Technical Note

SMART Command Feature Set for the 5100

Introduction

This technical note provides the self-monitoring, analysis, and reporting technology (SMART) command (B0h) feature set for the Micron 5100 SSD.

The intent of the SMART command feature set is 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. By monitoring and storing critical performance and calibration parameters, SMART feature set devices attempt to predict the likelihood of a near-term degradation or fault condition. Providing the host system the knowledge of a negative reliability condition allows the host system to warn the user of the impending risk of a data loss and advise the user of the appropriate action. Support of this feature set is indicated in the IDENTIFY DEVICE data.

Table 1: SMART Attribute Summary

Attrib ID	Hex ID	Name	SMART Trip	Implementation
1	01h	Raw Read Error Rate	Yes	Raw correctable and uncorrectable read error rate
5	05h	Reallocated NAND Block Count	No	Number of reallocated flash blocks
9	09h	Power-On Hours Count	No	Lifetime hours powered-on
12	0Ch	Power Cycle Count	No	Lifetime power cycle count
170	AAh	Reserved Block Count	Yes	Used reserved block count
171	ABh	Program Fail Count	No	Number of NAND program status failures
172	ACh	Erase Fail Count	No	Number of NAND erase Status failures
173	AD	Average Block Erase Count	No	Average erase count of all good blocks
174	AEh	Unexpected Power Loss Count	No	Number of times the device has been power-cycled unexpectedly
180	B4h	Unused Reserved (Spare) Block Count	No	The number of spare blocks remaining on the SSD
183	B7h	SATA Interface Downshift	No	Count of SATA link rate downshift events
184	B8h	Error Correction Count	Yes	–
187	BBh	Reported Uncorrectable Errors	No	Number of UECC correction failures
188	BCh	Command Timeouts	No	Upon any HRESET, COMRESET, SRST: adds active ATA commands in the queue to a lifetime counter
194	C2h	Drive Temperature	No	Drive temperature
195	C3h	Cumulative Corrected ECC	No	Tracks the total number of bits corrected over the lifetime of the device
196	C4h	Reallocation Event Count	No	Represents the total number of grown bad blocks
197	C5h	Current Pending Sector Count	No	This attribute is always 0, as reallocation is done in real time
198	C6h	Smart Off-line Scan Uncorrectable Error Count	No	Uncorrectable error count detected during SMART offline scan
199	C7h	Ultra DMA CRC Error Rate	No	All SATA (general) FIS CRC errors
202	CAh	Percentage of Lifetime Remaining	No	Percentage lifetime remaining
206	CEh	Write Error Rate	No	Number of NAND program status fails per MB of SATA data written
210	D2h	RAIN Success Recovered Page Count	No	The total number of translation units (TU) successfully recovered by RAIN
211	D3h	Integrity Scan Completed Count	No	Number of periodic data integrity scans completed
212	D4h	Integrity Scan Folding Count	No	Number of folding events as a result of the periodic data integrity scan
246	F6h	Cumulative Host Sectors Written	No	The total number of sectors (LBAs) written by the host over the life of the device
247	F7h	Host Program Page Count	No	Number of NAND pages of data written by the host
248	F8h	FTL Program Page Count	No	Number of NAND pages written by the FTL

SMART Attribute: Raw Read Error Rate (ID 1)

Attribute Flags (2Fh)

- Warranty = 1
- Offline = 1
- Performance = 1
- Error rate = 1
- Event count = 0
- Self-preservation = 1

Current Value (8 bits)

This value is the total number of correctable and uncorrectable ECC error events divided by the total host page reads over the life of the drive and multiplied by (100,000 x total block count ÷ 2).
Note: For (100,000 x total block count/2): The value of 100,000 is set to account for read disturb event thresholds for one block. (100,000 x total block count ÷ 2) is half of the total page read counts for the whole drive before read disturb needs to be factored.

Note that ECC errors occurring while reading non-user data will still contribute to this rate. The Current Value will not be calculated and remains as 64h until the host read page count is greater than (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 ever 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.

Reserved/Threshold (8 bits)

The threshold for this attribute is set to 32h, meaning that a SMART threshold trip occurs when the value becomes 50%.

