



CTWP015: S.M.A.R.T. Features for Cactus Technologies® Industrial-Grade Flash-Storage Products

Covered Products: 203, 303, 503 CF cards, 806/808 SD cards, 300 UFD and 900S SATA products

1 Introduction

Self Monitoring, Analysis and Reporting Technology, (a.k.a. SMART) is a feature set defined by the ANSI ATA Specifications. The feature set consists of a set of commands which allow the host to retrieve information about the storage device's health status. This allows the user to know in advance impending device failures and act accordingly before the device actually fails. SMART was originally introduced for use in hard disk drives but is now being adopted for use in flash based ATA storage devices. SMART is an optional feature per ATA specifications but is offered as a standard feature in Cactus Technologies® 303, 503 and 900S series products.

2 SMART Usage

SMART is an ATA command with a command code of B0h. Within this command, there are further subcommands defined, not all of which are mandatory. The subcommand is selected by the value programmed into the Feature Register. Cactus Technologies® 303 series products support the following set of subcommands:

Value	Command
D0h	SMART Read Data
D2h	SMART Enable/Disable Attribute Autosave
D8h	SMART Enable Operations
D9h	SMART Disable Operations
DAh	SMART Return Status

Cactus Technologies® 503 series products support the following set of subcommands:

Value	Command
D0h	SMART read data
D1h	SMART read attribute thresholds
D2h	SMART enable/disable attribute autosave
D5h	SMART read log
D6h	SMART write log
D8h	SMART enable operations
D9h	SMART disable operations
DAh	SMART return status

Cactus Technologies® 900S series products support the following set of subcommands:

Value	Command
D0	SMART Read Data
D1	SMART Read Attribute Thresholds
D2	SMART Enable/Disable Attribute Autosave
D5	SMART Read Log
D6	SMART Write Log
D8	SMART Enable Operations
D9	SMART Disable Operations
DA	SMART Return Status
E0	Read Remap Data
E1	Read Wear Level Data

The most common usage of SMART is to just check the device's status with subcommand DAh. This will return a pass/fail status to the host. This information, however, is not particularly useful because by the time the fail status is returned, the device has already gone bad.

The more useful way of using SMART is to read the device's attributes using the Read Data (D0h) command. This returns a list of attributes, one or more of which contains information that the user can use to predict the remaining life of the device.

3 SMART Attributes

The SMART Read Data command retrieves a list of device attributes. While the ANSI ATA specification defines the SMART command and subcommand codes and the data format, it does not specify what attributes the device should return. Therefore, the list of attributes varies from vendor to vendor. Since SMART was introduced in the mid 1990's, the hard disk drive manufacturers have more or less adopted a few attributes which are common to all the drives. These attributes are being adopted by some flash storage vendors as well. However, this is merely a de facto industry standard; it is not an ANSI ATA standard. There is no guarantee that the same attribute ID will return the same attribute from one vendor to another. Furthermore,

vendors often have additional attributes that are unique to their products.

There are some public domain SMART utilities available that will read and parse the attribute information. However, these utilities are relying on the de facto standard list of attributes and/or often done with some reverse engineering effort. Cactus Technologies® does not recommend using these utilities to interpret the SMART attributes from our products as it cannot be guaranteed that the data returned by these utilities is correct or accurate.

Cactus Technologies® SMART attributes vary slightly from product to product. The details of the SMART attributes are documented in the respective product manuals. If the user must rely on third party SMART utilities, the best way to use them is to have them dump out the raw attribute data and then interpret them using our product manuals.

4 Cactus Technologies® SMART utility

As there is no standard on SMART attributes, there are only two ways to accurately retrieve and parse SMART attributes from Cactus Technologies® products. The first method is for the user to write their own SMART utility based on information provided in our product manuals. This method is required when the application OS is not Windows or Linux or when the application requires live monitoring. The second method is to use SMART utility provided by Cactus Technologies®. Currently, this utility is available only as a Win32 application and runs in a Windows Command Prompt environment. For Linux OS, we will provide C source code so that the user can compile an utility for their specific Linux distribution. Please contact Cactus Technologies® sales to obtain these files. The Cactus Technologies® Windows SMART utility is a standalone, offline program and is, therefore, not suitable for those applications which requires live monitoring of the SMART attributes.

