



Technical Note

M500 SSD Firmware MU02 SMART Attributes Reference

Introduction

This technical note describes the self-monitoring, analysis, and reporting technology (SMART) feature set available for Micron's M500 SSD firmware version MU02. 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.

Note: See Micron's technical note, "TN-FD-22: Client SSD SMART Attribute Reference," for SMART parameters available with Micron's M500 SSD firmware version MU03 and later.

Questions relating to this document should be addressed to ssd-support@micron.com.

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 specification. These contain the SMART attribute data.

Table 1: 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 SMART 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 2: SMART Attribute Threshold Table Layout

The order of the threshold entries should match 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 3: SMART Attribute Entry Format and Definition

Offset	Length (Bytes)	Field Name	Data Description
0	1	ID	00h This attribute entry is invalid. 01h–FFh valid entry.
1	2	Flag	<p>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.</p> <p>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.</p> <p>Bit 2: Performance bit. 0 = Not a performance attribute. 1 = Performance attribute.</p> <p>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.</p> <p>Bit 4: Even count bit. 0 = Not an even count attribute. 1 = Even count attribute.</p> <p>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.</p> <p>Bit 6–15: Reserved.</p>

Table 3: SMART Attribute Entry Format and Definition (Continued)

Offset	Length (Bytes)	Field Name	Data Description
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 4: 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



SMART Attribute Definitions

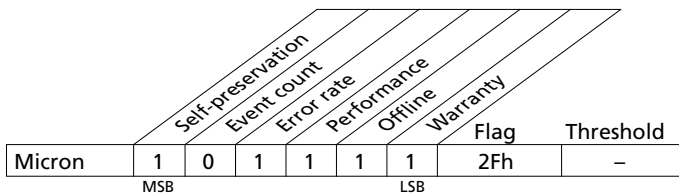
Table 5: SMART Attributes Definitions

ID (Dec)	ID (Hex)	Description	Flag	Trip	Threshold
1	1	Raw Read Error Rate	2Fh	Yes	32h
5	5	Reallocated Sector Count	33h	Yes	0Ah
9	9	Power-On Hours Count	32h	No	N/A
12	C	Power-Cycle Count	32h	No	N/A
170	AA	Reserved Block Count	33h	Yes	0Ah
171	AB	Program Fail Count	32h	No	N/A
172	AC	Erase Fail Count	32h	No	N/A
173	AD	Average Block-Erase Count	32h	Yes	0Ah
174	AE	Unexpected Power Loss Count	32h	No	N/A
181	B5	Unaligned Access Count	22h	No	N/A
183	B7	SATA Interface Downshift	32h	No	N/A
184	B8	Error Correction Count	32h	Yes	32h
187	BB	Reported Uncorrectable Errors	32h	No	N/A
188	BC	Command Timeout Count	32h	No	N/A
194	C2	Enclosure Temperature	22h	No	N/A
195	C3	Cumulative Corrected ECC	3Ah	No	N/A
196	C4	Reallocation Event Count	32h	No	N/A
197	C5	Current Pending Sector Count	32h	No	N/A
198	C6	SMART Off-line Scan Uncorrectable Error Count	30h	No	N/A
199	C7	Ultra-DMA CRC Error Count	32h	No	N/A
202	CA	Percent Lifetime Remaining	31h	No	N/A
206	CE	Write Error Rate	0Eh	No	N/A



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

Attribute Flags



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, and multiplied by a constant, C.

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

Where:

E_C = Total number of correctable errors

E_U = Total number of uncorrectable errors

H_P = Total number of pages read by the host

Constant, C, is defined as:

$$C = \left(\frac{100000(B_T)}{2} \right)$$

Where:

B_T = Total number of blocks on the device

ECC errors occurring while reading non-user data will still contribute to this rate. The current value will not be calculated and will remain as 0x64 until the host read page count is greater than C (100,000 × total block count ÷ 2).

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% (0x01 to 0x64).

Raw Data (48 bits)

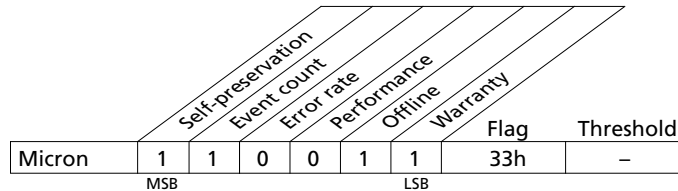
This data field holds the raw sum of correctable and uncorrectable ECC error events over the life of the drive. If it exceeds 0xFFFFFFFF, this value will wrap around.

