

Technical Note

SMART Command Feature Set for the eU500

Introduction

This technical note provides the self-monitoring, analysis, and reporting technology (SMART) command (B0h) feature set for the Micron® eU500 embedded USB mass storage drive.

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.

SMART Command Operation

SMART command communication to the eU500 device is conducted using SCSI/ATA PASS-THROUGH commands. These SMART commands can be accessed using either of the SCSI ATA pass-through opcodes and associated transfer lengths shown in the following table.

Table 1: SCSI ATA PASS-THROUGH Commands

SCSI Command	OpCode	Description
ATA PASS-THROUGH(12)	A1h	Provides a method to send ATA commands to the device
ATA PASS-THROUGH(16)	85h	

The ATA pass-through module of the eU500 firmware supports ATA SMART commands, accessed with the B0h command code and then further selected using the appropriate feature register value. SMART commands with feature register values not shown in the following table are not supported by the eU500 and will be aborted.

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	E0h	B0h
SMART READ ATTRIBUTE THRESHOLDS	D1h	01h	XX	4Fh	C2h	E0h	B0h
SMART ENABLE OPERATIONS	D8h	XX	XX	4Fh	C2h	E0h	B0h
SMART DISABLE OPERATIONS	D9h	XX	XX	4Fh	C2h	E0h	B0h
SMART RETURN STATUS	DAh	XX	XX	4Fh	C2h	E0h	B0h

Table 3: SMART Command Register Addressing – Input Versus Output

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

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

SMART READ DATA Command

Protocol PIO Data-In

Table 4: Input

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

Description

Command is aborted if either the signature in the LBA low or LBA high register is invalid, or if the SMART commands are disabled. This is an input-only command and does not return output values. In the 512 bytes returned by the SMART READ DATA command, bytes 0–361 (169h) contain the SMART attribute data and are marked as vendor-specific in the ATA8–ACS2 and ACS3 specifications.

SMART READ ATTRIBUTE THRESHOLDS Command

Protocol PIO Data-In

Table 5: Input

Register	7	6	5	4	3	2	1	0
Feature	D1h							
Sector count	01h							
Sector number	XX							
LBA low	4Fh							
LBA high	C2h							
Drive head	1	1	1	0	0	0	0	0
Command	B0h							

Description

This command is aborted if either the signature in the LBA low or LBA high register is invalid, or if the SMART commands are disabled. This is an input-only command and does not return output values. Not all attributes have associated thresholds; available thresholds are listed in the SMART Attribute sections of this technical note.

SMART ENABLE OPERATIONS Command

Protocol Non-Data

Table 6: Input

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

Description

This command enables access to the SMART capabilities of the eU500. The SMART ENABLE OPERATIONS command is aborted if either the signature in the LBA low or LBA high register is invalid. This is an input-only command and does not return output values. The SMART enabled state is preserved by the device during all power and reset events.

SMART DISABLE OPERATIONS Command

Protocol Non-Data

Table 7: Input

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

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. This is an input-only command and does not return output values. The SMART disabled state is preserved by the device during all power and reset events.

SMART RETURN STATUS Command

Protocol Non-Data

Table 8: Input

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

Table 10: Trip Output

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

Description

This command checks the device reliability status. In the normal output case, all SMART attribute values are currently higher than the threshold value associated with the attribute. If no threshold exceeded condition exists, the device will set the LBA low register to 4Fh and the LBA high register to C2h.

In the trip output case, at least a single SMART attribute value has fallen below the threshold value associated with the attribute. If a threshold exceeded condition exists for the spare block count attribute, spare block count worst channel attribute, or erase count attribute, the device sets the LBA low register to F4h and the LBA high register to 2Ch.

SMART Attributes

A SMART attribute is retrieved by the host issuing the SMART READ DATA (D0h) command. In the 512 bytes returned by the SMART READ DATA command, bytes 0–361 (169h) are marked as vendor-specific in the ATA8-ACS2 and ACS3 specifications. These bytes contain the SMART attribute data.

Table 11: SMART Attribute Table Layout

Byte Offset	Length (Bytes)	Description
0	2	SMART structure version (vendor-specific)
2	12	SMART attribute entry 1
2 + 12	12	SMART attribute entry 2
...
2 + (29 x 12)	12	SMART attribute entry 30

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. The host can retrieve the corresponding thresholds for the spare block count attribute and the erase count attribute by issuing the SMART READ ATTRIBUTE THRESHOLDS command. The SMART READ ATTRIBUTE command returns 512 bytes of data that the host can use to compare the threshold with the current value of each attribute. If the current value is less than or equal to the threshold, the device requires further attention from the system. This procedure is also called a SMART threshold trip and is only supported by the spare block count and erase count attributes.

