

Thermal Monitoring for Advanced Data Protection

*New Feature Helps Prevent Drive Failure
Caused By Overheating*

► OVERVIEW/EXECUTIVE SUMMARY

In its commitment to provide the highest quality, most reliable hard drives in the industry, Western Digital has added an important new feature to its advanced data protection package—Thermal Monitoring. As a new property of the S.M.A.R.T. (Self-Monitoring, Analysis, and Reporting Technology) interface, *thermal monitoring* specifically alerts the host to potential damage from the drive operating at too high a temperature. It provides information to the host whenever certain thresholds have been met for various conditions. S.M.A.R.T. is the industry standard reliability tool that monitors and controls hard drive operation to minimize the probability of drive failure.

The new thermal monitoring feature has been implemented in the WD Enterprise WDE18300 and WDE9180 Ultra2 SCSI hard drives. This new technology focuses on system-level protection and monitors the temperature of the drive, providing pertinent information to the host and modifying drive behavior as needed to protect the drive from damage.

► BACKGROUND

Data-intensive applications place very high demands on data storage devices. These devices are responsible for keeping critical data safe and providing fast, reliable access to that data. The effect of excessive heat, especially over long periods of time, is harmful to hard drives and could lead to permanent data loss. High temperatures can reduce drive reliability.

The S.M.A.R.T. reliability monitor assists users in preventing possible system downtime by warning of an impending risk of data loss. Through S.M.A.R.T., the drive can communicate its predicted reliability status to the user, thereby providing protection against system downtime and possible loss of productivity and data. Western Digital uses advanced diagnostics to monitor the hard drive's internal operations and provide early warnings of potential problems. The new thermal monitoring feature expands S.M.A.R.T.'s capabilities for preventing hard drive failure by monitoring the drive's temperature and alerting the host when the temperature goes beyond the recommended level. It also monitors and predicts the hard drive's performance and reliability. S.M.A.R.T. notifications warn of impending drive failure so the user can take corrective action before data is lost or operations are affected.

Thermal Monitoring Functions

In a hard drive, both the electronic and mechanical components such as actuator bearings, spindle motor and voice coil motor can be affected by excessive temperatures. See *Figure 1*. There are many conditions that could contribute to a temperature increase, such as:

- a clogged cooling fan
- a failed room air conditioner
- a cooling system that is overextended by too many drives

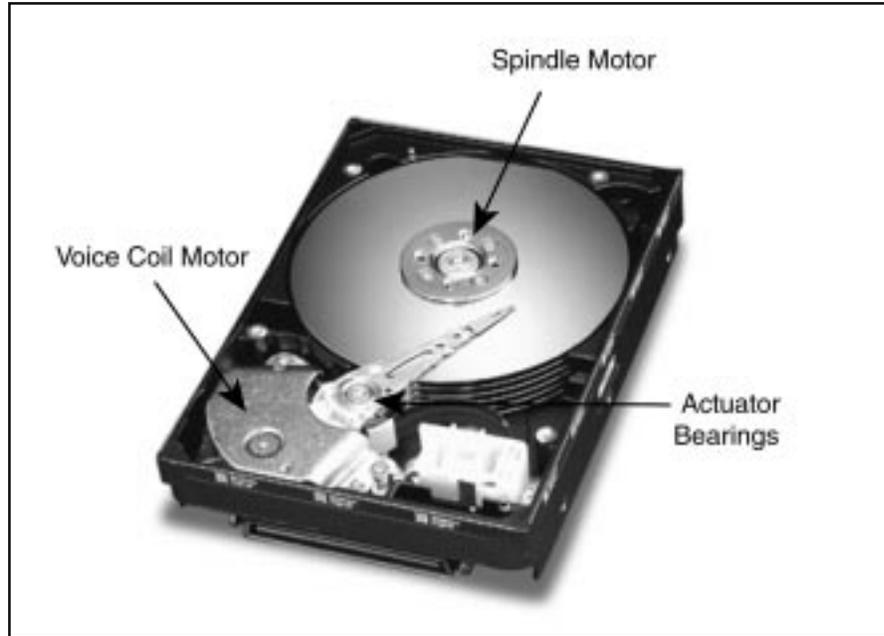


Figure 1. Three Hard Drive Mechanical Components

Running the drive for extended periods of time at too high a temperature can damage it and lead to permanent data loss. A thermal sensor can detect the environmental conditions that affect drive reliability, including ambient temperature, rate of cooling airflow, voltage, vibration, and duty cycle.

