

The SMART Command Feature Set for the P400e SSD Firmware 0142

Introduction

The SMART command (B0h) is the self-monitoring, analysis, and reporting technology (SMART) feature set.

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 data loss and advise the user of appropriate action. Support of this feature set is indicated in the IDENTIFY DEVICE data.

If the SMART feature set is implemented, these commands will be implemented:

- SMART ENABLE/DISABLE ATTRIBUTE AUTOSAVE
- SMART ENABLE OPERATIONS
- SMART DISABLE OPERATIONS
- SMART RETURN STATUS

If the SMART feature set is implemented, these commands are optional:

- SMART READ DATA
- SMART EXECUTE OFF-LINE IMMEDIATE
- SMART READ LOG
- SMART WRITE LOG

The SMART feature set implemented by Micron:

- SMART READ DATA
- SMART ENABLE/DISABLE ATTRIBUTE AUTOSAVE
- SMART ENABLE OPERATIONS
- SMART DISABLE OPERATIONS
- SMART RETURN STATUS
- SMART EXECUTE OFF-LINE IMMEDIATE
- SMART READ LOG
- SMART WRITE LOG
- SMART READ WARRANTY FAILURE THRESHOLDS

Table 1: 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 READ WARRANTY FAILURE THRESHOLDS | D1h | 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 | Sec count | Log addr | 4Fh | C2h | A0h | B0h |
| SMART WRITE LOG | D6h | Sec count | Log addr | 4Fh | C2h | A0h | B0h |
| SMART ENABLE OPS | D8h | XX | XX | 4Fh | C2h | A0h | B0h |
| SMART DISABLE OPS | D9h | XX | XX | 4Fh | C2h | A0h | B0h |
| SMART RETURN STATUS | DAh | XX | XX | 4Fh | C2h | A0h | B0h |

Command Interface with Host

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

Table 2: 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 |

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

SMART Read Data and Attributes

Protocol PIO Data-In

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 | | | | | | | |

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 returns the device SMART data structure to the host.

Vendor-Specific Data Bytes 0-361

| Byte Offset | Length (Bytes) | Attribute ID | Description |
|---------------|----------------|--------------|-------------------------|
| 0 | 2 | 0010h | SMART structure version |
| 2 + (12 × 0) | 12 | XXh | Attribute entry 1 |
| 2 + (12 × 1) | 12 | XXh | Attribute entry 2 |
| 2 + (12 × n) | 12 | XXh | Attribute entry n |
| ... | ... | ... | ... |
| 2 + (12 × 29) | | (Reserved) | - |

Table 3: Attribute Table Format

| Length (Bytes) | Description | Value |
|----------------|--|---|
| 1 | Attribute ID | 01h, 09h, 12h, and so forth... |
| 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 | Varies by attribute |
| 1 | Current value | Attribute-specific |
| 1 | Worst value | Attribute-specific |
| 4 | Data | 32 bits of raw attribute data |
| 2 | Attribute-specific | Some attributes use these two bytes to store raw data |
| 1 | Threshold | Attribute-specific |