4.1 Windows SMART utility

When the user runs our Windows SMART utility, it will automatically detect any supported Cactus Technologies® products that are mounted in the system, as shown in the following screen capture:

```
C:\Users\jchang\Documents\Cactus\503_smart.exe

The following devices are found:
Device Firmware Model Support SMART Enable SMART
-----
0 120716a CactusFlashCard Yes Yes
1 31-03-09 CactusFlashCard Yes Yes

Choose the drive number [0 , 1 or x to exit]: 0
```

This screen shows two Cactus Technologies® products mounted but typically, the user's system will have only one Cactus Technologies® product mounted, which the user can easily identify from the Model information. The user then selects the appropriate device and the utility will proceed to retrieve the SMART attributes which will be displayed as shown in the following screens:

```

C:\Users\jchang\Documents\Cactus\503_smart.exe
The following devices are found:
Device Firmware Model Support Enable
-----
0 120716a CactusFlashCard Yes Yes
1 31-03-09 CactusFlashCard Yes Yes

Choose the drive number [0 , 1 or x to exit]: 0
SMART Structure Version: 16
SMART Hyperstone Structure Version: 4
A1 Firmware Commit counter: 0x000030F4
A1 Firmware Wear Level Threshold: 0x00000FFF
Global Wear Leveling Active: 0
Global Bad Block Management Active: 0
Average Flash Block Erase Count: 574
Number of Flash Blocks involved into the Wear Leveling: 3931
Spare Block Count Attribute
- attribute ID 196
- flags 0x0003
- attribute value 100
- attribute value (worst value) 100
- sum of initial number of spare block of all chip 160
- sum of current number of all spare block of all chip 160
Spare Block Count Worst Chip Attribute
- attribute ID 213
- flags 0x0002
- attribute value 100
- attribute value (worst value) 100
- Initial number of spare block of chip with least spare 78
- Current number of spare block of chip with least spare 78
Erase Count Attribute
- attribute ID 229
- flags 0x0002
- attribute value 100
- attribute value (worst value) 100
- estimated total number of block erases 0x00000023D842
Total ECC Errors Attribute
- attribute ID 203
- flags 0x0002
- attribute value 100
- attribute value (worst value) 100
- total number of ECC errors 0x000014D1
Correctable ECC Errors Attribute
- attribute ID 204
- flags 0x0002
- attribute value 100
- attribute value (worst value) 100
- total number of correctable ECC errors 0x000014D1

```

```

C:\Users\jchang\Documents\Cactus\503_smart.exe
UDMA CRC Errors Attribute
- attribute ID                199
- flags                       0x0002
- attribute value             100
- attribute value (worst value) 100
- total number of UDMA CRC errors 0x00000000
Total Number of Reads Attribute
- attribute ID                232
- flags                       0x0002
- attribute value             100
- attribute value (worst value) 100
- total number of flash read commands 0x000114A0FCE2
Power On Count Attribute
- attribute ID                12
- flags                       0x0002
- attribute value             100
- attribute value (worst value) 100
- Number of Power On cycle    0x00000020
Total LBAs Written Attribute
- attribute ID                241
- flags                       0x0002
- attribute value             100
- attribute value (worst value) 100
- Total number of sectors written to the disk 0x00000001101F0000
Total LBAs Read Attribute
- attribute ID                242
- flags                       0x0002
- attribute value             100
- attribute value (worst value) 100
- Total number of sector read from the disk 0x0000000112470000
Anchor Block Status Attribute
- attribute ID                214
- flags                       0x0002
- attribute value             100
- attribute value (worst value) 100
- Anchor Block Write Count    0x00000000
Trim Status Attribute
- attribute ID                215
- flags                       0x0002
- attribute value             3
- attribute value (worst value) 1
SMART A1 Read Remap Data
-----
- Chip 0:  initial 78 spare block   current 78 spare block
- Chip 1:  initial 82 spare block   current 82 spare block

Press 'X' to exit ...

```

The user can then exit the utility by pressing “X”.