SMART Attribute: Reallocated NAND Block Count (ID 5)

Attribute Flags (32h)

- Warranty = 0
- Offline = 1
- Performance = 0
- Error rate = 0
- Event count = 1
- Self-preservation = 1

Current Value (8 bits)

This value is calculated as:

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

Where:
S_M = SMART_MAX_ATTRIBUTE_VALUE
B_G = Number of grown bad blocks
B_R = Total number of blocks reserved for use by the device

Worst Value (8 bits)

This field contains the value of the Current Value field.

Raw Data (48 bits)

The total number of reallocated blocks.

Reserved/Threshold (8 bits)

The threshold for this attribute is set to 1 and will never cause a SMART threshold trip.

SMART Attribute: Power-On Hours Count (ID 9)

Attribute Flags (32h)

- Warranty = 0
- Offline = 1
- Performance = 0
- Error rate = 0
- Event count = 1
- Self-preservation = 1

Current Value (8 bits)

This value is always 100% (64h).

Worst Value (8 bits)

This value is always 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.

Reserved/Threshold (8 bits)

The threshold for this attribute is set to 1 and will never cause a SMART threshold trip.

SMART Attribute: Power-Cycle Count (ID 12)

Attribute Flags (32h)

- Warranty = 0
- Offline = 1
- Performance = 0
- Error rate = 0
- Event count = 1
- Self-preservation = 1

Current Value (8 bits)

This value is always 100% (64h).

Worst Value (8 bits)

This value is always 100% (64h).

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 1 and will never cause a SMART threshold trip.

SMART Attribute: Reserved Block Count (ID 170)

Attribute Flags (33h)

- Warranty = 1
- Offline = 1
- Performance = 0
- Error rate = 0
- Event count = 1
- Self-preservation = 1

Current Value (8 bits)

This value represents the percentage of unused or remaining reserved blocks available. It is normalized as a percentage from 100% down to 1% (64h to 01h).
This value is calculated as:

$$V_C = 100 \left(1 - \frac{R_{USED}}{R_T}\right)$$

Where:
R_{USED} = Total number of reserved blocks currently used
R_T = Total number of blocks reserved by the device.

Worst Value (8 bits)

This value is always equal to the Current Value.

Raw Data (48 bits)

This value is the number of reserved blocks that have been used on the drive.

Reserved/Threshold (8 bits)

The threshold for this attribute is set to 0Ah. A SMART threshold trip occurs when the Current Value is 10%.

SMART Attribute: Program Fail Count (ID 171)

Attribute Flags (32h)

- Warranty = 0
- Offline = 1
- Performance = 0
- Error rate = 0
- Event count = 1
- Self-preservation = 1

Current Value (8 bits)

This value is calculated as:

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

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

Worst Value (8 bits)

This value is always 100% (64h).

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 and will never cause a SMART threshold trip.

SMART Attribute: Erase Fail Count (ID 172)

Attribute Flags (32h)

- Warranty = 0
- Offline = 1
- Performance = 0
- Error rate = 0
- Event count = 1
- Self-preservation = 1

Current Value (8 bits)

This value is calculated as:

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

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 1 and will never cause a SMART threshold trip.

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

Attribute Flags (32h)

- Warranty = 0
- Offline = 1
- Performance = 0
- Error rate = 0
- Event count = 1
- Self-preservation = 1

Current Value (8 bits)

This value is calculated as:

$$V_C = 100\left(1 - \frac{E_{AVG}}{B_L}\right)$$

Where:
E_{AVG} = The average erase count
B_L = The rated life of a block (the erase count for which the NAND part is rated.)

Worst Value (8 bits)

This value is equal the Current Value.

Raw Data (48 bits)

This value is the average erase count of all good blocks.

Reserved/Threshold (8 bits)

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

SMART Attribute: Unexpected Power Loss Count (ID 174)

Attribute Flags (32h)

- Warranty = 0
- Offline = 1
- Performance = 0
- Error rate = 0
- Event count = 1
- Self-preservation = 1

Current Value (8 bits)

This value is always 100% (64h).

Worst Value (8 bits)

This value is always 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.

Reserved/Threshold (8 bits)

The threshold for this attribute is set to 0 and will never cause a SMART threshold trip.

SMART Attribute: Unused Reserved (Spare) Block Count (ID 180)

Attribute Flags (33h)

- Warranty = 1
- Offline = 1
- Performance = 0
- Error rate = 0
- Event count = 1
- Self-preservation = 1

Current Value (8 bits)

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

Worst Value (8 bits)

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

Raw Data (48 bits)

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.

Reserved/Threshold (8 bits)

The threshold for this attribute is set to 0 and will never cause a SMART threshold trip.