Table 4: SMART Attribute Summary

| AttribID | HexID | Name | SMART Trip | Implementation | Description |
|----------|-------|--|------------|---|---|
| 1 | 01h | Raw Read Error Rate | Yes | Raw CECC + UECC correction events Normalized values are errors per MB | Tracks raw rate of media errors per MB of data over the SATA interface |
| 5 | 05h | Reallocated Sectors Count | Yes | New failing sector count | - |
| 9 | 09h | Power-On Hours Count | No | Lifetime hours powered on | Tracks total number of operation hours from the time the device leaves the factory |
| 12 | 0Ch | Power Cycle Count | No | Count of power cycles | Counts true power cycles, excluding power mode commands |
| 170 | AAh | Reserved Block Count | Yes | FTL reserved block count (Total BB - OTP BB) | Tracks the number of blocks/pages utilized to replace bad blocks; based on specified NAND part/die |
| 171 | ABh | Program Fail Count | No | Total number of NAND program failure events | - |
| 172 | ACh | Erase Fail Count | No | Total number of NAND erase failure events | - |
| 173 | ADh | Average Block Erase Count | Yes | Average erase count of all good blocks | - |
| 174 | A Eh | Unexpected Power Loss Count | No | Internal table rebuild count; for example, the DPT block is corrupted or the last page is corrupted | Counts the number of times unexpected power loss occurs |
| 181 | B5h | Non-Physical Page-Aligned Access Count | No | [16:0] unaligned reads counter [32:17] unaligned writes counter [48:33] sum of the other two counters All counters represent the internal raw value divided by 60,000 and stop at FFFFh. | Tracks the number of user data accesses (both reads and writes) where LBAs are not aligned to the physical NAND page size. |
| 183 | B7h | SATA Interface Downshift | No | Count of SATA Phy downshifts from 6.0G -> 3.0G or 3.0G -> 1.5G | Counts the number of interface downshifts encountered between the host and the device |
| 184 | B8h | Error Correction Count | Yes | Count of end-to-end corrections | - |
| 187 | BBh | Reported Uncorrectable Errors | No | Count of UECC events | Tracks the number of uncorrectable (UNC) media errors {51h 10h, 51h 44h, 51h 01h} reported back to the host for all data access commands. Errors encountered by drive self-test (DST) are NOT included. |
| 188 | BCh | Command Time-Out | No | Counts the number of commands that time out | Tracks the number of command time-outs as defined by an active command being interrupted by a HRESET, COMRESET, SRST, or other command |
| 189 | BDh | Factory Bad Block Count | No | OTP bad block count | - |

Table 4: SMART Attribute Summary (Continued)

| AttribID | HexID | Name | SMART Trip | Implementation | Description |
|----------|-------|---|------------|---|---|
| 194 | C2h | Enclosure Temperature | No | Reports the temperature as measured by the temperature sensor | [1:0] current temperature [3:2] MIN temperature [5:4] MAX temperature |
| 195 | C3h | Cumulative Corrected ECC | No | Count of total number of bits corrected by ECC over the life of the drive | - |
| 196 | C4h | Reallocation Event Count | No | New failing block count; each new failing block will be reallocated with a free block | - |
| 197 | C5h | Current Pending Sector Count | No | Will always be 0, as error handling will be done at the field | - |
| 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 | Tracks the rate of CRC errors occurring in Ultra ATA transfers to or from the host. See the Ultra ATA CRC specification for Normalized and Worst Ever definitions. |
| 202 | CAh | Percentage of Lifetime Remaining | No | Average erase count of all blocks on Channel 0 CE 0 divided by the specified MaxEraseCount (5000 for MLC or 100,000 for SLC) reported as a percentage from 0 to 100% (00h to 64h) | Sums block erase counts across one CE. The normalized total block erase count is between 0-100 using integer division. Divide by 50 for MLC NAND and 1000 for SLC NAND. The return value is the difference between the calculated number and 100. |
| 206 | CEh | Write Error Rate | No | Number of NAND program status fails per MB of SATA data written | Tracks raw error rate when writing |
| 242 | F2h | Write Protect Progress | No | Raw number of free blocks before the drive will enter write protect mode | When in write protect mode, the drive is read-only. |

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)

The Current Value field is calculated in `Mt_SmartCalcReadErrorRate()`.

The value is the total number of correctable and uncorrectable ECC error events (event is a correction per AU) divided by the total host page reads over the life of the drive, multiplied by $(100,000 \times \text{total block count}/2)$.

Note: For $(100,000 \times \text{total block count}/2)$: The value of 100,000 is set to account for read disturb event thresholds for one block. $100,000 \times \text{total block count}/2$ will be half of the total page read counts for the whole drive before read disturb needs to be factored.

ECC errors occurring while reading non-user data will still contribute to this rate. The current value will not be calculated and will remain set to 64h until the host read page count is not less than $(100,000 \times \text{total block count}/2)$.

Worst Value (8 bits)

This field contains the lowest value of the Current Value field ever calculated over the life of the drive. This value will always be between 1% and 100% (01h to 64h).

Raw Data (48 bits)

This data field contains the raw sum of correctable and uncorrectable ECC error events over the life of the drive. If this ever exceeds FFFFFFFFh, this value will wrap around.

Reserved/Threshold (8 bits)

The threshold for this attribute is set to 32h, meaning that the current raw read error rate threshold is 50%.