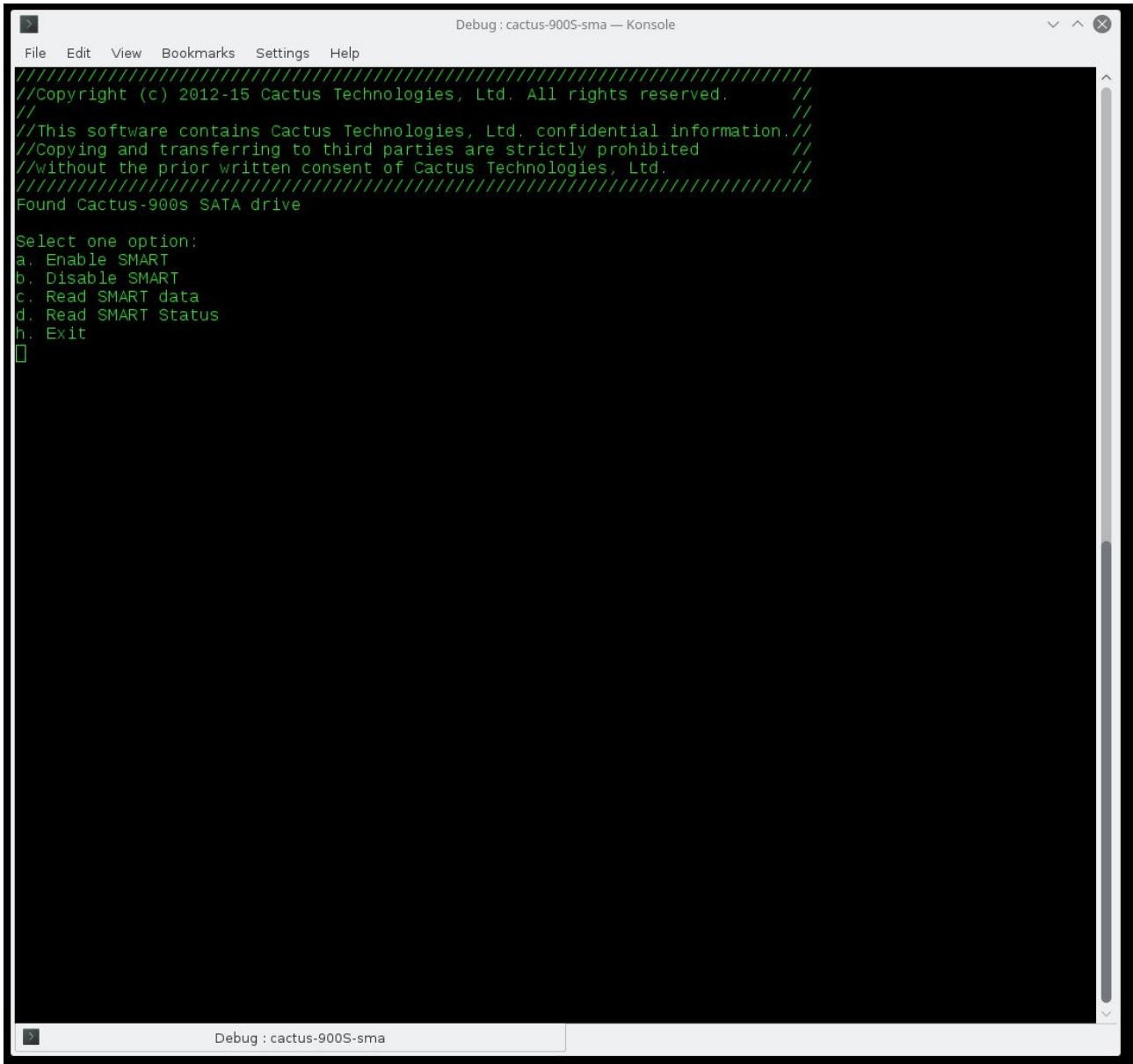
4.2 Linux SMART utility

As there are many different distributions of Linux with various kernel versions, instead of providing a pre-compiled binary, Cactus Technologies® will provide C source code instead. This allows the end user to compile their own SMART utility that will work for their particular Linux configuration. The Linux code uses SCSI ATA Translation (SAT) to issue the necessary ATA commands to the device. SAT is supported in Windows and in standard Linux kernel driver and will work over a USB to SATA bridge as long as the bridge chip supports the SCSI ATA Passthrough feature also.

