Reference Guide

S.M.A.R.T. Attributes

Technical Reference for Xcel-10 Solid State Drives

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1.0 INTRODUCTION

SMART Modular Technologies drives support several self-monitoring analysis and reporting technology (S.M.A.R.T.) subcommands designed to alert you of possible drive problems. With these subcommands, you can retrieve information regarding S.M.A.R.T. attributes, such as the current drive temperature. While SMART adheres to the ATA Specification for S.M.A.R.T. commands, the attributes are vendor-specific and include the following attributes:

- Power-On Hours
- Power Cycle Count
- Power-Off Retract Count
- Temperature
- Number of ECC Errors
- Uncorrectable Errors Count
- UDMA CRC Error Count
- Minimum Spares Remaining
- Newly Added Bad Flash Blocks
- Total Erase Flash Block Count

This document describes how to use S.M.A.R.T. attributes to determine the "health" of the -32N Xcel-10 drives only. To obtain a technical reference for other drives, contact your SMART sales representative.

2.0 S.M.A.R.T. SUBCOMMANDS

As indicated in the ATA Specification, the S.M.A.R.T. Operations command supports several subcommands, including Return Status and Read Data. For the purpose of monitoring drive health, the subcommands described in the following table are used.

Table 1: S.M.A.R.T. Commands

Command Name	Function	Page
Enable Operations	Enables S.M.A.R.T. functions on the drive. All other S.M.A.R.T. commands return an ABORT if this command is not issued first.	5
Return Status	Indicates whether or not an attribute value has exceeded the defined threshold. This command does not specify the attribute that triggered the response.	6
Read Data	Returns the current value for each supported attribute.	7
Read Attribute Threshold	Returns the defined threshold value for each supported attribute.	10

The following sections define the command and output registers.

2.1 S.M.A.R.T. Subcommand Registers

All S.M.A.R.T. subcommands are issued with the S.M.A.R.T. Operations command (code B0h). The Features register of the S.M.A.R.T. Operations command defines the subcommand, with all other registers set to the values indicated in the following table.

Table 2: S.M.A.R.T. Command Input Registers

	Bit							
Register	7	6	5	4	3	2	1	0
Features	Subcommand Code							
Sector Count	00h							
LBA Low	00h							
LBA Mid	4Fh							
LBA High	C2h							
Device/Head	0h			Dev	0h			
Command	B0h							

The drive returns an error if the any of the registers are not set properly (for example, LBA Mid is set to 00h).

2.2 Output Registers

When the command succeeds, the drive returns the values indicated in the following table.

Table 3: Output Register

	Bit							
Register	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
Features	00h							
Sector Count	00h							
LBA Low	00h							
LBA Mid	4Fh							
LBA High	C2h							
Device/Head	0h			Dev	0h			
Status	50h							

If an error occurs, the Status register is set to 51h, and the Error register (the first register) identifies the error that occurred. See the ATA specification for a description of the possible Error bytes.

NOTE: The drive returns an error with the ABRT bit set if the drive receives a S.M.A.R.T. subcommand and S.M.A.R.T. operations are not enabled. See the following section for more information.

If successful, the Read Data and Read Attribute Thresholds subcommands return 512 bytes of data containing the S.M.A.R.T. attribute information. See page 7 and 10 for more information.

3.0 S.M.A.R.T. ATTRIBUTE COMMANDS

This section describes the S.M.A.R.T. subcommands used to retrieve S.M.A.R.T. attribute data.

3.1 Enable/Disable S.M.A.R.T. Operations

Features: D8h (Enable); D9h (Disable)

Use: Enables S.M.A.R.T. on the drive. Before you can retrieve S.M.A.R.T. data, you must first enable S.M.A.R.T. operations. S.M.A.R.T. operations remain enabled across power cycles. To disable S.M.A.R.T. operations, issue the Disable S.M.A.R.T. Operations subcommand (D9h in the Features register).

Transfer: None

Input: See the following table for the input registers.

Table 4: S.M.A.R.T. Enable Operations Registers

	Bit							
Register	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
Features	D8h (Enable) or D9h (Disable)							
Sector Count	00h							
LBA Low	00h							
LBA Mid	4Fh							
LBA High	C2h							
Device/Head	0h			Dev	0h			
Command	B0h							

3.2 Return Status

Features: DAh

Use: Indicates the current status of the supported S.M.A.R.T. attributes. If the drive returns 4Fh in the LBA Mid and C2h in the LBA High registers, the attribute values are below the specified threshold. If the LBA Mid and LBA High registers contain F4h and 2Ch (that is, the nibbles are reversed), one or more of the attributes exceeded the defined threshold level.