Table 12: SMART Attribute Threshold Table Layout

Byte Offset	Length (Bytes)	Description
0	2	SMART structure version (vendor-specific)
2	12	SMART attribute threshold entry 1
2 + 12	12	SMART attribute threshold entry 2
...
2 + (29 x 12)	12	SMART attribute threshold entry 30

Table 13: SMART Attribute Summary

Attribute ID	Hex ID	SMART Attribute Name	Description
12	0Ch	Power-On Count	Count of power-on events
194	C2h	Controller Temperature	Controller temperature in Celsius (°C)
196	C4h	Spare Block Count	Initial and current number of total available NAND spare blocks
199	C7h	UDMA CRC Errors	Dummy attribute not used in the eU500; included for legacy reasons
203	CBh	Total ECC Errors	All recorded ECC errors
204	CCh	Total Correctable ECC Errors	Total recorded ECC errors that were corrected during the life of the drive
213	D5h	Spare Block Count – Worst NAND	Spare block count for the NAND with the lowest number of remaining spare blocks
214	D6h	Anchor Block Status	Total number of times the anchor block has been updated
229	E5h	Erase Count	Estimated number of total NAND block erases
232	E8h	Total Number of Reads	Total number of NAND READ commands
241	F1h	Total LBAs Written	Total amount of data written to the disk
242	F2h	Total LBAs Read	Total amount of data read from the disk

Table 14: SMART Attribute Response Format Summary

Byte Offset	Length (Bytes)	Field Name	Data Description
0	1	ID	01h–FFh are valid entries; 00h are invalid entries
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 1 = Prefailure: The device is distressed and is about to fail</p> <p>Bit 1: Online collection bit 0 = Not used 1 = Attribute is updated online during normal operation</p> <p>Bit 2–15: Reserved</p>
3	1	Current Value	Normalized (normally from the raw data) attribute value. 1–253 (FDh) are valid entries; 0, FEh, and FFh are invalid entries. 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. 1–253 (FDh) are valid entries; 0, FEh, and FFh are invalid entries
5	6	Raw Data	Vendor- and/or attribute-specific
11	1	Reserved	00h

SMART Attribute: Power-On Count (ID 12)

Attribute Flags (0002h)

- Advisory = 0
- Online = 1

Attribute Threshold (8 bits)

Threshold is set to 00h and not used as a threshold trip parameter.

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 number of power-on events in byte offsets 5–8 experienced over the life of the eU500.

Reserved (8 bits)

This value is always 00h.

SMART Attribute: Controller Temperature (ID 194)

Attribute Flags (0002h)

- Advisory = 0
- Online = 1

Attribute Threshold (8 bits)

Threshold is set to 00h and not used as a threshold trip parameter.

Current Value (8 bits)

This value is the current temperature in Celsius (°C) of the eU500 controller.

Worst Value (8 bits)

This value is the maximum temperature in Celsius (°C) of the eU500 controller.

Raw Data (48 bits)

The current temperature of the eU500 controller is stored in byte offset 5, the minimum controller temperature is stored in byte offset 6, and the maximum controller temperature is stored in byte offset 7. All temperatures are in Celsius (°C) and are updated every four seconds during normal operation of the eU500 device.

Reserved (8 bits)

This value is always 00h.

SMART Attribute: Spare Block Count (ID 196)

Attribute Flags (0003h)

- Prefailure = 1
- Online = 1

Attribute Threshold (8 bits)

The threshold for this attribute is set to 10% (0Ah) and is issued as a threshold trip parameter. If a threshold exceeded condition exists for the spare block count attribute, the device sets the LBA low register to F4h and the LBA high register to 2Ch, which can be read through the SMART return status feature.

Current Value (8 bits)

This value is calculated as:

$$100 \left(\frac{\text{All Current Spare Blocks}}{\text{All Initial Spare Blocks}} \right)$$

This attribute is used for the SMART RETURN STATUS command. If the value in this field is less than the spare block threshold (currently fixed at 10% [0Ah]), the SMART RETURN STATUS command indicates a threshold exceeded condition. The initial value is 100% (64h).

Worst Value (8 bits)

This value is always equivalent to the Current Value.

Raw Data (48 bits)

The sum of the initial number of all eU500 spare blocks is stored in byte offsets 5–7. The sum of the current number of eU500 spare blocks is stored in byte offsets 8–10.

Reserved (8 bits)

This value is always 00h.

SMART Attribute: UDMA CRC Errors (ID 199)

Attribute Flags (0002h)

- Advisory = 0
- Online = 1

Attribute Threshold (8 bits)

Threshold is set to 00h and not used as a threshold trip parameter.

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 always 0% (0000h). This attribute is only included for legacy reasons; all fields in this attribute contain static data.

Reserved (8 bits)

This value is always 00h.

SMART Attribute: Total ECC Errors (ID 203)

Attribute Flags (0002h)

- Advisory = 0
- Online = 1

Attribute Threshold (8 bits)

Threshold is set to 00h and not used as a threshold trip parameter.

Current Value (8 bits)

This value is always 100% (64h).

Worst Value (8 bits)

This value is always 100% (64h).