The following example shows a Linux 900S SATA SSD SMART utility compiled for Fedora Linux. To run this utility, the user needs to have superuser privilege. First, identify the SCSI device assigned to the drive; in this example, it is /dev/sdc. Start the utility by typing the following command:

```
> cactus-900S-smart-util /dev/sdc
```

A command menu will be displayed as shown in the following screen capture:



The screenshot shows a terminal window titled "Debug : cactus-900S-sma — Konsole". The terminal output is as follows:

```
File Edit View Bookmarks Settings Help
////////////////////////////////////
//Copyright (c) 2012-15 Cactus Technologies, Ltd. All rights reserved. //
//
//This software contains Cactus Technologies, Ltd. confidential information.//
//Copying and transferring to third parties are strictly prohibited //
//without the prior written consent of Cactus Technologies, Ltd. //
////////////////////////////////////
Found Cactus-900s SATA drive

Select one option:
a. Enable SMART
b. Disable SMART
c. Read SMART data
d. Read SMART Status
h. Exit

```

Select 'c' to read the SMART attributes, as shown in the following screen captures:

```
Debug: cactus-9005-sma — Konsole
File Edit View Bookmarks Settings Help
//
//This software contains Cactus Technologies, Ltd. confidential information.//
//Copying and transferring to third parties are strictly prohibited      //
//without the prior written consent of Cactus Technologies, Ltd.        //
////////////////////////////////////
Found Cactus-900s SATA drive

Select one option:
a. Enable SMART
b. Disable SMART
c. Read SMART data
d. Read SMART Status
h. Exit
c
COMMAND: feat=d0, nsect=01, lbal=00, lbam=4f, lbah=c2, dev=e0, cmd=b0

Command issued successfully
STATUS: error=00, nsect=00, lbal=00, lbam=00, lbah=00, dev=00, stat=50

Attributes found:

ID: 196 - Spare Block Count
Raw attribute data: 00000b42000b4264640003c4
Percent spare blocks remaining: 100
Percent spare blocks remaining, worse value: 100
Initial number of spare blocks: 2882
Current number of spare blocks: 2882