Transfer: None

Input: See the following table for the input registers.

Table 5: S.M.A.R.T. Return Status Registers

	Bit							
Register	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
Features	DAh							
Sector Count	00h							
LBA Low	00h							
LBA Mid	4Fh							
LBA High	C2h							
Device/Head	0h			Dev	0h			
Command	B0h							

NOTE: If the Return Status subcommand indicates one of the attribute thresholds was exceeded, SMART strongly recommends issuing the Read Data subcommand to identify the attribute.

3.3 Read Data

Features: D0h

Use: Returns 512 bytes of information specific to each supported S.M.A.R.T. attribute.

Transfer: PIO Data-In

Input: See the following table for the input registers.

Table 6: S.M.A.R.T. Read Data Registers

	Bit							
Register	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
Features	D0h							
Sector Count	00h							
LBA Low	00h							
LBA Mid	4Fh							
LBA High	C2h							
Device/Head	0h			Dev	0h			
Command	B0h							

Output: Each offset defines the specific attribute and the associated raw data. Any data exceeding one byte in length is little endian (that is, the first byte is the least-significant byte, and the last byte is the most-significant byte). See the following table for the byte values (in hexadecimal format) and Figure 1 for an example of returned data.

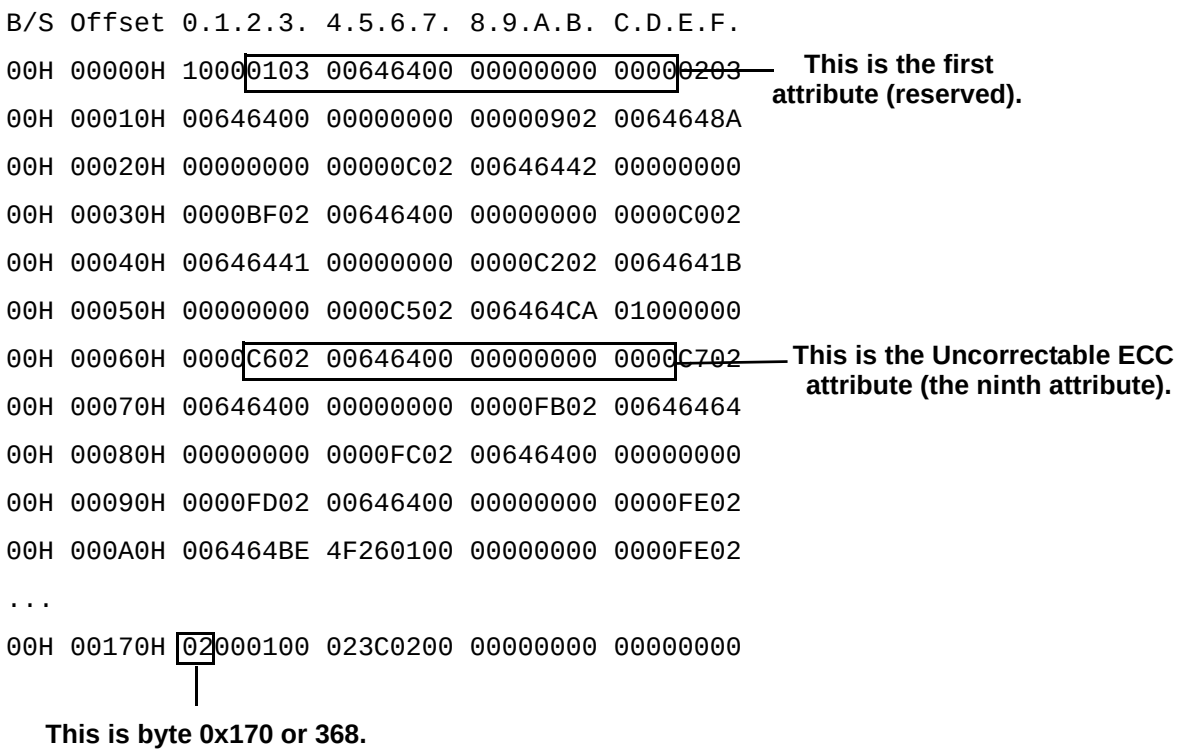
Table 7: Read Data Bytes

Byte(s)	Data		Comments
	Field Size	Content	
0-1	1 Word	Revision (Little Endian)	Set to 1000h
2-13	12 Bytes	1st Attribute	Attribute Layout (Each) Byte 0 = ID Number Bytes 1-2 = 0200h Bytes 3-4 = Constant Value Bytes 5-11 = Value
14-25	12 Bytes	2nd Attribute	
26-37	12 Bytes	3rd Attribute	
...	...	...	
350-361	12 Bytes	30th Attribute	
362	Byte	Offline Collection Status	00h = Data collection activity never started
363	Byte	Self-Test Execution Status	00h = Self-test was not run
364-365	Word	Offline Time Remaining (Little Endian)	Number of seconds remaining for offline sequence
366	Byte	Reserved	
367	Byte	Offline Collection Capability	Reserved

Table 7: Read Data Bytes *(Continued)*

Byte(s)	Data		Comments
	Field Size	Content	
368-369	Word	SMART Capability (Little Endian)	0002h = Device supports the Enable/Disable Attribute Autosave subcommand