Reserved/Threshold (8 bits)

The threshold for this attribute is set to 32h (50%).

SMART ID 5 (05h): Reallocated Sector Count

Attribute Flags



Current Value (8 bits)

This value is calculated as:

$$V_C = S_M - \left(\frac{S_M B_G}{B_R} \right)$$

Where:

B_G = The number of grown bad sectors

B_R = The total number of sectors reserved for use by the device

S_M = SMART_MAX_ATTRIBUTE_VALUE

Worst Value (8 bits)

This field contains the value of the Current Value.

Raw Data (48 bits)

The total number of reallocated sectors. This value is calculated as:

$$V_R = B_G \times \text{BLOCK_SECTOR_COUNT}$$

Note that the retirement of a single defective area on a NAND-based SSD will be done at the NAND block level. This means that many sectors will be reallocated during a single block retirement. For the M500, 16,384 sectors are retired for each single reallocation event.

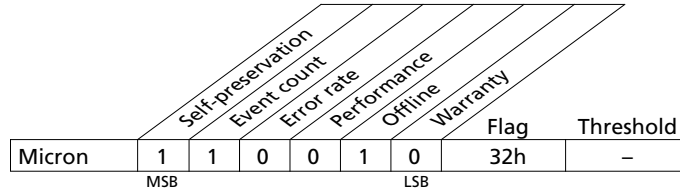
Reserved/Threshold (8 bits):

The threshold for this attribute is set to 0x0A, meaning the threshold shall represent no value greater than 90% of the total available reallocated sectors.



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

Attribute Flags



Current Value (8 bits)

This value is hard-coded to 100% (0x64).

Worst Value (8 bits)

This value is hard-coded to 100% (0x64).

Raw Data (48 bits)

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

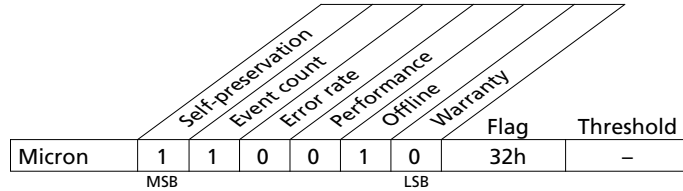
Reserved/Threshold (8 bits)

The threshold for this attribute is set to 0. This will not cause a SMART threshold trip.



SMART ID 12 (0Ch): Power-Cycle Count

Attribute Flags



Current Value (8 bits)

This value is hard-coded to 100% (0x64).

Worst Value (8 bits)

This value is hard-coded to 100% (0x64).

Raw Data (48 bits)

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

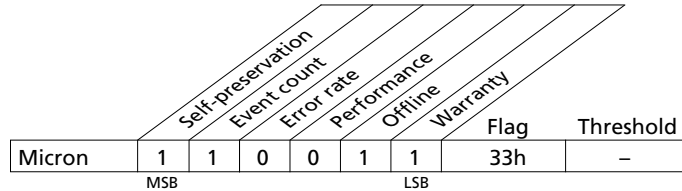
Reserved/Threshold (8 bits)

The threshold for this attribute is set to 0. This will not cause a SMART threshold trip.

SMART ID 170 (AAh): Reserved Block Count

Note: This attribute definition is applicable to firmware version MU02 only.

Attribute Flags



Current Value (8 bits)

This value is calculated as:

$$V_C = S_M - 100 \left(\frac{R_{USED}}{R_T} \right)$$

Where:

R_{USED} = Total number of reserved blocks

R_T = Total number of blocks reserved by the device

Worst Value (8 bits)

This field contains the value of the Current Value.

Raw Data (48 bits)

This value is calculated as:

$$V_R = B_T - B_F$$

Where:

B_T = Total bad block count of the drive

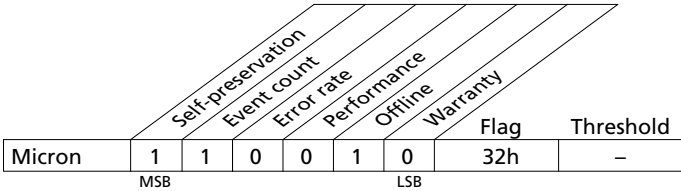
B_F = Total number of OTP bad blocks

Reserved/Threshold (8 bits):

The threshold for this attribute is set to 0. This will not cause a SMART threshold trip.