ID: 213 - Worse Chip Spare Block Count
Raw attribute data: 0000015e00015e64640002d5
Initial number of spare blocks: 350
Current number of spare blocks: 350

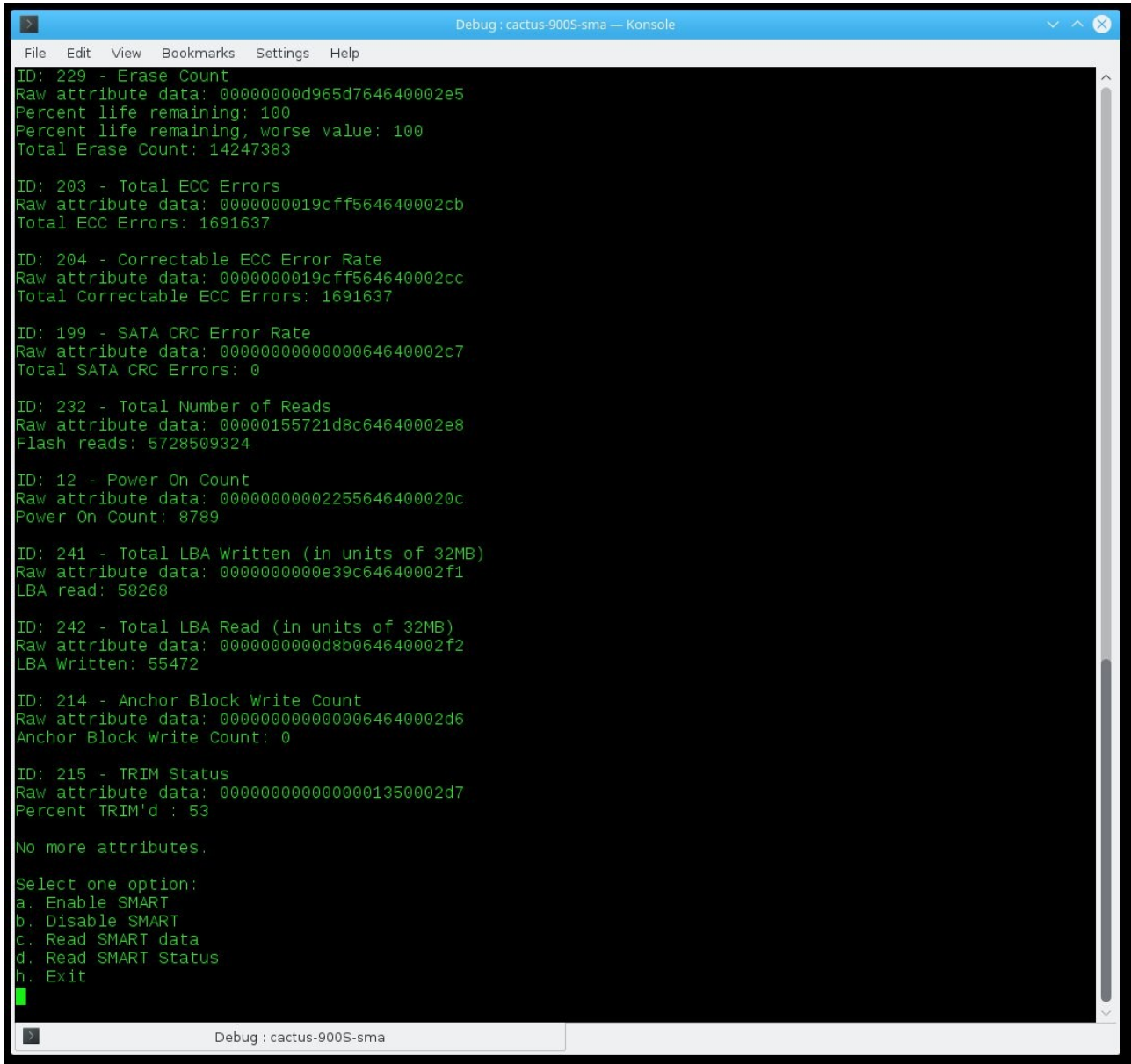
ID: 229 - Erase Count
Raw attribute data: 00000000d965d764640002e5
Percent life remaining: 100
Percent life remaining, worse value: 100
Total Erase Count: 14247383

ID: 203 - Total ECC Errors
Raw attribute data: 0000000019cff564640002cb
Total ECC Errors: 1691637

ID: 204 - Correctable ECC Error Rate
Raw attribute data: 0000000019cff564640002cc
Total Correctable ECC Errors: 1691637

ID: 199 - SATA CRC Error Rate
Raw attribute data: 0000000000000064640002c7
Total SATA CRC Errors: 0

Debug: cactus-9005-sma
```

```
Debug: cactus-9005-sma — Konsole
File Edit View Bookmarks Settings Help
ID: 229 - Erase Count
Raw attribute data: 0000000d965d764640002e5
Percent life remaining: 100
Percent life remaining, worse value: 100
Total Erase Count: 14247383

ID: 203 - Total ECC Errors
Raw attribute data: 0000000019cff564640002cb
Total ECC Errors: 1691637

ID: 204 - Correctable ECC Error Rate
Raw attribute data: 0000000019cff564640002cc
Total Correctable ECC Errors: 1691637

ID: 199 - SATA CRC Error Rate
Raw attribute data: 0000000000000064640002c7
Total SATA CRC Errors: 0

ID: 232 - Total Number of Reads
Raw attribute data: 00000155721d8c64640002e8
Flash reads: 5728509324

ID: 12 - Power On Count
Raw attribute data: 00000000002255646400020c
Power On Count: 8789

ID: 241 - Total LBA Written (in units of 32MB)
Raw attribute data: 0000000000e39c64640002f1
LBA read: 58268

ID: 242 - Total LBA Read (in units of 32MB)
Raw attribute data: 0000000000d8b064640002f2
LBA Written: 55472

ID: 214 - Anchor Block Write Count
Raw attribute data: 0000000000000064640002d6
Anchor Block Write Count: 0

ID: 215 - TRIM Status
Raw attribute data: 0000000000000001350002d7
Percent TRIM'd : 53

No more attributes.

Select one option:
a. Enable SMART
b. Disable SMART
c. Read SMART data
d. Read SMART Status
h. Exit
█
```

Finally, select 'h' to exit the utility.