370	Byte	Error Logging Capability	01h = Device supports error logging
371	Byte	Reserved	
372	Byte	Short Test Polling Time	Self-tests not supported
373	Byte	Extended Test Polling Time	
374	Byte	Conveyance Test Polling Time	
375...385	11 Bytes	Reserved	Zero
386...509	124 Bytes	Vendor-Specific Reserved	Zero
510	1 Byte	Reserved	Zero
511	1 Byte	Checksum	Total of Previous 511 Bytes

Figure 1. Read Data Bytes



The Xcel-10 drive returns several attributes, some of which are reserved. For example, the first two attributes (IDs 01h and 02h) are reserved and are not examined when the drive receives a Return Status command. See the following table for returned attributes (both supported and not supported).

Table 8: Returned Attributes

ID Number	Attribute	Page
01h (1 decimal)	Not Supported	N/A
02h (2 decimal)	Not Supported	N/A
09h (9 decimal)	Power-On Hours	12
0Ch (12 decimal)	Power Cycle Count	13
BFh (191 decimal)	Not Supported	N/A
C0h (192 decimal)	Power-Off Retract Count	14
C2h (194 decimal)	Temperature	15
C5h (197 decimal)	Number of ECC Errors	16
C6h (198 decimal)	Uncorrectable Errors Count	17
C7h (199 decimal)	UDMA CRC Error Count	18
FBh (251 decimal)	Minimum Spare Blocks Remaining	19
FCh (252 decimal)	Newly Added Bad Flash Block Count	20
FDh (253 decimal)	Not Supported	N/A
FEh (254 decimal)	Total Erase Blocks	21

Although the corresponding bytes for the non-supported attributes may contain data, those bytes are reserved and are not examined when determining the health of the drive. For supported attributes, the drive returns 12 bytes of data for each attribute, as indicated in Table 6: S.M.A.R.T. Read Data Registers. For attribute details, see page 12.

3.4 Read Attribute Thresholds

NOTE:	ATA-3 defines the Read Attribute Thresholds subcommand.

Features: D1h

Use: Returns 512 bytes of information specific to each supported S.M.A.R.T. attribute.

Transfer: PIO Data-In

Input: See the following table for the input registers.

Table 9: S.M.A.R.T. Read Attribute Thresholds Registers

	Bit							
Register	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
Features	D1h							
Sector Count	00h							
LBA Low	00h							
LBA Mid	4Fh							
LBA High	C2h							
Device/Head	0h			Dev	0h			
Command	B0h							