SMART ID 171 (ABh): Program Fail Count

Attribute Flags



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)

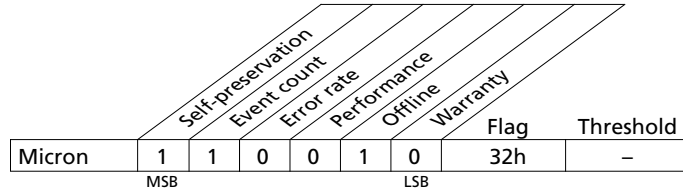
This value contains the raw number of program failure events over the life of the drive.

Reserved/Threshold (8 bits)

The threshold for this attribute is set to 0. This will not cause a SMART threshold trip.

SMART ID 172 (ACh): Erase Fail Count

Attribute Flags



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.

Reserved/Threshold (8 bits)

The threshold for this attribute is set to 0. This will not cause a SMART threshold trip.



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

Attribute Flags

Micron	1	1	0	0	1	0	Flag	Threshold
	MSB			LSB			32h	-

Current Value (8 bits)

This value is calculated as:

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

Where:

V_C = Current value

S_M = SMART_MAX_ATTRIBUTE_VALUE

E_{AVG} = Average erase count

B_L = Rated life of a block (the erase count for which the part is rated)

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.

Reserved/Threshold (8 bits)

The threshold for this attribute is set to 0. This will not cause a SMART threshold trip.



SMART ID 174 (AEh): Unexpected Power Loss Count

Attribute Flags

	Self-preservation	Event count	Error rate	Performance	Offline	Warranty	Flag	Threshold
Micron	1	1	0	0	1	0	32h	-
	MSB			LSB				

Current Value (8 bits)

This value is hard-coded to 100% (0x64).

Worst Value (8 bits)

This value is hard-coded to 100% (0x64).

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.

Reserved/Threshold (8 bits)

The threshold for this attribute is set to 0. This will not cause a SMART threshold trip.



SMART ID 181 (B5h): Unaligned Access Count

Note: This attribute definition is applicable to firmware version MU02 only.

Attribute Flags

Micron	1	0	0	0	1	0	Flag	Threshold
	MSB			LSB			22h	-

Current Value (8 bits)

This value is fixed to the SMART_ATTRIBUTE_VALUE.

Worst Value (8 bits)

This value is fixed to the SMART_ATTRIBUTE_VALUE.

Raw Data (48 bits)

This attribute provides data that is tracked by Micron engineering. It is not indicative of SSD wear or of impending failure.

Reserved/Threshold (8 bits):

The threshold for this attribute is set to 0. This will not cause a SMART threshold trip.



SMART ID 183 (B7h): SATA Interface Downshift

Attribute Flags

	Self-preservation	Event count	Error rate	Performance	Offline	Warranty	Flag	Threshold
Micron	1	1	0	0	1	0	32h	-
	MSB						LSB	

Current Value (8 bits)

This value is hard-coded to 100% (0x64).

Worst Value (8 bits)

This value is hard-coded to 100% (0x64).

Raw Data (48 bits)

The total number of downshifts.

Reserved/Threshold (8 bits)

The threshold for this attribute is set to 0. This will not cause a SMART threshold trip.

SMART ID 184 (B8h): Error Correction Count

Attribute Flags

							Self-preservation	Event count	Error rate	Performance	Offline	Warranty	Flag	Threshold
Micron	1	1	0	0	1	0							32h	-
	MSB						LSB							

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 is the same as the current value.

Raw Data (48 bits)

This value is the count of end-to-end correction events.

Reserved/Threshold (8 bits)

The threshold for this attribute is set to 0. This will not cause a SMART threshold trip.



SMART ID 187 (BBh): Reported Uncorrectable Errors

Attribute Flags

Micron	1	1	0	0	1	0	Flag	Threshold
	MSB					LSB	32h	-

Diagram showing the bit fields for the Attribute Flags: Self-preservation, Event count, Error rate, Performance, Offline, and Warranty.

Current Value (8 bits)

This value is hard-coded to 100% (0x64).

Worst Value (8 bits)

This value is hard-coded to 100% (0x64).

Raw Data (48 bits)

This value is the total number of UECC correction failures reported by the sequencer.