SMART Attribute: SATA Interface Downshift (ID 183)

Attribute Flags (32h)

- Warranty = 0
- Offline = 1
- Performance = 0
- Error rate = 0
- Event count = 1
- Self-preservation = 1

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).

Reserved/Threshold (8 bits)

The threshold for this attribute is set to 0 and will never cause a SMART threshold trip.

SMART Attribute: Error Correction Count (ID 184)

Attribute Flags (32h)

- Warranty = 0
- Offline = 1
- Performance = 0
- Error rate = 0
- Event count = 1
- Self-preservation = 1

Current Value (8 bits)

This attribute indicates how many end-to-end data path errors have occurred. The formula for the current value is as follows: MAX (1, 100 - the number of end-to-end error counts). The current value = 100 - the raw value.

Worst Value (8 bits)

This value holds the lowest-ever current value.

Raw Data (48 bits)

This value is the count of end-to-end error corrections.

Reserved/Threshold (8 bits)

The threshold for this attribute is set to 0 and will never cause a SMART threshold trip.

SMART Attribute: Reported Uncorrectable Errors (ID 187)

Attribute Flags (32h)

- Warranty = 0
- Offline = 1
- Performance = 0
- Error rate = 0
- Event count = 1
- Self-preservation = 1

Current Value (8 bits)

This value is always 100% (64h).

Worst Value (8 bits)

This value is always 100% (64h).

Raw Data (48 bits)

This value is the total number of ECC correction failures.

Reserved/Threshold (8 bits)

The threshold for this attribute is set to 0 and will never cause a SMART threshold trip.

SMART Attribute: Command Timeouts (ID 188)

Attribute Flags (32h)

- Warranty = 0
- Offline = 1
- Performance = 0
- Error rate = 0
- Event count = 1
- Self-preservation = 1

Current Value (8 bits)

This value is always 100% (64h).

Worst Value (8 bits)

This value is always 100% (64h).

Raw Data (48 bits)

This counter is incremented by the number of outstanding commands when the host issues a soft reset or a comreset. If the value ever exceeds FFFFFFFFFFFFh, it wraps around.

Reserved/Threshold (8 bits)

The threshold for this attribute is set to 0 and will never cause a SMART threshold trip.

SMART Attribute: Enclosure Temperature (ID 194)

Attribute Flags (22h)

- Warranty = 0
- Offline = 1
- Performance = 0
- Error rate = 0
- Event count = 0
- Self-preservation = 1

Current Value (8 bits)

This value is calculated as 100 - Current Temperature in degrees Celsius. If the current temperature is > 100, this value will wrap. For example, 101 is reported as 255, 102 is reported as 254, and so on.

Worst Value (8 bits)

This value is calculated as 100 - MAX temperature. If the MAX temperature is > 100, this value will wrap. For example, 101 is reported as 255, 102 is reported as 254, and so on.

Raw Data (48 bits)

The value is defined as:

Bytes					
5	4	3	2	1	0
MAX temperature (T_M)		MIN temperature		Current temperature (T_C)	

Reserved/Threshold (8 bits)

The threshold for this attribute is set to 0, meaning that it will never cause a SMART threshold trip.

SMART Attribute: Cumulative Corrected ECC (ID 195)

Attribute Flags (32h)

- Warranty = 0
- Offline = 1
- Performance = 0
- Error rate = 0
- Event count = 1
- Self-preservation = 1

Current Value (8 bits)

This value is always 100% (64h).

Worst Value (8 bits)

This value is always 100% (64h).

Raw Data (48 bits)

This value gives the total number of bits corrected by ECC over the life of the drive.

Reserved/Threshold (8 bits)

The threshold for this attribute is set to 0 and will never cause a SMART threshold trip.

SMART Attribute: Reallocation Even Count (ID 196)

Attribute Flags (32h)

- Warranty = 0
- Offline = 1
- Performance = 0
- Error rate = 0
- Event count = 1
- Self-preservation = 1

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 calculated as:

$V_R = B_T - B_F$

Where:

B_T = Total number of bad blocks on the drive.
B_F = Total number of factory-marked (OTP) bad blocks and manufacturing burn-in blocks.

Reserved/Threshold (8 bits)

The threshold for this attribute is set to 0 and will never cause a SMART threshold trip.