SMART Attribute: Reallocated Sector Count (ID 5)

Attribute Flags (33h)

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

Current Value (8 bits)

This field contains unused reserved blocks/total reserved blocks. This number is normalized as a percentage value from 1% to 100% (01h to 64h64h).

Worst Value (8 bits)

This field contains the lowest-ever value of the Current Value field.

Raw Data (48 bits)

This value is calculated via $Mt_CalcReservedBlocksUsed() \times BLOCK_SECTOR_COUNT$. It gives (the total bad block count of the drive - the number of OTP bad blocks) \times (the number of sectors per block).

Reserved/Threshold (8 bits)

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

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 hard-coded to 100% (64h).

Worst Value (8 bits)

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

Raw Data (48 bits)

This value contains the raw number of hours that the device has been online over its life.

Calculation: `MetaInfo.smart.PowerOnTime/60`

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: 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 hard-coded to 100% (64h).

Worst Value (8 bits)

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

Raw Data (48 bits)

This value contains the raw number of power cycle events that this drive has experienced.

This value is stored in `MetaInfo.smart.PowerOnCycles`.

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: 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 is calculated as $100 - (\text{unused reserved blocks} / \text{total reserved blocks}) \times 100$.
This number is normalized as a percentage value from 1% to 100% (01h01h to 64h).

Worst Value (8 bits)

This value is the lowest-ever current value. It should always equal the current value.

Raw Data (48 bits)

This value contains the total bad block count of the drive minus the number of OTP bad blocks.

Reserved/Threshold (8 bits)

The threshold for this attribute is set to 0ah, meaning that the threshold shall represent no value greater than 90% of the total available blocks/pages.

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 will always be 100% (64h).

Worst Value (8 bits)

This value will always be 100% (64h).

Raw Data (48 bits)

This value contains the raw number of program failure events.

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: 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 will always be 100 (64h).

Worst Value (8 bits)

This value contains the lowest-ever current value. It should always equal the current value.

Raw Data (48 bits)

This value contains the raw number of ERASE failure events.

Reserved/Threshold (8 bits)

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

SMART Attributes: Average Block Erase Count (ID 173)

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 calculated as $(100 - (\text{Average Erase Count} / \text{BLOCK_LIFE}) \times 100)$. It is normalized as a percentage value from 1% to 100% (01h to 64h).

Worst Value (8 bits)

This value contains the lowest-ever current value. It should always 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 0ah, meaning that the threshold shall represent no value greater than 90% of the total wear-leveling capability.

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 will always be 100% (64h).

Worst Value (8 bits)

This value will always be 100% (64h).

Raw Data (48 bits)

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

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: Non-Physical Page-Aligned Access Count (ID 181)

Attribute Flags (22h)

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

Current Value (8 bits)

This value will always be 100% (64h).

Worst Value (8 bits)

This value will always be 100% (64h).

Raw Data (48 bits)

The low-order 16 bits of the raw data contain the total unaligned reads counter, divided by 60,000, with a ceiling value of FFFFh.

The middle-order 16 bits of the raw data contain the total unaligned writes counter, divided by 60,000, with a ceiling value of FFFFh.

The high-order 16 bits of the raw data contain the sum total of the unaligned read and unaligned write counters, divided by 60,000, with a ceiling value of FFFFh. The division of the sum is done after summing the raw values of reads and writes—the sum of the two counters may appear higher than summing normalized reads and writes.

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: 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 will always be 100% (64h).

Worst Value (8 bits)

This value will always be 100% (64h).

Raw Data (48 bits)

At the completion of speed negotiation between the host and the device, the firmware records the value of the newly negotiated speed. This value is compared to the previously recorded value; if the new value is lower than the previous, a downshift has occurred, and the downshift counter is incremented.

The downshift counter is stored in the global variable SmartSataSpeedDownshiftRate.

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: Error Correction Count (ID 184)

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 calculated as $(100 - \# \text{ of nonrecoverable errors} - (\text{recoverable errors}/2))/100$.

Worst Value (8 bits)

This value contains the lowest-ever current value. It should always equal the current value.

Raw Data (48 bits)

This 48-bit value contains the number of end-to-end corrections.

Reserved/Threshold (8 bits)

The threshold for this attribute is set to 32h, meaning that an error-correction rate larger than 50% will 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 will always be 100% (64h).