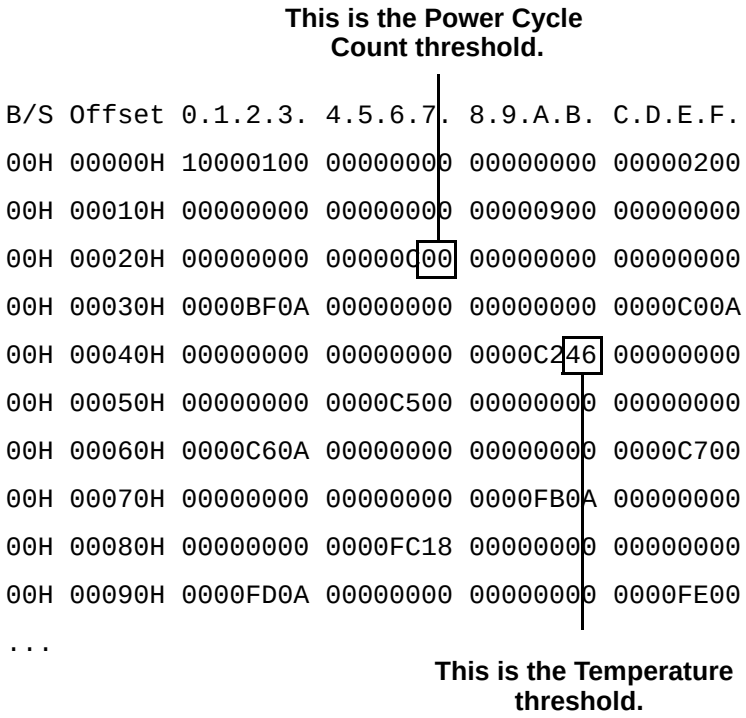
Output: Like the Read Data subcommand, the Read Attribute Thresholds subcommand returns 512 bytes of data. However, the data specifies only the attribute ID and threshold value for each attribute. All other attribute-specific bytes are set to 00h (see the following table).

Table 10: Read Attribute Thresholds Bytes

Byte(s)	Data		Comments
	Field Size	Content	
0-1	1 Word	Revision	Vendor-specific
2-13	12 Bytes Each	1st Attribute	Attribute Layout (Each) Bytes 0 = Attribute ID Byte 1 = Threshold Bytes 2-11 = 00h
14-25	12 Bytes Each	2nd Attribute	
26-37	12 Bytes Each	3rd Attribute	
...	...	...	
350-361	12 Bytes Each	30th Attribute	
362-510	147 Bytes	00h	
511	1 Byte	Checksum	Total of Previous 511 Bytes

If the threshold value for an attribute is 00h, the drive does not examine the attribute value when responding to the Return Status subcommand. For example, based on the bytes in the following figure, the drive may indicate the Temperature attribute exceeded the threshold, but not the Power Cycle Count attribute.

Figure 2. Read Attribute Thresholds Bytes



4.0 SUPPORTED ATTRIBUTES

4.1 Power-On Hours

Attribute ID: 09h (9 decimal)

Threshold: None

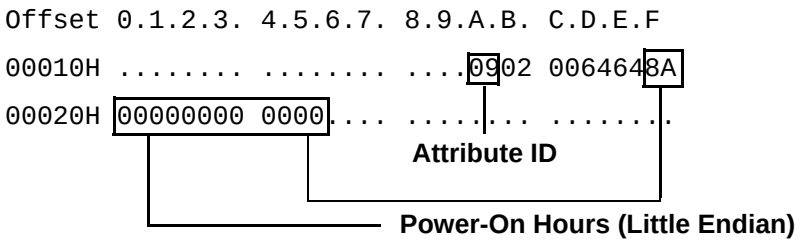
Description: The Power-On Hours attribute specifies the total number of hours the drive has been operational. This counter starts when the drive is first manufactured and continues whenever the drive is powered on. See the following table for the byte definitions.

Table 11: Power-On Hours Attribute

Byte(s)	Value	Indication
0	09h	This is the attribute ID (9 decimal).
1-2	0200h	Set to 0200h to indicate the attribute does not trigger an imminent failure (that is, the pre-fail advisory bit is not set).
3	64h	Each of these bytes is set to a constant value, which is always 64h (100 decimal).
4	64h	
5-11	Variable	These bytes are little endian and indicate the total number of hours the drive has been powered on.

Example: Using the data in Figure 1, attribute 9 is the third attribute (offsets 1Ah through 25h). The bytes indicating the power-on hours are 0x8A000000000000, but because the bytes are little endian, the value is 0x8A, or 138. See the following figure for an illustration.

Figure 3. Power-On Hours Example



NOTE:	Little endian means the least-significant byte is the first byte, and the most-significant byte is the last byte. For example, in Figure 4, the most-significant byte value is 00h, and the least-significant byte value is 8Ah.