SMART Attribute: Current Pending Sector Count (ID 197)

Attribute Flags (32h)

- Warranty = 0
- Offline = 1
- Performance = 0
- Error rate = 0
- Event count = 1
- Self-preservation = 1

Current Value (8 bits)

This value is always 100% (64h).

Worst Value (8 bits)

This value is always 100% (64h).

Raw Data (48 bits)

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

Reserved/Threshold (8 bits)

The threshold for this attribute is set to 0 and will never cause a SMART threshold trip.

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

Attribute Flags (30h)

- Warranty = 0
- Offline = 0
- Performance = 0
- Error rate = 0
- Event count = 1
- Self-preservation = 1

Current Value (8 bits)

This value is always 100% (64h).

Worst Value (8 bits)

This value is always 100% (64h).

Raw Data (48 bits)

This value is the cumulative number of unrecoverable read errors found in a background media scan.

Reserved/Threshold (8 bits)

The threshold for this attribute is set to 0 and will never cause a SMART threshold trip.

SMART Attribute: Ultra-DMA CRC Error Rate (ID 199)

Attribute Flags (32h)

- Warranty = 0
- Offline = 1
- Performance = 0
- Error rate = 0
- Event count = 1
- Self-preservation = 1

Current Value (8 bits)

This value is always 100% (64h).

Worst Value (8 bits)

This value is always 100% (64h).

Raw Data (48 bits)

This value is the total number of both read and write CRC interface errors experienced over the life of the drive.

Reserved/Threshold (8 bits)

The threshold for this attribute is set to 1 and will never cause a SMART threshold trip.

SMART Attribute: Percent Lifetime Remaining (ID 202)

Attribute Flags (30h)

- Warranty = 0
- Offline = 0
- Performance = 0
- Error rate = 0
- Event count = 1
- Self-preservation = 1

Current Value (8 bits)

The Current Value indicates the estimated percentage of lifetime remaining based upon the average block erase count and the rated block erase count. That is, if 30% of the lifetime has been used, this value reports 70%. A value of 0% indicates that 100% of the expected lifetime has been used. Note that the Current Value differs from the Raw Data value below which gives the threshold inverted value of the Current Value. The Current Value starts at 100% and counts down to 0% whereas the Raw Data value starts at 0% and counts up.

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 expressed as a percentage of the average erase count and the rated erase count of the media, which is the percentage of lifetime used as opposed to the Current Value which is the percentage of lifetime remaining.

Reserved/Threshold (8 bits)

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

SMART Attribute: Write Error Rate (ID 206)

Attribute Flags (0Eh)

- Warranty = 0
- Offline = 1
- Performance = 1
- Error rate = 1
- Event count = 0
- Self-preservation = 0

Current Value (8 bits)

This value represents the normalized number of NAND program failures per megabyte of host data written as a percentage.

Worst Value (8 bits)

This is the lowest calculated Current Value in the overall device history.

Raw Data (48 bits)

This value stores the number of NAND program failures.

Reserved/Threshold (8 bits)

The threshold for this attribute is set to 0 and will never cause a SMART threshold trip.

SMART Attribute: RAIN Success Recovered Page Count (ID 210)

Attribute Flags (32h)

- Warranty = 0
- Offline = 1
- Performance = 0
- Error rate = 0
- Event count = 1
- Self-preservation = 1

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)

The total number of translation units (TU) successfully recovered by Micron's redundant array of independent NAND (RAIN) technology; increments when RAIN successfully recovers user data.

Reserved/Threshold (8 bits)

The threshold for this attribute is set to 0 and will never cause a SMART threshold trip.

SMART Attribute: Integrity Scan Completed Count (ID 211)

Attribute Flags (32h)

- Warranty = 0
- Offline = 1
- Performance = 0
- Error rate = 0
- Event count = 1
- Self-preservation = 1

Current Value (8 bits)

This value is always 100% (64h).

Worst Value (8 bits)

This value is always 100% (64h).

Raw Data (48 bits)

This value gives the total count of the periodic data integrity scans that have been completed.

Reserved/Threshold (8 bits)

The threshold for this attribute is set to 0 and will never cause a SMART threshold trip.

SMART Attribute: Integrity Scan Folding Completed Count (ID 212)

Attribute Flags (32h)

- Warranty = 0
- Offline = 1
- Performance = 0
- Error rate = 0
- Event count = 1
- Self-preservation = 1

Current Value (8 bits)

This value is always 100% (64h).

Worst Value (8 bits)

This value is always 100% (64h).

