value (8 bits)

This field holds the same value as the current value because the current value is monotonically decreasing.

Raw Data (48 bits)

This value is defined as:

$$V_R = 100\left(\frac{MAX(E_{AVG})}{B_L}\right)$$

Where:
E_{AVG} = Average erase count of all blocks.
B_L = Erase count for which the part is rated (block life)

SMART ID 206 (CEh): Write Error Rate

Current Value (8 bits)

Represents a ratio of the number of NAND program fails to the number of host sectors written. This value is defined as:

$$V_C = \frac{100F_N}{S_T}$$

Where:
F_N = Total number of NAND program failures
S_T = Total number of sectors written

Worst Value (8 bits)

This field is the lowest value of the Current Value field over the life of the drive.

Raw Data (48 bits)

This value is the NAND program fail count.

SMART ID 210 (D2h): Successful RAIN Recovery Count

Current Value

This value is hard-coded to 100% (64h).

Worst Value

This value is hard-coded to 100% (64h).

Raw Data

The total number of translation units (TUs) successfully recovered by Micron's redundant array of independent NAND (RAIN) technology.

SMART ID 246 (F6h): Cumulative Host Sectors Written

Current Value

This value is hard-coded to 100% (64h).

Worst Value

This value is hard-coded to 100% (64h).

Raw Data

The total number of sectors written by the host.

SMART ID 247 (F7h): Host Program NAND Pages Count

Current Value

This value is always 100% (64h).

Worst Value

This value is always 100% (64h).

Raw Data

This value stores the cumulative host program NAND page count.

SMART ID 248 (F8h): FTL Program NAND Pages Count

Current Value

This value is always 100% (64h).

Worst Value

This value is always 100% (64h).

Raw Data

This value stores the cumulative FTL program page count. This attribute tracks the number of NAND pages programmed by the FTL which are in addition to operations programmed by the host.

Write amplification factor can be calculated by:

$$WAF = \frac{(Attrib\_247 + Attrib\_248)}{Attrib\_247}$$

Mechanism

A SMART attribute is retrieved by the host issuing the SMART READ DATA command. In the 512-bytes returned by the SMART READ DATA command, bytes 0–361 (169h) are marked as vendor-specific in the ATA8-ACS2 and ACS3 specifications. These contain the SMART attribute data.

Table 4: SMART Attribute Table Layout

Offset	Length (Bytes)	Description
0	2	SMART structure version (vendor-specific)
2	12	Attribute entry #1
2 + 12	12	Attribute entry #2
…		…
2 + (29 * 12)	12	Attribute entry #30

Each attribute entry contains 12 bytes, comprised of the following fields: ID, Flag, Current Value, Worst Value, Raw Data, and Reserved. There is no requirement on the order of the attributes in the table.

For each attribute, there is a corresponding threshold that is retrieved by the host issuing the SMART READ ATTRIBUTE THRESHOLDS command. In the 512-bytes data returned by the command, the host can compare the threshold with the current value of each attribute. If the current value is less than or equal to the threshold, the device is in a status that requires further attention from the system. This procedure is also called a SMART threshold trip.

The SMART RETURN STATUS command will compare the current value attributes with the threshold and return a status that specifies the self test has either completed without error (C24Fh) or detected a threshold has been exceeded (2CF4h). The SMART RETURN STATUS command replaces the functionality of the READ THRESHOLD VALUE and WRITE WARRANTY FAILURE THRESHOLD commands, and provides backward-compatibility with existing SMART applications.

Table 5: SMART Attribute Threshold Table Layout

The order of the threshold entries matches those in SMART Attribute Table Layout.

Offset	Length (Bytes)	Description
0	2	SMART structure version (vendor-specific)
2	12	Threshold entry #1
2 + 12	12	Threshold entry #2
…		…
2 + (29 * 12)	12	Threshold entry #30

Attribute Definition

Table 6: SMART Attribute Entry Format and Definition

Offset	Length (Bytes)	Field Name	Data Description
0	1	ID	00h Invalid entry. 01h–FFh valid entry.
1	2	Flag	Bit 0: Prefailure/advisory bit. Applicable only when the current value is less than or equal to its threshold. 0 = Advisory: the device has exceeded its intended design life; the failure is not covered under the drive warranty. 1 = Prefailure: warrantable, failure is expected in 24 hours and is covered in the drive warranty.
			Bit 1: Online collection bit. 0 = Attribute is updated only during off-line activities 1 = Attribute is updated during both online and off-line activities.
			Bit 2: Performance bit. 0 = Not a performance attribute. 1 = Performance attribute.
			Bit 3: Error Rate bit. Expected, non-fatal errors that are inherent in the device. 0 = Not an error rate attribute. 1 = Error rate attribute.
			Bit 4: Even count bit. 0 = Not an even count attribute. 1 = Even count attribute.
			Bit 5: Self-preserving bit. The attribute is collected and saved by the drive without host intervention. 0 = Not a self-preserving attribute. 1 = Self-preserving attribute.
			Bit 6–15: Reserved.
3	1	Current value	Normalized (normally from the raw data) attribute value. Valid range 1–253 (FDh); initial value 00 (64h). Values of 0, FEh, and FFh are invalid. This value can be compared to the threshold set by the device. The device should collect enough data before updating the normalized value to ensure statistical validity.
4	1	Worst value	Worst ever normalized value. Valid range 1–253 (FDh); initial value 100 (64h). Values of 0, FEh, and FFh are invalid.
5	6	Raw data	Vendor and/or attribute-specific.
11	1	Reserved	00h

Threshold Entry Definition

Table 7: SMART Attribute Threshold Entry Format and Definition

Offset	Length (Bytes)	Field Name	Data Description
0	1	ID	Corresponds to the ID field in the SMART Attribute Entry Format and Definition table.
1	1	Threshold	00h = Valid threshold value, always passing, as the current value will always be larger.
			01h = Valid threshold value.
			FDh = Maximum value.
			FEh = Invalid threshold value.
			FFh = Valid threshold value, always failing.
2	10	Reserved	00h

Notes:
1. For SMART attributes that do not use thresholds, the Threshold field is set to 00h to indicate an always-passing condition.
2. For SMART attributes that use thresholds, the thresholds are specified in the SMART Attributes Using Non-Zero Threshold Values section.

Revision History

Rev. D – 9/16

- Added 1100 and MX300 to list of applicable SSDs.
- Added descriptions for IDs 247 and 248.
- Added SATA to document title.
- Reformatted document for easier reference.

Rev. C – 12/14

- Added the MX200 SSD.
- Added notes to SMART Attribute Threshold Entry Format and Definition table.
- Added the SMART Attributes Using Non-Zero Threshold Values section.
- Removed the Attribute Flags and Reserved/Threshold sections from each SMART ID section.

Rev. B – 10/14

- Updated to include M500 (MU03 Firmware and Later), M510, M550, MX100, and M600 client SSDs with firmware versions beginning in "MU."
- Updates to SMART Attribute Definitions table.

Rev. A – 3/14

- Initial release

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