The most useful attributes are the Spare Block Count and Erase Count attributes. Either one can be used as a predictor of the remaining life left on the storage device. Another useful attribute is the ECC Count attribute; if the user starts seeing uncorrectable ECC counts (obtained by subtracting the Correctable ECC Error Count from the Total ECC Error Count), it is time to replace the device as Uncorrectable ECC errors usually start showing up near the end of life of the product.

5 SMART for -203 Series Products

Cactus Technologies® -203 series products were first introduced in 2005 and are still in production today. This product series does not support the ATA SMART Feature Set. However,

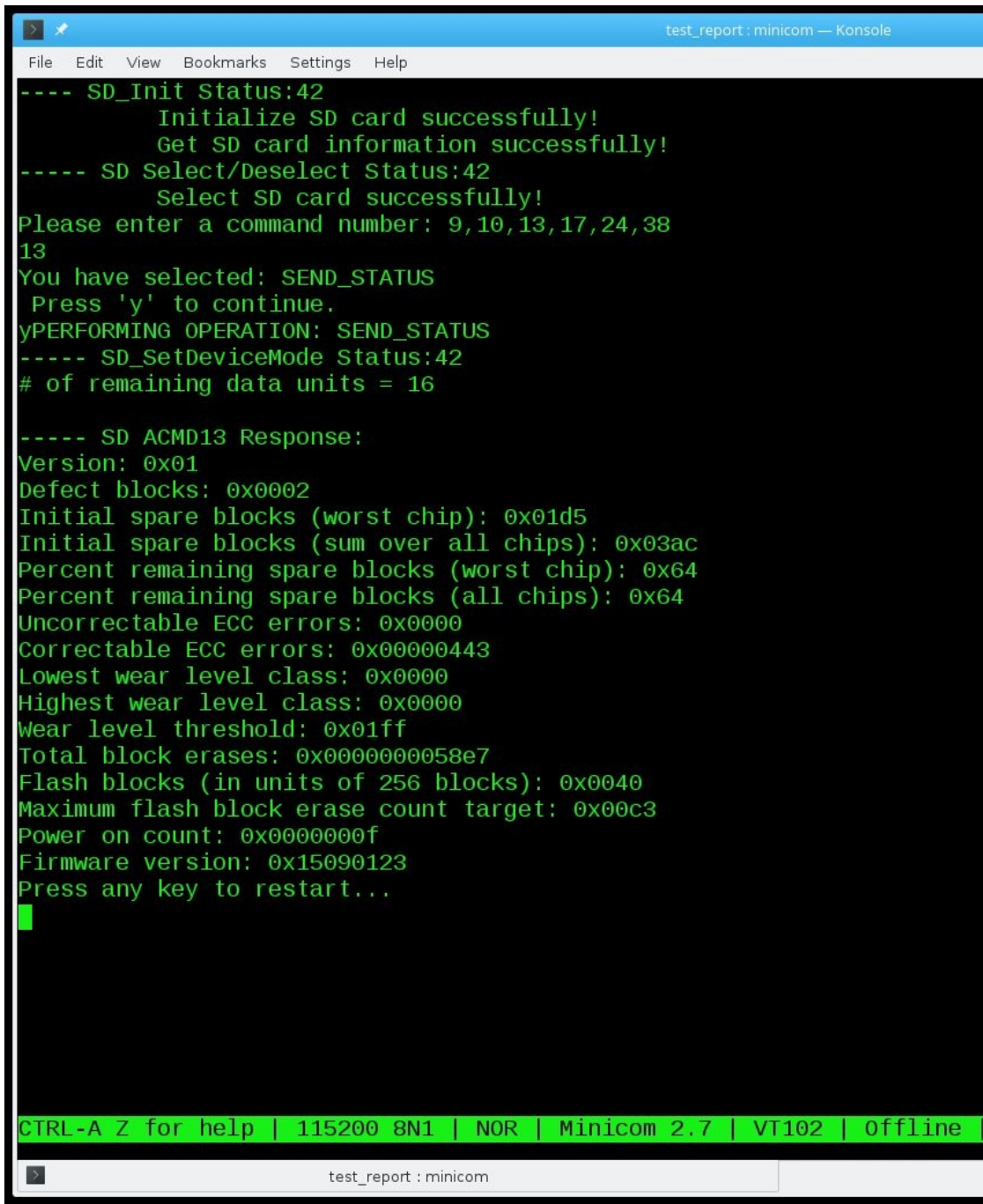
we can still provide users with information that can allow them to predict end of life of the product. This information is retrieved from the drive using Vendor Specific commands. Cactus Technologies® has written an utility for this purpose. This is an older utility which runs only in a pure DOS environment (not a Windows DOS prompt). If any of our customer is interested in this utility, please contact Cactus Technologies® sales for more information.