Raw Data (48 bits)

This value gives the total count of folding events completed as a result of the periodic data integrity scan.

Reserved/Threshold (8 bits)

The threshold for this attribute is set to 0 and will never cause a SMART threshold trip.

SMART Attribute: Cumulative Host Sectors Written (ID 246)

Attribute Flags (32h)

- Warranty = 0
- Offline = 1
- Performance = 0
- Error rate = 0
- Event count = 1
- Self-preservation = 1

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 total number of host sectors (LBAs) written by the host over the life of the drive.

Reserved/Threshold (8 bits)

The threshold for this attribute is set to 0 and will never cause a SMART threshold trip.

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

Attribute Flags (32h)

- Warranty = 0
- Offline = 1
- Performance = 0
- Error rate = 0
- Event count = 1
- Self-preservation = 1

Current Value (8 bits)

This value is always 100% (64h).

Worst Value (8 bits)

This value is always 100% (64h).

Raw Data (48 bits)

This value stores the cumulative host program NAND page count.

Reserved/Threshold (8 bits)

The threshold for this attribute is set to 0, meaning that it never causes a SMART threshold trip.

SMART Attribute: FTL Program Page Count (ID 248)

Attribute Flags (32h)

- Warranty = 0
- Offline = 1
- Performance = 0
- Error rate = 0
- Event count = 1
- Self-preservation = 1

Current Value (8 bits)

This value is always 100% (64h).

Worst Value (8 bits)

This value is always 100% (64h).

Raw Data (48 bits)

This value stores the cumulative FTL program page count. This attribute tracks the number of NAND pages programed by the FTL which are in addition to operations programed by the host. Write amplification factor can be calculated by WAF = (Attrib_247 + Attrib_248) / Attrib_247.

Reserved/Threshold (8 bits)

The threshold for this attribute is set to 0, meaning that it never causes a SMART threshold trip.

SMART Commands

Table 2: SMART Commands

Command	Feature	Sector Count	LBA Low	LBA Middle	LBA High	Drive Head	Command
SMART READ DATA	D0h	01h	XX	4Fh	C2h	A0h	B0h
SMART ENABLE ATTRIBUTE AUTOSAVE	D2h	F1h	XX	4Fh	C2h	A0h	B0h
SMART DISABLE ATTRIBUTE AUTOSAVE	D2h	00h	XX	4Fh	C2h	A0h	B0h
SMART EXECUTE OFF-LINE IMMEDIATE	D4h	Sub-cmd	XX	4Fh	C2h	A0h	B0h
SMART READ LOG	D5h	Number of pages	Log address	4Fh	C2h	A0h	B0h
SMART WRITE LOG	D6h	Number of pages	Log address	4Fh	C2h	A0h	B0h
SMART ENABLE OPS	D8h	XX	XX	XX	C2h	A0h	B0h
SMART DISABLE OPS	D9h	XX	XX	XX	C2h	A0h	B0h
SMART RETURN STATUS	DAh	XX	XX	XX	C2h	A0h	B0h

Command Interface with Host

Communication to or from the device is through the data register and command block registers.

Table 3: Register Addressing

Offset Address	Read	Write	Value Type
00h	Data	Data	Word
01h	Error	Feature	Byte
02h	Sector count	Sector count	Byte
03h	LBA low	LBA low	Byte
04h	LBA middle	LBA middle	Byte
05h	LBA high	LBA high	Byte
06h	Drive head	Drive head	Byte
07h	Status	Command	Byte

Note: 1. Input = from host to device; output = from device to host

SMART Read Data

Protocol PIO Data-In

Table 4: Input

Register	7	6	5	4	3	2	1	0
Feature	D0h							
Sector count	01h							
LBA low	XX							
LBA middle	4Fh							
LBA high	C2h							
Drive head	1	0	1	0	0	0	0	0
Command	B0h							

Table 5: Normal Output

Register	7	6	5	4	3	2	1	0
Error	XX							
Sector count	XX							
LBA low	XX							
LBA middle	XX							
LBA high	XX							
Drive head	XX							
Status	50h							

Description

A SMART attribute is retrieved when the host issues 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 ACS-3 specification. These contain the SMART attribute data.