4.2 Power Cycle Count

Attribute ID: 0Ch (12 decimal)

Threshold: None

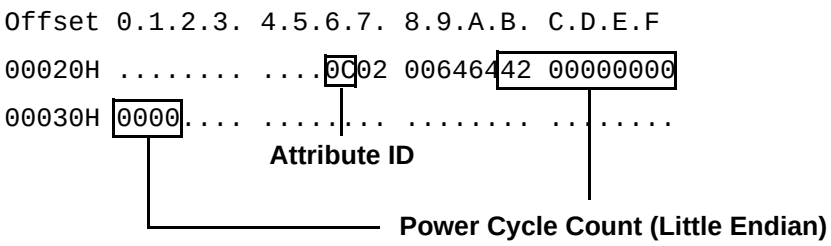
Description: The Power Cycle Count attribute indicates the total number of times power has cycled on the drive. See the following table for the byte definitions.

Table 12: Power Cycle Count Attribute

Byte(s)	Value	Indication
0	0Ch	This is the attribute ID (12 decimal).
1-2	0200h	Set to 0200h to indicate the attribute does not trigger an imminent failure (that is, the pre-fail advisory bit is not set).
3	64h	Each of these bytes is set to a constant value, which is always 64h (100 decimal).
4	64h	
5-11	Variable	These bytes are little endian and indicate the total number of times the drive has powered on.

Example: Using the data in Figure 1, attribute 12 is the fourth attribute (offsets 26h through 31h). The bytes indicating the power cycle count are 0x42000000000000, but because the bytes are little endian, the value is 0x42, or 66. See the following figure for an illustration.

Figure 4. Power Cycle Count Example



4.3 Power-Off Retract Count

Attribute ID: C0h (192 decimal)

Threshold: 0Ah (10 decimal)

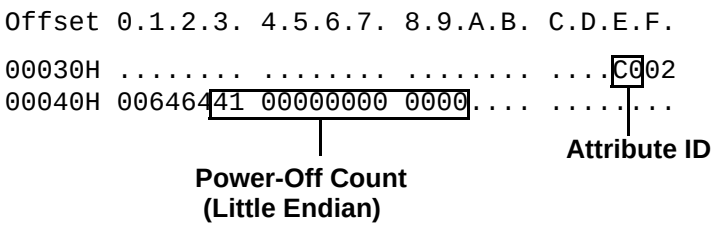
Description: The Power-Off Retract Count attribute returns the number of times the drive has been powered-off. This value is one less than the Power-Cycle Count attribute value. See the following table for more information.

Table 13: Power-Off Retract Count Bytes

Byte(s)	Value	Indication
0	C0h	This is the attribute ID (192 decimal).
1-2	0200h	Set to 0200h to indicate the attribute does not trigger an imminent failure (that is, the pre-fail advisory bit is not set).
3	64h	Each of these bytes is set to a constant value, which is always 64h (100 decimal).
4	64h	
5-11	Variable	These bytes are little endian and indicate the total number of times the drive has been powered off.

Example: Using the data in Figure 1, attribute C0h is the sixth attribute (offsets 3Eh through 49h). The bytes indicate the drive powered off 0x00000000000041, or 65 times, as shown in the following figure.

Figure 5. Power-Off Retract Count Example



4.4 Temperature

Attribute ID: C2h (194 decimal)

Threshold: 46h (70 decimal)

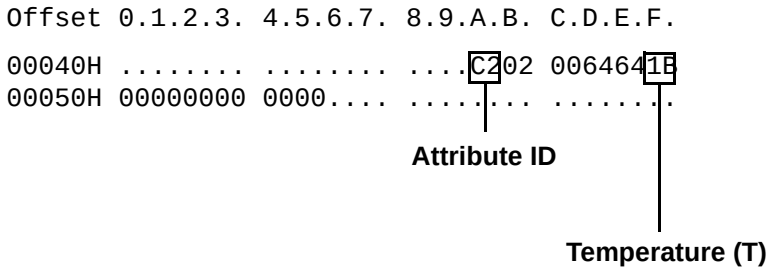
Description: The Temperature attribute indicates the current drive temperature in degrees Celsius. See the following table for the byte definitions.