Worst Value (8 bits)

This value will always be 100% (64h).

Raw Data (48 bits)

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

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: 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 will always be 100% (64h).

Worst Value (8 bits)

This value will always be 100% (64h).

Raw Data (48 bits)

This counter is incremented by the number of outstanding commands when the host issues a soft reset, host reset, or a comreset. This value is stored in `MetaInfo.smart.CommandTimeout`.

The raw data contains the value of this counter. If it ever exceeds `FFFFFFFFh`, it will wrap around.

Reserved/Threshold (8 bits)

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

SMART Attributes: Factory Bad Block Count (ID 189)

Attribute Flags (0Eh)

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

Current Value (8 bits)

This value will always be 100% (64h).

Worst Value (8 bits)

This value will always be 100% (64h).

Raw Data (48 bits)

This value is the OTP bad block count.

Reserved/Threshold (8 bits)

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

SMART Attributes: Device 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)

Current temperature.

Worst Value (8 bits)

Maximum temperature.

Raw Data (48 bits)

- [1:0] current temperature as measured by the thermal sensor on the drive's PCB
- [3:2] MIN temperature as measured by the thermal sensor on the drive's PCB
- [5:4] MAX temperature as measured by the thermal sensor on the drive's PCB

Reserved/Threshold (8 bits)

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

SMART Attributes: Cumulative Corrected ECC (ID 195)

Attribute Flags (3Ah)

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

Current Value (8 bits)

This value will always be 100% (64h).

Worst Value (8 bits)

This value will always be 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, meaning that it will never cause a SMART threshold trip.

SMART Attributes: Reallocation Event 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 will always be 100% (64h).

Worst Value (8 bits)

This value will always be 100% (64h).

Raw Data (48 bits)

This value is calculated via `Mt_CalcReservedBlocksUsed()`.

This value gives the total bad block count of the drive minus the number of OTP bad blocks.

Reserved/Threshold (8 bits)

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

SMART Attributes: 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 will always be 100% (64h).

Worst Value (8 bits)

This value will always be 100% (64h).

Raw Data (48 bits)

This value will always be 0 because reallocation will be done on-the-fly (OTF).

Reserved/Threshold (8 bits)

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

SMART Attributes: SMART Off-Line Scan Uncorrectable Error Count (ID 198)

Attribute Flags (30h)

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

Current Value (8 bits)

This value will always be 100% (64h).

Worst Value (8 bits)

This value will always be 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, meaning that it 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 will always be 100% (64h).

Worst Value (8 bits)

This value will always be 100% (64h).

Raw Data (48 bits)

This value is the number of captured FIS interface general CRC errors over the life of the drive, for both reads and writes, since the most recent power cycle.

This counter is stored in the global variable SmartCrcErrorRate.

If this counter ever reaches FFFFFFFFh, it will wrap around.

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: Percentage Lifetime Remaining (ID 202)

Attribute Flags (18h)

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

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%. If the value reports 0%, then 100% of the drive's lifetime has been used.

Worst Value (8 bits)

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

Raw Data (48 bits)

The percentage of lifetime used is calculated using the below formula:

$$\text{PercentageLifetimeUsed} = \frac{\text{MaxAverageEraseCount}}{\text{BlockLifeEraseCount}} \times 100$$

In this formula:

MaxAverageEraseCount is the maximum value of the average erase count on all segments.

BlockLifeEraseCount is specified as the rated (qualified) cycle count of the media used. For the P400e, this value is 3000.

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: 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 calculated error rate.

Worst Value (8 bits)

This field gives the lowest calculated value in the history of the device for the Current Value calculation above.

Raw Data (48 bits)

This value stores the number of NAND program failure events.

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: Write Protect Progress (ID 242)

Attribute Flags (02h)

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

Current Value (8 bits)

Current percentage of blocks left before the drive will enter write protect mode.

Worst Value (8 bits)

Worst percentage of blocks left before the drive will enter write protect mode.

Raw Data (48 bits)

This value gives the raw number of free blocks available before the drive will enter write protect mode and be rendered read-only.

Reserved/Threshold (8 bits)

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

SMART Enable Attribute Auto Save

Protocol PIO Non-Data

Input

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

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 enables the optional auto save attribute of the device.