6 SMART for SD Card Products

SD Cards were originally targeted for consumer markets, where long product life and early failure prediction are not essential features. However, as SD Cards begin to be more widely adopted for use in industrial applications, the need for a SMART like capability becomes apparent. Unfortunately, the SD Association has yet to define a SMART like command in the SD command set.

In light of this shortcoming of SD card products, Cactus Technologies® has worked with our supplier to implement a SMART like feature in our -806/808 series SD Card products. This feature works by returning SMART like information in the 'Reserved for Vendor' section of the status register, which is retrieved using ACMD13. Essentially, this feature returns information similar to the Spare Block Count attribute in ATA SMART feature. This spare block count information will allow the user to calculate percentage remaining life of the product. Details of the data returned via this status command are documented in the -806/808 SD Card product manuals.

The following is an example of the output obtained by running an -808 SD SMART utility written for ARM Cortex M3 MCU:



```
test_report : minicom — Konsole
File Edit View Bookmarks Settings Help
---- SD_Init Status:42
      Initialize SD card successfully!
      Get SD card information successfully!
----- SD Select/Deselect Status:42
      Select SD card successfully!
Please enter a command number: 9,10,13,17,24,38
13
You have selected: SEND_STATUS
Press 'y' to continue.
yPERFORMING OPERATION: SEND_STATUS
----- SD_SetDeviceMode Status:42
# of remaining data units = 16

----- SD ACMD13 Response:
Version: 0x01
Defect blocks: 0x0002
Initial spare blocks (worst chip): 0x01d5
Initial spare blocks (sum over all chips): 0x03ac
Percent remaining spare blocks (worst chip): 0x64
Percent remaining spare blocks (all chips): 0x64
Uncorrectable ECC errors: 0x0000
Correctable ECC errors: 0x00000443
Lowest wear level class: 0x0000
Highest wear level class: 0x0000
Wear level threshold: 0x01ff
Total block erases: 0x0000000058e7
Flash blocks (in units of 256 blocks): 0x0040
Maximum flash block erase count target: 0x00c3
Power on count: 0x0000000f
Firmware version: 0x15090123
Press any key to restart...
█

CTRL-A Z for help | 115200 8N1 | NOR | Minicom 2.7 | VT102 | Offline |
test_report : minicom
```

Here again, the Spare Block Count and ECC Count attributes would be useful as a predictor for remaining card life.

7 SMART for USB Products

Cactus Technologies 300 series USB products can support reporting of SMART attributes. This is done by using the ATA Passthrough feature of USB standard. By using this feature, the standard ATA SMART command (B0h) can be issued to the device. The subcommand features supported the 300 series USB products are as follows:

Value	Command
D0h	SMART Read Data
D1h	SMART Read Attribute Thresholds
D8h	SMART Enable Operations
D9h	SMART Disable Operations
DAh	SMART Return Status

The list of reported attributes are documented in the 300 series USB product manual.

Currently, Cactus Technologies® is working on a SMART reporting utility for the 300 series USB products but it is not available yet. For users who are interested, please contact our sales team to inquire about future availability. For the time being, users can use a third party utility, such as smartmontools; this can dump out the raw attribute data which the user can then interpret by using the information in the product manual.