To carry out the new feature's thermal monitoring capability, a dedicated thermal sensor, mounted on the printed circuit board assembly (PCBA), automatically polls, records, and analyzes drive temperature at set intervals as dictated by the drive firmware. Using this data, the hard drive can:

- report the current temperature of the drive
- log drive temperatures over time
- maintain a record of the highest observed temperature
- provide S.M.A.R.T. notifications on reaching a customer-specified temperature
- provide S.M.A.R.T. notifications upon reaching a drive-threatening temperature
- optimize drive operations to keep drive temperatures under acceptable levels
- spin down, if enabled to do so, upon reaching a drive-threatening temperature

How Thermal Monitoring Works

Thermal monitoring capabilities can be enabled and controlled using various Mode Page parameters, i. e., commands using regular parameter structures referred to as pages. The Enable Warning Additional Sense Code (EWASC) bit in the Information Exceptions Control Page (page 1Ch) controls whether or not any S.M.A.R.T. notifications will be generated due to thermal monitoring events. When this bit is set to 1, all thermal monitoring S.M.A.R.T. notifications will be generated, with the possible exception of the customer threshold, which can be individually disabled if desired.

The first thermal threshold—the customer threshold, is entirely user-defined and programmable in Mode Page 0 (default value 60°C). A disable bit allows the customer to disable this specific threshold in cases where other thermal monitoring notifications are desired but no customer threshold is set. When this threshold is crossed, the drive returns a 01/0B/01 error code (*Warning–Specified Temperature Exceeded*). This threshold can provide a warning before the temperature becomes critical. The results can indicate an event to be logged, user intervention requested, or supplemental ventilation required.

The second thermal threshold—the shutdown threshold, is not programmable by the customer. (*Figure 2* compares both thresholds—the customer and the shutdown.) This threshold is set at 65°C, the temperature at which the drive should be shut down to prevent damage or reduced service life. Upon reaching this threshold, the drive returns a 01/0B/80 error code (*Vendor Unique: Warning–Drive should be shutdown due to over-temperature condition*). On the first temperature reading over the shutdown threshold, the thermal polling interval is set to read the temperature again in three minutes. If the temperature is still over the threshold and spin down is enabled in page 0 by the Enable Thermal Spin-down (ETS) bit, the motor is spun down. A Start Unit command is required to spin up the drive again.

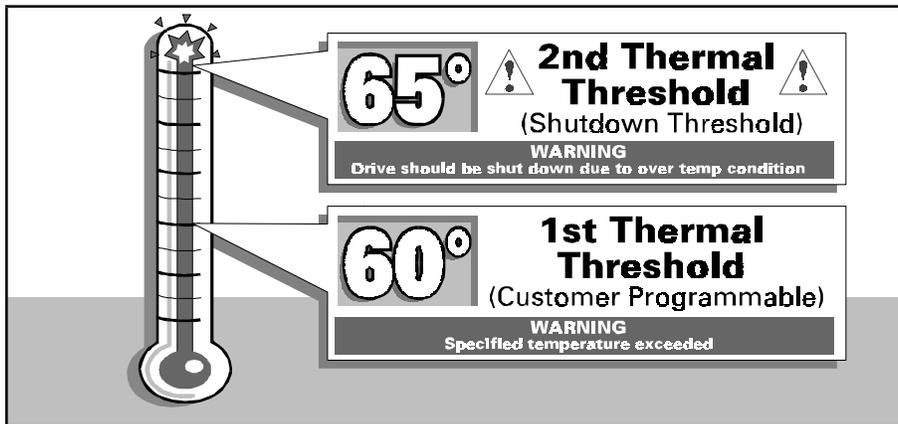


Figure 2. Thermal and Shutdown Thresholds

Warnings are issued when the temperature exceeds the customer set threshold (or the default value 60°C). While this threshold can be disabled by the customer, the shutdown threshold, set to 65°C, cannot.

During normal operations, the S.M.A.R.T. thermal parameter is updated and logged every 25 minutes. A reading of log sense page 2F will force an immediate update and logging of the thermal parameters. When the temperature is between the customer threshold and the shutdown threshold, the parameter is updated every 15 minutes. When the temperature rises above the shutdown threshold, it is updated every 3 minutes. A re-zero unit will also force the temperature to be logged.

Information on the current temperature as well as historical data can be retrieved using the Information Exceptions Status Log Page (page 2FH), as explained in the *Implementation* section below.

The thermal sensor used to generate both the above information and the S.M.A.R.T. notifications is also used by the servo system to limit the operational characteristics of the hard drive when temperatures exceed allowable limits. Though these operational limitations are rarely required, combinations of external temperatures and unusually stressful seek patterns can result in unacceptably high coil temperatures. The thermal sensor prevents potential damage or reduced service life resulting from these conditions by limiting the seek operations to keep the temperatures within an acceptable range. This capability is always enabled, regardless of the state of any other thermal monitoring features.