Raw Data (48 bits)

The total number of both correctable and uncorrectable ECC errors for the device are stored in byte offsets 5–8. This attribute provides the total number of ECC errors that have occurred during flash READ commands during firmware runtime. This attribute is not used for the SMART RETURN STATUS command.

Reserved (8 bits)

This value is always 00h.



SMART Attribute: Total Correctable ECC Errors (ID 204)

Attribute Flags (0002h)

- Advisory = 0
- Online = 1

Attribute Threshold (8 bits)

Threshold is set to 00h and not used as a threshold trip parameter.

Current Value (8 bits)

This value is always 100% (64h).

Worst Value (8 bits)

This value is always 100% (64h).

Raw Data (48 bits)

The total number of correctable ECC errors for the device is stored in byte offsets 5-8. This attribute provides the total number of correctable ECC errors that have occurred during flash READ commands during firmware runtime. This attribute is not used for the SMART RETURN STATUS command.

Reserved (8 bits)

This value is always 00h.

SMART Attribute: Spare Block Count – Worst NAND (ID 213)

Attribute Flags (0003h)

- Prefailure = 1
- Online = 1

Attribute Threshold (8 bits)

The threshold is set to 10% (0Ah) and is used as a threshold trip parameter. If a threshold exceeded condition exists for this attribute, the device sets the LBA low register to F4h and the LBA high register to 2Ch, which can be read through the SMART return status feature.

Current Value (8 bits)

This value is calculated as:

$$100 \left(\frac{\text{Lowest Current Spare Blocks}}{\text{Lowest Initial Spare Blocks}} \right)$$

This attribute is used for the SMART RETURN STATUS command. If the value in this field is less than the spare block threshold (currently fixed at 10% [0Ah]), the SMART RETURN STATUS command will indicate a threshold exceeded condition. The initial value is 100% (64h).

Worst Value (8 bits)

This value is always equivalent to the Current Value.

Raw Data (48 bits)

The initial number of spare blocks for the NAND with the lowest number of remaining spare blocks is stored in byte offsets 5–7. The current number of spare blocks for the NAND with the lowest number of remaining spare blocks is stored in byte offsets 8–10.

Reserved (8 bits)

This value is always 00h.

SMART Attribute: Anchor Block Status (ID 214)

Attribute Flags (0002h)

- Advisory = 0
- Online = 1

Attribute Threshold (8 bits)

Threshold is set to 00h and not used as a threshold trip parameter.

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 attribute reports the number of times the anchor block of the card has been rewritten, either by the anchor block repair routine or by a firmware update stored in byte offsets 5–8.

Reserved (8 bits)

This value is always 00h.

SMART Attribute: Erase Count (ID 229)

Attribute Flags (0002h/0003h)

- Advisory = 0/Prefailure = 1
- Online = 1

Attribute Threshold (8 bits)

Threshold is set to 10% (0Ah) and is used as a threshold trip parameter. If a threshold exceeded condition exists for this attribute, the device sets the LBA low register to F4h and the LBA high register to 2Ch, which can be read through the SMART return status feature.

Current Value (8 bits)

This value is an estimate of the remaining percentage of card life based on the number of flash block erases compared to the target number of erase cycles per block. If the value in this field is less than the erase count threshold (currently fixed at 10% [0Ah]), the SMART RETURN STATUS command indicates a threshold exceeded condition. The initial value is 100% (64h).

Worst Value (8 bits)

This value is always equivalent to the Current Value.

Raw Data (48 bits)

This value is the estimated total number of all block erases; all byte offsets 5–10 are used in this field.

Reserved (8 bits)

This value is always 00h.

SMART Attribute: Total Number of Reads (ID 232)

Attribute Flags (0002h)

- Advisory = 0
- Online = 1

Attribute Threshold (8 bits)

Threshold is set to 00h and not used as a threshold trip parameter.

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 all NAND READ commands; all byte offsets 5–10 are used in this field.

Reserved (8 bits)

This value is always 00h.

SMART Attribute: Total Number of LBAs Written (ID 241)

Attribute Flags (0002h)

- Advisory = 0
- Online = 1

Attribute Threshold (8 bits)

Threshold is set to 00h and not used as a threshold trip parameter.

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 amount of all data written in units of 32MB (total number of LBAs written/65536 sectors); this value can be converted to terabytes written by dividing the raw attribute value by 2^{15} . All byte offsets 5–10 are used in this field.

Reserved (8 bits)

This value is always 00h.



SMART Attribute: Total Number of LBAs Read (ID 242)

Attribute Flags (0002h)

- Advisory = 0
- Online = 1

Attribute Threshold (8 bits)

Threshold is set to 00h and not used as a threshold trip parameter.

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 disk reads in units of 32MB (total number of LBAs read/65536 sectors); this value can be converted to terabytes read by dividing the raw attribute value by 2^{15} . All byte offsets 5–10 are used in this field.

Reserved (8 bits)

This value is always 00h.

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 – 9/17

- Updated the publication date and footer information

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- Initial release

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