This command may allow the device, after some vendor-specified event, to save the device-updated attributes to nonvolatile memory. The state of the auto save attribute will be preserved by the device during all power and reset events.



SMART Enable/Disable Attribute Auto Save

Protocol PIO Non-Data

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 | | | | | | | |

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 our drive at this point.

SMART Enable Operations

Protocol PIO Non-Data

Input

| Register | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|--------------|-----|---|---|---|---|---|---|---|
| Feature | D8h | | | | | | | |
| Sector count | XX | | | | | | | |
| LBA low | XX | | | | | | | |
| LBA middle | 4Fh | | | | | | | |
| LBA high | C2h | | | | | | | |
| Drive head | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| Command | B0h | | | | | | | |

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 enables access to all SMART capabilities within the device. The SMART-enabled state will be preserved by the device during all power and reset events.

SMART Disable Operations

Protocol PIO Non-Data

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 | | | | | | | |

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 SMART ENABLE OPERATIONS command, all other SMART commands, including SMART DISABLE OPERATIONS commands are disabled and will be command-terminated by the device. The SMART-disabled state will be preserved by the device during all power and reset events.

Any offline self-test/data collection will also be terminated.

SMART Return Status

Protocol PIO Non-Data

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 | B0h | | | | | | | |

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 | | | | | | | |

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 that attribute.

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

SMART Read Warranty Thresholds

Protocol PIO Data-In

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 | | | | | | | |

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

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

Table 5: SMART Attribute Entry Format

| Byte Offset | Length (bytes) | Contents ID | Description |
|--------------------------|----------------|-------------|---|
| 0 | 2 | 0010h | SMART structure version |
| 2 + (12 × <i>n</i>) | 1 | AttributeID | The attribute ID |
| 2 + (12 × <i>n</i>) + 1 | 1 | Threshold | The threshold value for it |
| 2 + (12 × <i>n</i>) + 2 | 10 | 00h | Reserved |
| 362 | 18 | 00h | Reserved |
| 380 | 131 | VU | VU space |
| 511 | 1 | Checksum | Two's complement checksum of preceding 511B |



SMART Execute Off-Line Immediate

Protocol PIO Non-Data

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 | | | | | | | |

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

Allow the host to request various self-tests. Refer to ATA8-ACS2(T13/2015-D Revision 2) 7.55.5 for more information.

The implementation will resume 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 6: 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 |
| 80h-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 |

Refer to Annex A of ACS-2 for a detailed description of these logs.

For log address 6/7 (SMART self-test logs), note that the entry is logged after the self-test is started, but not until the test is completed.



SMART Read Log

Protocol PIO Data-In

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 | | | | | | | |

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 READ Log via GPL (READ LOG EXT)

Protocol PIO Data-In

48-bit Command

| Name | Description | | |
|---------|-------------|---------------|----------------------------|
| Feature | XX | | |
| Count | 01h | | |
| LBA | Bit | Description | Value |
| | 47:40 | Reserved | 00h |
| | 39:32 | Page # (15:8) | XX (ignored) |
| | 31:16 | Reserved | 00h |
| | 15:8 | Page # (7:0) | XX (ignored) |
| | 7:0 | Log address | Refer to 10.3.1 and 10.3.2 |
| Device | 00h | | |
| Command | (7:0) 2Fh | | |

SMART Write Log

Protocol PIO Data-In

Input

| Register | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|--------------|-------------|---|---|---|---|---|---|---|
| Feature | D6h | | | | | | | |
| Sector count | Log Address | | | | | | | |
| LBA low | XX | | | | | | | |
| LBA middle | 4Fh | | | | | | | |
| LBA high | C2h | | | | | | | |
| Drive head | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| Command | B0h | | | | | | | |

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

1. T13/2015-D, "Information technology - ATA/ATAPI Command Set - 2 (ACS-2)," Revision 2, American National Standard of Accredited Standards Committee INCITS, August 3, 2009.



Revision History

| | |
|---|--------------|
| Rev. B | 12/12 |
| <ul style="list-style-type: none">• Update to the raw data of the Percentage Lifetime Remaining (ID 202) SMART attribute. | |
| Rev. A | 3/12 |
| <ul style="list-style-type: none">• Initial release. | |

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