Table 14: Temperature Attribute

Byte(s)	Value	Indication
0	C2h	This is the attribute ID (194 decimal).
1-2	0200h	Set to 0200h to indicate the attribute does not trigger an imminent failure (that is, the pre-fail advisory bit is not set).
3	64h	Each of these bytes is set to a constant value, which is always 64h (100 decimal).
4	64h	
5	Variable	This byte indicates the current temperature in degrees Celsius.
6-11	00h	These bytes are set to a constant value, which is always 00h.

Example: Based on the data in Figure 1, attribute C2 is the seventh attribute (offsets 4Ah through 55h). The bytes indicate the drive temperature is 1Bh, or 27°C, as shown in the following figure.

Figure 6. Temperature Example



4.5 Number of ECC Errors

Attribute ID: C5h (197 decimal)

Threshold: None

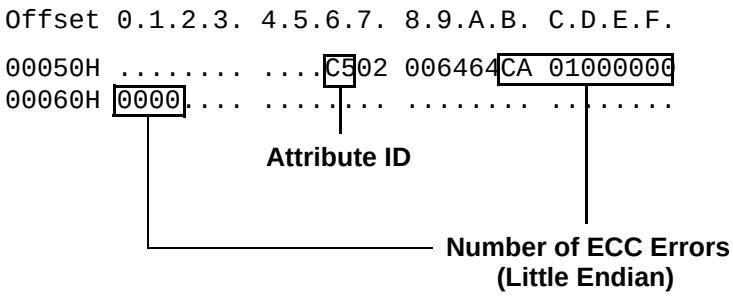
Description: The Number of ECC Errors attribute specifies the number of sectors that encountered an ECC error and were recovered. See the following table for the byte definitions.

Table 15: ECC Errors Attribute

Byte(s)	Value	Indication
0	C5h	This is the attribute ID (197 decimal).
1-2	0200h	Set to 0200h to indicate the attribute does not trigger an imminent failure (that is, the pre-fail advisory bit is not set).
3	64h	Each of these bytes is set to a constant value, which is always 64h (100 decimal).
4	64h	
5-11	Variable	These bytes are little endian and specify the number recovered ECC errors.

Example: Based on the data in Figure 1, attribute C5 is the eighth attribute (offsets 56h through 61h). The bytes indicating the number of pending sectors are 0xCA010000000000, but because the bytes are little endian, the value is 0x01CA, or 458. See the following figure.

Figure 7. Pending Sector Count Example



4.6 Uncorrectable Errors Count

Attribute ID: C6h (198 decimal)

Threshold: Non-Zero

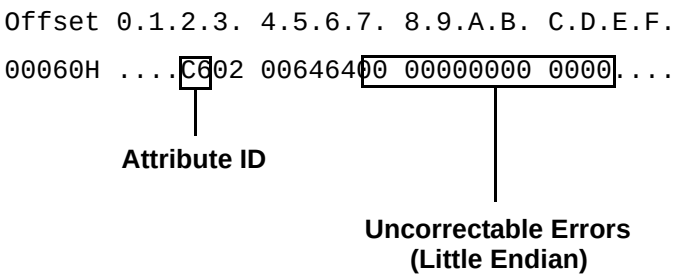
Description: The Uncorrectable Errors Count attribute returns the number of uncorrectable ECC errors that occurred. This counter increments if more than four bits in the affected sector are uncorrectable. See the following table for the byte definitions.

Table 16: Uncorrectable Errors Attribute

Byte(s)	Value	Indication
0	C6h	This is the attribute ID (198 decimal).
1-2	0200h	Set to 0200h to indicate the attribute does not trigger an imminent failure (that is, the pre-fail advisory bit is not set).
3	64h	Each of these bytes is set to a constant value, which is always 64h (100 decimal).
4	64h	
5-11	Variable	These bytes specify the number of uncorrectable ECC errors that occurred. These bytes are little endian.

Example: Based on the data in Figure 1, attribute C6 is the ninth attribute (offsets 62h through 6Dh). The bytes indicating no sectors encountered an uncorrectable ECC error, as show in the following figure.

