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:

<table>
<thead>
<tr>
<th>Value</th>
<th>Command</th>
</tr>
</thead>
<tbody>
<tr>
<td>D0h</td>
<td>SMART Read Data</td>
</tr>
<tr>
<td>D2h</td>
<td>SMART Enable/Disable Attribute Autosave</td>
</tr>
<tr>
<td>D8h</td>
<td>SMART Enable Operations</td>
</tr>
<tr>
<td>D9h</td>
<td>SMART Disable Operations</td>
</tr>
<tr>
<td>DAh</td>
<td>SMART Return Status</td>
</tr>
</tbody>
</table>
Cactus Technologies® 503 series products support the following set of subcommands:

<table>
<thead>
<tr>
<th>Value</th>
<th>Command</th>
</tr>
</thead>
<tbody>
<tr>
<td>D0h</td>
<td>SMART read data</td>
</tr>
<tr>
<td>D1h</td>
<td>SMART read attribute thresholds</td>
</tr>
<tr>
<td>D2h</td>
<td>SMART enable/disable attribute autosave</td>
</tr>
<tr>
<td>D5h</td>
<td>SMART read log</td>
</tr>
<tr>
<td>D6h</td>
<td>SMART write log</td>
</tr>
<tr>
<td>D8h</td>
<td>SMART enable operations</td>
</tr>
<tr>
<td>D9h</td>
<td>SMART disable operations</td>
</tr>
<tr>
<td>DAh</td>
<td>SMART return status</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Value</th>
<th>Command</th>
</tr>
</thead>
<tbody>
<tr>
<td>D0</td>
<td>SMART Read Data</td>
</tr>
<tr>
<td>D1</td>
<td>SMART Read Attribute Thresholds</td>
</tr>
<tr>
<td>D2</td>
<td>SMART Enable/Disable Attribute Autosave</td>
</tr>
<tr>
<td>D5</td>
<td>SMART Read Log</td>
</tr>
<tr>
<td>D6</td>
<td>SMART Write Log</td>
</tr>
<tr>
<td>D8</td>
<td>SMART Enable Operations</td>
</tr>
<tr>
<td>D9</td>
<td>SMART Disable Operations</td>
</tr>
<tr>
<td>DA</td>
<td>SMART Return Status</td>
</tr>
<tr>
<td>E0</td>
<td>Read Remap Data</td>
</tr>
<tr>
<td>E1</td>
<td>Read Wear Level Data</td>
</tr>
</tbody>
</table>

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 manufactures 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:
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:
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:

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

A command menu will be displayed as shown in the following screen capture:
Select 'c' to read the SMART attributes, as shown in the following screen captures:
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-909S SATA drive

Select one option:
1. Enable SMART
2. Disable SMART
3. Read SMART data
4. Read SMART Status
5. Exit

COMMAND: feat=0, nsect=01, lbal=00, lbam=4f, lbah=c2, dev=e0, cmd=00

Command issued successfully

STATUS: error=0, nsect=00, lbal=00, lbam=00, lbah=00, dev=00, stat=50

Attributes found:
ID: 196 - Spare Block Count
Raw attribute data: 00000000000000000000000000000000
Percent spare blocks remaining: 100
Initial number of spare blocks: 2882
Current number of spare blocks: 2882

ID: 213 - Worse Chip Spare Block Count
Raw attribute data: 00000000000000000000000000000000
Initial number of spare blocks: 350
Current number of spare blocks: 350

ID: 133 - Erase Count
Raw attribute data: 00000000000000000000000000000000
Percent life remaining: 100
Total Erase Count: 1207503

ID: 204 - Total ECC Errors
Raw attribute data: 0000000019c000000000000000000000
Total ECC Errors: 1691037

ID: 199 - SATA CRC Error Rate
Raw attribute data: 00000000000000000000000000000000
Total SATA CRC Errors: 0
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:
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:
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:

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

<table>
<thead>
<tr>
<th>Version</th>
<th>Date</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>March 24, 2014</td>
<td>Initial Version</td>
</tr>
<tr>
<td>2.0</td>
<td>November 7, 2016</td>
<td>Updated to add Linux utility description and USB SMART info</td>
</tr>
</tbody>
</table>