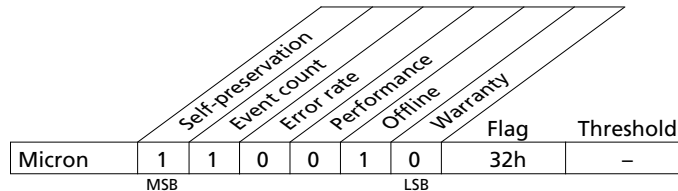
Reserved/Threshold (8 bits)

The threshold for this attribute is set to 0. This will not cause a SMART threshold trip.

SMART ID 188 (BCh): Command Timeout Count

Note: This attribute definition is applicable to firmware version MU02 only.

Attribute Flags



Current Value (8 bits)

This value is hard-coded to 100% (0x64).

Worst Value (8 bits)

This value is hard-coded to 100% (0x64).

Raw Data (48 bits)

This value is the total number of command timeouts. This attribute tracks the number of command timeouts as defined by an active command being interrupted by an HRESET, COMRESET, SRST, or another command.

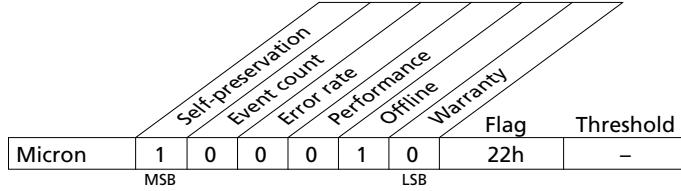
Reserved/Threshold (8 bits):

The threshold for this attribute is set to 0. This will not cause a SMART threshold trip.



SMART ID 194 (C2h): Enclosure Temperature

Attribute Flags



Current Value (8 bits)

This value is calculated as:

$$V_C = S_M - T_C$$

Where:

S_M = SMART_MAX_ATTRIBUTE_VALUE

T_C = Current temperature

Worst Value (8 bits)

This value is calculated as:

$$V_W = S_M - T_M$$

Where:

S_M = SMART_MAX_ATTRIBUTE_VALUE

T_M = Maximum temperature recorded for the device

Raw Data (48 bits)

The value is defined as:

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

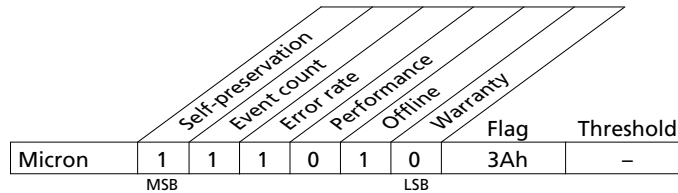
Reserved/Threshold (8 bits)

The threshold for this attribute is set to 0. This will not cause a SMART threshold trip.

SMART ID 195 (C3h): Cumulative Corrected ECC

Note: This attribute definition is applicable to firmware version MU02 only.

Attribute Flags



Current Value (8 bits)

This value is hard-coded to 100% (0x64).

Worst Value (8 bits)

This value is hard-coded to 100% (0x64).

Raw Data (48 bits)

This attribute provides data that is tracked by Micron engineering. It is not indicative of SSD wear or of impending failure.

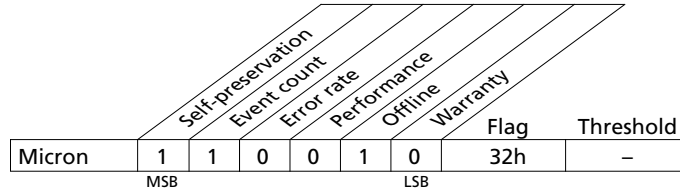
Reserved/Threshold (8 bits):

The threshold for this attribute is set to 0. This will not cause a SMART threshold trip.



SMART ID 196 (C4h): Reallocation Event Count

Attribute Flags



Current Value (8 bits)

This value is hard-coded to 100% (0x64).

Worst Value (8 bits)

This value is hard-coded to 100% (0x64).

Raw Data (48 bits)

This value is calculated as:

$$V_R = B_T - B_F$$

Where:

B_T = Total number of bad block counts on the drive

B_F = Number of factory marked OTP bad blocks

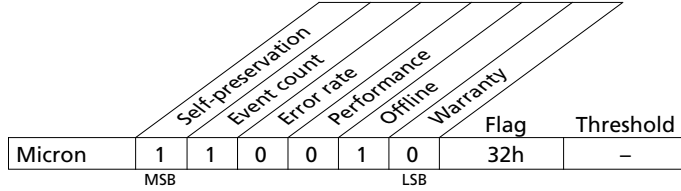
Reserved/Threshold (8 bits)

The threshold for this attribute is set to 0. This will not cause a SMART threshold trip.