Figure 8. Uncorrectable Errors Example



4.7 UDMA CRC Error Count

Attribute ID: C7h (199 decimal)

Threshold: None

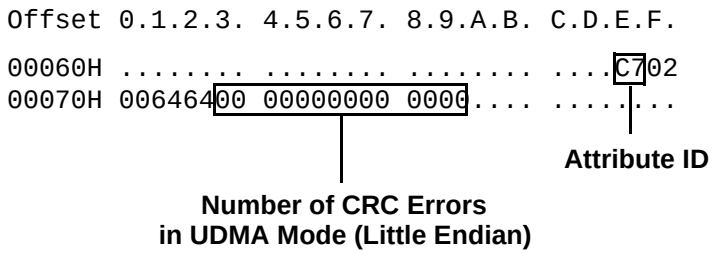
Description: The UDMA CRC Error Count attribute indicates the number of sectors that encountered a CRC error while in UDMA mode. See the following table for the byte definitions.

Table 17: UDMA CRC Error Count Attribute

Byte(s)	Value	Indication
0	C7h	This is the attribute ID (199 decimal).
1-2	0200h	Set to 0200h to indicate the attribute does not trigger an imminent failure (that is, the pre-fail advisory bit is not set).
3	64h	Each of these bytes is set to a constant value, which is always 64h (100 decimal).
4	64h	
5-11	Variable	These bytes specify the number of UDMA CRC errors that occurred. These bytes are little endian.

Example: Based on the data in Figure 1, attribute C7 is the tenth attribute (offsets 6Eh through 79h). The bytes indicate no sectors encountered a CRC error while in UDMA mode, as show in the following figure.

Figure 9. UDMA CRC Error Count Example



4.8 Minimum Spares Remaining

Attribute ID: FBh (251 decimal)

Threshold: 0Ah (10 decimal)

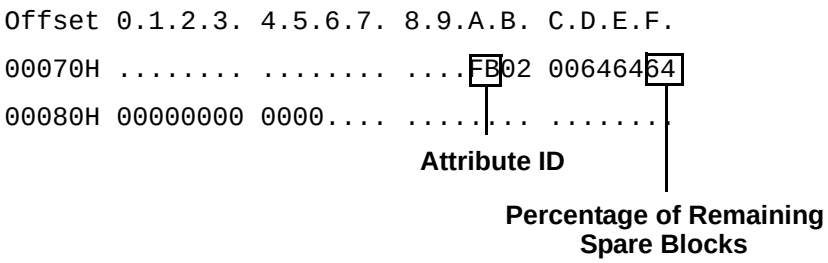
Description: The Minimum Spares Remaining attribute indicates the number of remaining spare blocks as a percentage of the total number of spare blocks available. See the following table for the byte definitions.

Table 18: Minimum Spares Remaining Attribute

Byte(s)	Value	Indication
0	FBh	This is the attribute ID (251 decimal).
1-2	0200h	Set to 0200h to indicate the attribute does not trigger an imminent failure (that is, the pre-fail advisory bit is not set).
3	64h	Each of these bytes is set to a constant value, which is always 64h (100 decimal).
4	64h	
5	Variable	This byte specifies the percentage of remaining spare blocks.
6-11	00h	Each of these bytes is set to 00h.

Example: Based on the data in Figure 1, attribute FB is the eleventh attribute (offsets 7Ah through 85h). The bytes indicate there are 100% (0x64) of the spares remaining, as shown in the following figure.

Figure 10. Minimum Spares Remaining Example



4.9 Newly Added Bad Flash Block

Attribute ID: FCh (252 decimal)

Threshold: None

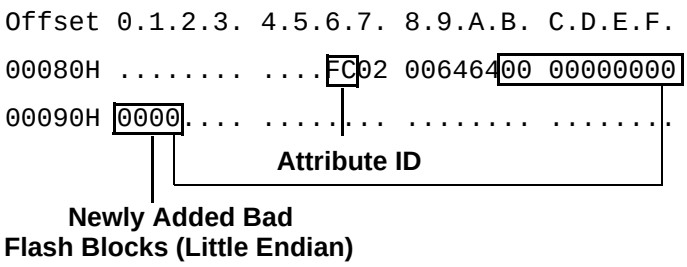
Description: The Newly Added Bad Flash Block attribute indicates the total number of bad flash blocks the drive detected since it was first initialized in manufacturing. See the following table for the byte definitions.

Table 19: Newly Added Bad Flash Block Attribute

Byte(s)	Value	Indication
0	FCh	This is the attribute ID (252 decimal).
1-2	0200h	Set to 0200h to indicate the attribute does not trigger an imminent failure (that is, the pre-fail advisory bit is not set).
3	64h	Each of these bytes is set to a constant value, which is always 64h (100 decimal).
4	64h	
5-11	Variable	These bytes specify the number of detected bad flash blocks. These bytes are little endian.