Table 6: SMART Attribute Table Layout

Byte Offset	Length (Bytes)	Value	Description
0	2	0010h	SMART structure version
2 + (12 x 0)	12	XXh	Attribute entry 1
2 + (12 x 1)	12	XXh	Attribute entry 2
2 + (12 x n)	12	XXh	Attribute entry n
...	...	...	...
2 + (12 x 29)	–	(Reserved)	–

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

Table 7: Attribute Data Structure

Length (Bytes)	Description	Value
1	Attribute ID	01h, 09h, 12h...
2	Flags: Bit 0 – Warranty Bit 1 – Offline Bit 2 – Performance Bit 3 – Error rate Bit 4 – Event count Bit 5 – Self-preservation Bits 6–15 – Reserved	Feature
1	Current value	Attribute specific
1	Worst value	Attribute specific
4	LBA middle	32 bits of raw attribute data
2	LBA high	Attributes use these bytes to store raw data
1	Drive head	Attribute specific

For each attribute, there is a corresponding threshold that is retrieved when the host issues the SMART READ ATTRIBUTE THRESHOLDS command. In the 512 bytes of 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 compares the current value attributes with the threshold and returns a status that specifies if the self test has either completed without error (C24Fh) or detected a threshold has been exceeded (2CF4h).

SMART Enable/Disable Attribute Auto Save

Protocol PIO Non-Data

Table 8: Input

Register	7	6	5	4	3	2	1	0
Feature	D2h							
Sector count	00h or F1h							
LBA low	XX							
LBA middle	4Fh							
LBA high	C2h							
Drive head	1	0	1	0	0	0	0	0
Command	B0h							

Table 9: Normal Output

Register	7	6	5	4	3	2	1	0
Error	XX							
Sector count	XX							
LBA low	XX							
LBA middle	XX							
LBA high	XX							
Drive head	XX							
Status	50h							

Description

- If the sector count is 00h, the SMART Auto Save attribute is disabled.
- If the sector count is F1h, the SMART Auto Save attribute is enabled.
- This command has no practical effect on the drive at this point.

SMART Disable Operations

Protocol PIO Non-Data

Table 10: Input

Register	7	6	5	4	3	2	1	0
Feature	D9h							
Sector count	XX							
LBA low	XX							
LBA middle	4Fh							
LBA high	C2h							
Drive head	1	0	1	0	0	0	0	0
Command	B0h							

Table 11: Normal Output

Register	7	6	5	4	3	2	1	0
Error	XX							
Sector count	XX							
LBA low	XX							
LBA middle	XX							
LBA high	XX							
Drive head	XX							
Status	50h							

Description

This command disables access to all SMART capabilities within the device. After receipt of this command by the device, with the exception of the SMART ENABLE OPERATIONS command, all other SMART commands including SMART DISABLE OPERATIONS commands are disabled and are command-terminated by the device. The SMART disabled state is preserved by the device during all power and reset events.

Any offline self-test/data collection is also terminated.

SMART Return Status

Protocol PIO Non-Data

Table 12: Input

Register	7	6	5	4	3	2	1	0
Feature	DAh							
Sector count	XX							
LBA low	XX							
LBA middle	4Fh							
LBA high	C2h							
Drive head	1	0	1	0	0	0	0	0
Command	B0							

Table 13: Normal Output

Register	7	6	5	4	3	2	1	0
Error	XX							
Sector count	XX							
LBA low	XX							
LBA middle	4Fh							
LBA high	C2h							
Drive head	XX							
Status	50h							

Table 14: Trip Output

Register	7	6	5	4	3	2	1	0
Error	XX							
Sector count	XX							
LBA low	XX							
LBA middle	F4h							
LBA high	2Ch							
Drive head	XX							
Status	50h							

Description

In the normal output case, all SMART attribute values are currently higher than the threshold value associated with the attribute.

In the trip output case, at least a single SMART attribute value has fallen below the threshold value associated with the attribute.

SMART Read Warranty Thresholds

Protocol PIO Non-Data

Table 15: Input

Register	7	6	5	4	3	2	1	0
Feature	D1h							
Sector count	XX							
LBA low	XX							
LBA middle	4Fh							
LBA high	C2h							
Drive head	1	0	1	0	0	0	0	0
Command	B0h							

Table 16: Normal Output

Register	7	6	5	4	3	2	1	0
Feature	XX							
Sector count	XX							
LBA low	XX							
LBA middle	XX							
LBA high	XX							
Drive head	XX							
Status	50h							

Description

Returns a sector in the following format, *n*, varying from 0 to 29, one for each table entry.