SMART ID 197 (C5h): Current Pending Sector Count

Attribute Flags



Current Value (8 bits)

This value is hard-coded to 100% (0x64).

Worst Value (8 bits)

This value is hard-coded to 100% (0x64).

Raw Data (48 bits)

This value gives the number of blocks waiting to be remapped.

Reserved/Threshold (8 bits)

The threshold for this attribute is set to 0. This will not cause a SMART threshold trip.



SMART ID 198 (C6h): SMART Off-line Scan Uncorrectable Error Count

Attribute Flags

Micron	1	1	0	0	0	0	Flag	Threshold
	MSB					LSB	30h	-

Diagram showing the bit fields for the Attribute Flags: Self-preservation, Event count, Error rate, Performance, Offline, and Warranty.

Current Value (8 bits)

This value is hard-coded to 100% (0x64).

Worst Value (8 bits)

This value is hard-coded to 100% (0x64).

Raw Data (48 bits)

This value is the cumulative number of unrecoverable read errors found in a background media scan. If no background media scan has been run, a value of 0 will be returned.

Reserved/Threshold (8 bits)

The threshold for this attribute is set to 0. This will not cause a SMART threshold trip.



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

Attribute Flags

	Self-preservation	Event count	Error rate	Performance	Offline	Warranty	Flag	Threshold	
Micron	1	1	0	0	1	0	32h	-	
	MSB		LSB						

Current Value (8 bits)

This value is hard-coded to 100% (0x64).

Worst Value (8 bits)

This value is hard-coded to 100% (0x64).

Raw Data (48 bits)

This value is the cumulative number of FIS interface general CRC (cycle redundancy check) error counts over the life of the drive, for both reads and writes, since the most recent power cycle.

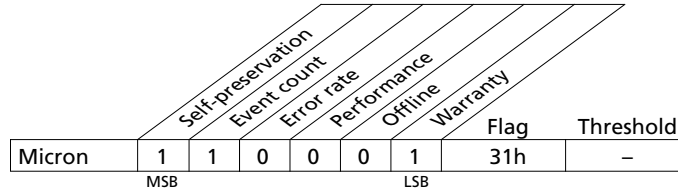
Reserved/Threshold (8 bits)

The threshold for this attribute is set to 0. This will not cause a SMART threshold trip.



SMART ID 202 (CAh): Percent Lifetime Remaining

Attribute Flags



Current Value (8 bits)

This value gives the threshold inverted value of the 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:

$$V_C = S_M - V_R$$

Where:

S_M = SMART_MAX_ATTRIBUTE_VALUE

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:

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

Where:

E_{AVG} = Average erase count for a super block (stripe of blocks)

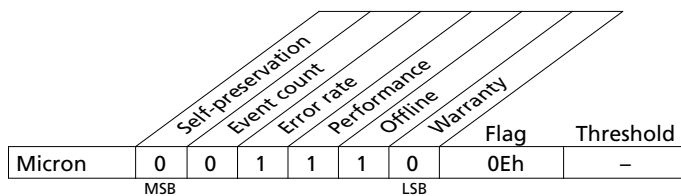
B_L = Erase count for which the part is rated (block life)

Reserved/Threshold (8 bits)

The threshold for this attribute is set to 0. This will not cause a SMART threshold trip.

SMART ID 206 (CEh): Write Error Rate

Attribute Flags



Current Value (8 bits)

This value is defined as:

$$V_C = \frac{(100)2^{11}F_N}{S_T} \text{ reduces to } V_C = \frac{100F_N}{S_T}$$

Where:

F_N = Total number of NAND program failures

S_T = Total number of sectors written

Worst Value (8 bits)

This value is the worst current value.

Raw Data (48 bits)

This value is the NAND program fail count.

Reserved/Threshold (8 bits)

The threshold for this attribute is set to 0. This will not cause a SMART threshold trip.



TN-FD-21: M500 SSD Firmware MU02 SMART Attributes SMART ID 206 (CEh): Write Error Rate



Revision History

Rev. C – 12/14

- Moved support for MU03 firmware into Micron's technical note, "TN-FD-22: Client SSD SMART Attribute Reference."

Rev. B – 09/13

- Added support for MU03 firmware

Rev. A – 05/13

- Initial release

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