Temperature Settings	Actions Taken
65°C and higher	Thermal parameter is logged every 3 minutes. Drive shutdown warnings begin. S.M.A.R.T. report (if EWASC=1), Spin Down (if ETS=1)
Between 60 - 65°C	Thermal activity/level is logged every 15 minutes. CTTE notifications begin. S.M.A.R.T. report (if EWASC=1 and DCCT=0)
Up to 60°C or Customer Defined	Thermal activity/level is logged every 25 minutes. S.M.A.R.T. report (if EWASC=1)

Table 1. Temperature Settings and Resulting Actions

Implementation

As with other S.M.A.R.T. features, thermal monitoring is controlled using Mode Select and Mode Sense pages. The Enable Warning ASC (EWASC) bit in the Information Exceptions Control Page (page 1Ch) controls whether or not any S.M.A.R.T. notifications will be generated due to thermal monitoring events (see *Table 2*). This bit can be set to 1 to enable thermal monitoring S.M.A.R.T. notifications, or set to 0 to prevent the generation of any S.M.A.R.T. notifications due to thermal monitoring threshold crossings. However, clearing this bit will not turn off thermal analysis or logging of thermal data, nor will it prevent operational limits from being imposed to protect the integrity of the drive.

	Bit								
Byte	7	6	5	4	3	2	1	0	
0	RSVD			Page Code = 1Ch					
1	Page Length = 0Ah								
2	Perf	Reserved	Reserved	EWASC	DEXCPT	TEST	Reserved	LOGGER	
3	Reserved				MRIE				
4-7	Interval Timer								
9-11	Report Count								
EWASC: Set to 1 to enable thermal warning.				Set to 0 to disable notifications.					

Table 2. Information Exceptions Control Page (1Ch)

The rest of the parameters used to control thermal monitoring are contained in the WD Vendor Unique Mode Page (page 00h) (see *Table 3*). The Customer Thermal Threshold temperature is the temperature at which the drive will start generating “Customer Thermal Threshold Exceeded” S.M.A.R.T. notifications. The default value for this field is 60°C. The Disable Customer Thermal Threshold (DCTT) bit disables the generation of this customer threshold notification. If this bit is set to 0, the Customer Thermal Threshold must be set to the desired threshold temperature. If this bit is set to 1, only this notification is disabled (the rate of change and shutdown temperature threshold notifications will still be generated), and the Customer Thermal Threshold is ignored.

The last parameter controls whether the drive will automatically spin the drive down to prevent possible damage when the shutdown temperature threshold has been exceeded. If the ETS bit is set to 1, the drive will be spun down immediately when the shutdown temperature has been exceeded for two consecutive readings (three minutes apart). If this bit is set to 0, the drive does not spin down automatically; instead the host decides whether or not to spin the drive down. Regardless of the setting of the ETS bit, the S.M.A.R.T. notification for exceeding the shutdown temperature threshold will be issued.

	Bit							
Byte	7	6	5	4	3	2	1	0
0	RSVD			Page Code = 00h				
1	Page Length = 0Eh							
...								
3					BFC			
...								
8							ETS	DCTT
9	Customer Thermal Threshold in degrees Celsius							
...								
<p>BFC: Background Function Control allows background functions that may cause delays in processing.</p> <p>DCCT: Disable Customer Thermal Threshold disables the first threshold checks for S.M.A.R.T. notifications.</p> <p>Customer Thermal Threshold: The temperature in Celsius at which 01/0B/01 S.M.A.R.T. threshold is alerted.</p> <p>ETS: Enable Thermal Spin-down allows the drive to spin down the motor to prevent damage associated with very high temperatures</p>								

Table 3. Western Digital Vendor Unique Mode Page (00h)

The Information Exceptions Status Log Page (see *Table 4*) has been enhanced to reflect thermal monitoring.

Byte	Bit							
	7	6	5	4	3	2	1	0
0	RSVD		Page Code = 2Fh					
1	Reserved							
2-3	Page Length = 0018h							
4-5	Parameter Code							
6	Reserved							
7	Parameter Length = 14h							
8	Sense Code Byte							
9	Sense Code Qualifier							
10	Most recent temperature reading in degrees Celsius							
11	Shutdown temperature threshold in degrees Celsius							
12-13	Thermal Polling interval in minutes							
14-17	Power On Hours in hours							
18	Highest Temperature Ever							
19	Number of Shutdown threshold crossings							
20-23	Time of highest temperature in hours							
24-27	Time of last thermal threshold crossing in hours							

Table 4. Information Exceptions Status Log Page (2Fh)

► **THERMAL MONITORING ADDS IMPORTANT NEW FUNCTIONS TO S.M.A.R.T.**

Western Digital’s commitment to provide the highest quality, most reliable hard drives in the industry involves more than design and manufacturing excellence. It also involves operational features and capabilities that allow both the hard drive, and the system in which it is used, to monitor and control the hard drive’s operation to minimize the possibility of drive failure.

Thermal monitoring, the newest S.M.A.R.T. feature, is now being implemented on Western Digital drives, beginning with the WD Enterprise WDE18300 and WDE9180 Ultra2 SCSI hard drives. This new technology concentrates on system-level protection and monitors the temperature of the drive. It also provides relevant information to the host, and modifies drive behavior to prevent drive damage due to high temperature conditions.