

S.M.A.R.T. Technology

White Paper

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Version 1.2

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Abstract

S.M.A.R.T. (SMART), an acronym stands for Self-Monitoring, Analysis and Reporting Technology, is an open standard allowing an individual disk drive in the ATA/IDE or SCSI interface to automatically monitor its own health and report potential problems in order to prevent data loss. This failure warning technology provides predictions from unscheduled downtime by observing and storing critical drive performance and calibration parameters. Ideally, this should allow taking hands-on actions to keep from impending drive failure.

Apacer's SMART features follow the specification of SATA Rev. 2.5 and ATA/ATAPI-7 specification by using the standard SMART command to read data from the flash drive. Running on the host, Apacer's SMART utility analyzes and reports the disk status periodically to the host before the drive is in critical condition.

Development

Early in 1992, IBM introduced the industry's first hard disk monitoring technology for its SCSI-2 drives, which was named Predictive Failure Analysis (PFA). Later, Compaq announced a breakthrough in diagnostic design called IntelliSafe™ for the ATA/IDE environment and supported by hard drive manufacturers. The resulting jointly-developed standard was named S.M.A.R.T., which combines conceptual elements of Compaq's IntelliSafe™ and IBM's PFA. The S.M.A.R.T. function is also described in the ATA-3 specification released by the ANSI standard group.

According to PFA, failures are divided into two categories: those that can be predicted and those that cannot. Predictable failures occur gradually over time, and the decline in performance can be detected; on the other hand, unpredictable failures happen very sudden without any warning. These failures may be caused by power surges or related to electronic components. The purpose of the SMART implementation is to predict near-term failures of each individual disk drive and generate a warning to prevent unfortunate loss.

In addition to adopting flash media without any moving parts to provide compact and rugged storage with significantly lower power consumption and less heat generation than conventional hard drives; however, solid-state drives should suffer from losing the ability to retain data after millions cycles of write/erase. Apacer's S.M.A.R.T. technology accurately monitors and reports the storage status to the host system, allowing taking hands-on actions to keep from impending drive failures. Together with Apacer's wear-leveling and ECC schemes, S.M.A.R.T. will ensure a level of data reliability and integrity that has never been achieved before.

Apacer SMART Commands

SMART Read Data (B0h):

COMMAND CODE – B0h

SUBCOMMAND – D0h (To read SMART data, including attribute ID, attribute value, worst value, and raw data)

PROTOCOL – PIO data in

INPUTS – The Features register shall be set to D0h. The LBA Mid register shall be set to 4Fh. The LBA High register shall be set to C2h.

Register	7	6	5	4	3	2	1	0
Command	B0h							
Device	1	na	1	DEV	na	na	na	na
LBA High	C2h							
LBA Mid	4Fh							
LBA Low	na							
Sector Count	na							
Features	D0h							

NORMAL OUTPUTS – If this command succeeds, the drive will return 512 bytes of data and normal status; otherwise, the drive will return error status.

Register	7	6	5	4	3	2	1	0
Status	BSY	DRDY	DF	na	DRQ	na	na	ERR
Device	1	na	1	DEV	na	na	na	na
LBA High	na							
LBA Mid	na							
LBA Low	na							
Sector Count	na							
Error	na							

Device register

DEV indicates the selected device

Status register

BSY shall be cleared to zero

DRDY shall be set to one

DF (Device Fault) shall be cleared to zero

DRQ shall be cleared to zero

ERR shall be cleared to zero

ERROR OUTPUTS –

Register	7	6	5	4	3	2	1	0
Status	BSY	DRDY	DF	na	DRQ	na	na	ERR
Device	1	na	1	DEV	na	na	na	na
LBA High	na							
LBA Mid	na							
LBA Low	na							
Sector Count	na							
Error	na	na	na	na	na	ABRT	na	na

Error register

ABRT may be set to one if the device is not able to complete the action requested by the command

Device register

DEV indicates the selected device

Status register

BSY shall be cleared to zero
 DRDY shall be set to one
 DF (Device Fault) shall be cleared to zero
 DRQ shall be cleared to zero
 ERR shall be cleared to zero

Attribute Value & Calculation

Four vendor-specific SMART attributes, average erase count, maximum erase count, good block count, and spare block count, are applied in Apacer S.M.A.R.T. utility. Their formats in percentage present friendly readability.

Definitions of variables

Value: presenting in percentage as an index of status in its respective category

RawData: a returned number by SMART command

N: the constant of SLC P/E cycles

Average Erase Count –

Average Erase Count registers the average value of memory erasures of every die in the device. Therefore, a value can be referable when considering the status of the device. Below equation shows only the calculation of the value on a single die. After values of every single die are collected, the average value will be exhibited in its corresponding column.

$$Value = \{100 - [(RawData) / 1.2 \times N \div 100]\} \times 100(\%)$$

$$N = 100,000$$

A threshold is set to 17%, which means a “Warning” string will be revealed at the status column when the value in average erase count is equal to or below the threshold; otherwise, an “OK” string will be displayed. The value column always shows 0 when the calculated value reaches zero or below.

Max Erase Count –

Maximum Erase Count registers the maximum value of erasures in a certain die of the device. Its difference between Average Erase Count can be a reference to the condition of the device. Below equation shows only the calculation of the value on a single die. After values of every single die are collected and sorted, the maximum value will be exhibited in its corresponding column.

$$Value = \{100 - [(RawData) / 1.2 \times N \div 100]\} \times 100(\%)$$

$$N = 100,000$$

A threshold is set to 17%, which means a “Warning” string will be revealed at the status column when the value in maximum erase count is equal to or below the threshold; otherwise, an “OK” string will be displayed. The value column always shows 0 when the calculated value reaches zero or below.

Good Block Count –

Good Block Count registers all available blocks excluding reserved blocks and can be viewed as manageable space of the memory bank.

$$Value = \{100 - [(4096 - (RawData))^2 / 1000]\} \times 100(\%)$$

A threshold is set to 6%, which means a “Warning” string will be revealed at the status column when the value in good block count is equal to or below the threshold; otherwise, an “OK” string will be displayed. The value column always shows 0 when the calculated value reaches zero or below.

Spare Block Count –

Spare Block Count registers vacant blocks that can be occupied by the host directly, and its value fluctuates from time to time depending on the usage and the refills of the controller.

$$Value = 2 \times RawData / 385 + 80$$

In case the value in RAW DATA column is above 250

$$Value = RawData \times 8 / 25$$

In case the value in RAW DATA column is below 250

A threshold is set to 7%, which means a “Low” string will be revealed at the status column when the value in free list count is equal to or below the threshold; otherwise, an “OK” string will be displayed. The value column always shows 0 when the calculated value reaches zero or below.

With these attributes, Apacer S.M.A.R.T. utility is able to work with its algorithm to maximize the availability of the drive by thoroughly managing data read/write cycles on memory blocks to extend the duration of usage of the drive, and, moreover, to produce evocative messages precisely in case the drive’s lifetime is about coming to the end so that the essential decision to backup the drive can be made to keep from permanent data loss.

Revision History

Revision	Date	Description	Remark
1.0	April 23, 2008	Initial Release	
1.1	October 1, 2008	SMART attribute ID updated	
1.2	January 5, 2009	Context refined	

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