The following screen capture shows the output of smartctl on 300 series USB drive:

```

company_doc: bash — Konsole
File Edit View Bookmarks Settings Help
[root@jyc-510p company_doc]# smartctl -a -d sat /dev/sdc
smartctl 6.5 2016-05-07 r4318 [x86_64-linux-4.7.10-100.fc23.x86_64] (local build)
Copyright (C) 2002-16, Bruce Allen, Christian Franke, www.smartmontools.org

=== START OF INFORMATION SECTION ===
Device Model:          CactusFlashCard
Serial Number:         KU300      91000063
Firmware Version:     160727C2
User Capacity:         4,009,754,624 bytes [4.00 GB]
Sector Size:           512 bytes logical/physical
Device is:             Not in smartctl database [for details use: -P showall]
ATA Version is:       ATA8-ACS (minor revision not indicated)
SATA Version is:      ATA8-AST
Local Time is:        Mon Nov  7 15:09:58 2016 PST
SMART support is:     Available - device has SMART capability.
SMART support is:     Enabled

=== START OF READ SMART DATA SECTION ===
SMART Status not supported: Incomplete response, ATA output registers missing
SMART overall-health self-assessment test result: PASSED
Warning: This result is based on an Attribute check.

General SMART Values:
Offline data collection status:  (0x00) Offline data collection activity
                                   was never started.
                                   Auto Offline Data Collection: Disabled.

Total time to complete Offline
data collection:                  (   0) seconds.
Offline data collection
capabilities:                       (0x00) Offline data collection not supported.
SMART capabilities:                (0x0003) Saves SMART data before entering
                                   power-saving mode.
                                   Supports SMART auto save timer.
Error logging capability:           (0x00) Error logging NOT supported.
                                   No General Purpose Logging support.

SMART Attributes Data Structure revision number: 16
Vendor Specific SMART Attributes with Thresholds:
ID# ATTRIBUTE_NAME          FLAG         VALUE WORST THRESH TYPE      UPDATED  WHEN_FAILED RAW_VALUE
196 Reallocated_Event_Count 0x0003       100   100   010   Pre-fail Always    -         482 (1 57856)
213 Unknown_Attribute       0x0002       100   100   000   Old_age Always    -         4026532080
229 Unknown_Attribute       0x0002       100   100   010   Old_age Always    -          30
203 Run_Out_Cancel          0x0002       100   100   000   Old_age Always    -          0
204 Soft_ECC_Correction     0x0002       100   100   000   Old_age Always    -          0
199 UDMA_CRC_Error_Count    0x0002       100   100   000   Old_age Always    -          0
232 Available_Reservd_Space 0x0002       100   100   000   Old_age Always    -        27940
 12 Power_Cycle_Count        0x0002       100   100   000   Old_age Always    -          2
241 Total_LBAs_Written       0x0002       100   100   000   Old_age Always    -          0
242 Total_LBAs_Read          0x0002       100   100   000   Old_age Always    -          0
214 Unknown_Attribute       0x0002       100   100   000   Old_age Always    -          0
215 Unknown_Attribute       0x0002       099   001   000   Old_age Always    -          0

```

Users should ignore the Attribute Name and cross reference the Attribute ID with what is

documented in the -300 USB product manual for correct interpretation of the attribute's value reported in the Raw Value column.

Note that the -d sat switch is used, which tells the USB controller to use the SCSI ATA Passthrough feature. It should also be noted that not all USB controllers support the ATA Passthrough feature; in those cases, it may not be possible to retrieve the SMART attributes from the device.

8 Summary

In summary, SMART attributes contain useful information about the health status of the storage device. Cactus Technologies® -303, -503 and -900S series products fully supports the ATA SMART Feature Set. However, due to the lack of standardization of the SMART attributes, the only accurate way of retrieving SMART attributes from our products is to either write your own utility or use the one provided by Cactus Technologies®. In addition, Cactus Technologies® has implemented similar SMART capabilities in our -806/808 series SD card products and 300 series USB products.

9 Version History

Version	Date	Change
1.0	March 24, 2014	Initial Version
2.0	November 7, 2016	Updated to add Linux utility description and USB SMART info