Example: Based on the data in Figure 1, attribute FC is the twelfth attribute (offsets 86h through 91h). The bytes indicate the drive has not detected any bad flash blocks, as shown in the following figure.

Figure 11. Newly Added Bad Flash Block Example



4.10 Total Erase Blocks

Attribute ID: FEh (254 decimal)

Threshold: None

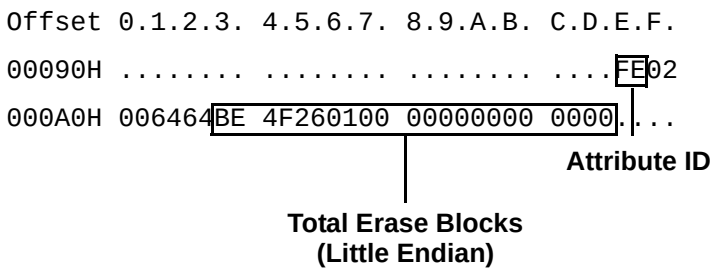
Description: The Total Erase Blocks attribute indicates the total number of times the drive has erased any erase block. Because a secure erase operation erases every block, this number increases significantly whenever a secure erase is performed. See the following table for the byte definitions.

Table 20: Total Erase Blocks Attribute

Byte(s)	Value	Indication
0	FEh	This is the attribute ID (254 decimal).
1-2	0200h	Set to 0200h to indicate the attribute does not trigger an imminent failure (that is, the pre-fail advisory bit is not set).
3	64h	Each of these bytes is set to a constant value, which is always 64h (100 decimal).
4	64h	
5-11	Variable	These bytes specify the total number of times the drive has erased a block. These bytes are little endian.

Example: Based on the data in Figure 1, attribute FE is the fourteenth attribute (offsets 9Eh through ADh). The bytes indicate the drive has executed 0x01264FBE (19,287,998 decimal) fast clear operations, as shown in the following figure.

Figure 12. Total Erase Blocks Example



5.0 EXAMPLE USING ATADEMO

This section provides an example of issuing the S.M.A.R.T. subcommands and attributes using ATADEMO. ATADEMO sends vendor-specific ATA commands to the drive to enable S.M.A.R.T. operations. For a copy of the ATADEMO test program, visit *http://www.ata-atapi.com/atademo.html*. Before using the ATADEMO program, SMART recommends you download and review the User Guide.

To issue S.M.A.R.T. subcommands in ATADEMO:

1. Start ATADEMO, entering the correct bus, device, drive, and host adapter information to communicate with the drive.
2. Type `ndx 0xD8 0x00 0x00 0x4F 0xC2 0x01 0xB0` and press **ENTER** to enable S.M.A.R.T. operations.
3. Type ndx `0xDA 0x00 0x00 0x4F 0xC2 0x01 0xB0` and press **ENTER** to view the current status of the S.M.A.R.T. attributes.
4. Type `showcb` and press **ENTER** to view the command block and verify the LBA Mid and LBA High registers contain 0x4F and 0xC2, respectively. If the nibbles are reversed, one or more of the S.M.A.R.T. attributes exceeded the threshold.
5. Type `fillz` and press **ENTER** to fill the buffer with zeroes.

NOTE:	Although filling the buffer with zeroes is not required, it is recommended that you first fill the buffer to ensure you are receiving updated data.

6. Type `pdix 0xD1 0x00 0x00 0x4F 0xC2 0x01 0xB0 1` and press **ENTER** to retrieve the S.M.A.R.T. attribute threshold values.
7. Type `dump` and press **ENTER** to view all 512 bytes.
8. Type `fillz` and press **ENTER** to fill the buffer with zeroes.
9. Type `pdix 0xD0 0x00 0x00 0x4F 0xC2 0x01 0xB0 1` and press **ENTER** to retrieve the S.M.A.R.T. data.
10. Type `dump` and press **ENTER** to view all 512 bytes.

6.0 SALES AND TECHNICAL SUPPORT

Contact the SSD Design Center, for technical support, application questions, data sheets, and documentation. Normal business hours are Monday through Friday, 8am to 5pm, MST. Please note that Arizona does not observe Daylight Savings Time.

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