Table 17: SMART Attribute Entry Format

Byte Offset	Length (bytes)	Contents ID	Description
0	2	00h10	SMART structure version
2 + (12 x n)	1	AttributeID	The attribute ID
2 + (12 x n) + 1	1	Threshold	The threshold value
2 + (12 x n) + 2	10	00h	Reserved
362	18	00h	Reserved
380	131	VU	VU space
511	1	Checksum	Two's compliment checksum of preceding 511B

SMART Execute Off-Line Immediate

Protocol PIO Non-Data

Table 18: Input

Register	7	6	5	4	3	2	1	0
Feature	D4h							
Sector count	XX							
LBA low	Subcommand							
LBA middle	4Fh							
LBA high	C2h							
Drive head	1	0	1	0	0	0	0	0
Command	B0h							

Table 19: Normal Output

Register	7	6	5	4	3	2	1	0
Error	XX							
Sector count	XX							
LBA low	XX							
LBA middle	XX							
LBA high	XX							
Drive head	XX							
Status	50h							

Description

This command allows the host to request various self-tests. Refer to the ACS-3 specification for more information.

The implementation resumes the offline self-test upon completing a new host command unless the command is SMART DISABLE OPERATIONS, SMART ABORT OFF-LINE MODE SELF-TEST, IDLE IMMEDIATE, STANDBY IMMEDIATE, or SLEEP.

SMART Logging

Supported SMART/GPL (General Purpose Logging) Logs

Table 20: Supported SMART/GPL Logs

Log Address	Page Count	Log Name	R/W	Access
00h	1	SMART Log Directory	RO	SMART/GPL
01h	1	Summary SMART Error Log	RO	SMART
02h	51	Comprehensive SMART Error Log	RO	SMART
03h	16383	Extended Comprehensive SMART Error Log	RO	GPL
04h	255	Device Statistics	RO	SMART/GPL
06h	1	SMART Self-Test Log	RO	SMART
07h	3449	Extended SMART Self-Test Log	RO	GPL
09h	1	Selective Self-Test Log	R/W	SMART
10h	1	NCQ Command Error	RO	GPL
11h	1	SATA Phy Event Counters	RO	GPL
21h	1	Write Stream Error Log	RO	GPL
22h	1	Read Stream Error Log	RO	GPL
80g-9Fh	16 each	Host Vendor-Specific Logs	R/W	SMART/GPL
A0h		Error Log [VU]	RO	SMART/GPL
E0h	1	SCT Command/Status	R/W	SMART/GPL
E1h	1	SCT Data Transfer	R/W	SMART/GPL

Notes:
1. Refer to Annex A of ACS-3 for a detailed description of these logs.
2. For log address 6/7 (SMART Self-Test Logs), the entry is logged after the self-test starts and the test is complete.
3. As indicated in the table, these Logs can be read and written with the SMART READ LOG and SMART WRITE LOG commands and/or the READ LOG EXT, READ LOG DMA EXT, WRITE LOG EXT, and WRITE LOG DMA EXT commands.

SMART Read Log

Protocol PIO Data-In

Table 21: Input

Register	7	6	5	4	3	2	1	0
Feature	D5h							
Sector count	01h							
LBA low	Log address							
LBA middle	4Fh							
LBA high	C2h							
Drive head	1	0	1	0	0	0	0	0
Command	B0h							

Table 22: Normal Output

Register	7	6	5	4	3	2	1	0
Error	XX							
Sector count	01h							
LBA low	XX							
LBA middle	XX							
LBA high	XX							
Drive head	XX							
Status	50h							

SMART Write Log

Protocol PIO Data-In

Table 23: Input

Register	7	6	5	4	3	2	1	0
Feature	D5h							
Sector count	01h							
LBA low	Log address							
LBA middle	4Fh							
LBA high	C2h							
Drive head	1	0	1	0	0	0	0	0
Command	B0h							

Table 24: Normal Output

Register	7	6	5	4	3	2	1	0
Error	XX							
Sector count	01h							
LBA low	XX							
LBA middle	XX							
LBA high	XX							
Drive head	XX							
Status	50h							

Reference

T13/2061-D, “Information technology - ATA/ATAPI Command Set - 3 (ACS-3),” Revision 5, American National Standard of Accredited Standards Committee INCITS, October 28, 2013.

Revision History

Rev. B – 8/19

- Added new attributes 211 and 212

Rev. A – 12/16

- Initial release

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