

Fly Height Monitor Improves Hard Drive Reliability

*New Feature Significantly Reduces
Hard Error Rates*

► OVERVIEW/EXECUTIVE SUMMARY

Western Digital's Fly Height Monitor protects write operations by detecting when a recording head is flying outside its normal operating range. If an unsafe fly height condition is encountered, the write process is stopped, and the information is rewritten or reallocated to a safe region of the hard drive. This constant monitoring process increases the reliability of write operations and reduces the probability of read errors.

The new Fly Height Monitor is being implemented in Western Digital's drives, beginning with the WD Enterprise WDE18300 and WDE9180 Ultra2 SCSI hard drives, and will be included on all future WD Enterprise products.

► BACKGROUND

The amount of data that can be stored on a disk is a measure of its areal recording density, i.e., the tracks per inch and the data bits per square inch. The product of these two is areal density in bits per square inch. Therefore, to increase areal density you must increase the number of bits on a track or the number of tracks per inch. Unfortunately, as the number of bits increases, the read signals generated by the bits weaken. This situation, in turn, makes it more difficult for the hard drive's read channel electronics to identify the bit patterns that re-create the user data.

The best way for read/write heads to maximize areal density is to reduce the distance from the head to the disk—the head's "fly height". A reduction in fly height makes the bit pattern's output signal stronger and easier to detect. The objective of reducing fly height is to improve the signal quality, and not create a condition that might damage stored data.

The fly height is controlled by the suspension attached to the slider and the airbearing of the slider. (*See Figure 1.*) This aerodynamic system controls the variation in fly height as the slider is positioned over the surface of the media. Traversing the head between the inner and outer radius of the disk causes a two-to-one change in velocity. Prior to current technology in airbearing designs, this change in velocity would have created a two-to-one change in nominal fly height. With new innovative airbearing designs, this variation can be reduced to a fraction of the nominal value. For magnetic purposes, the fly height is measured as a distance between the read/write elements and the magnetic surface. Current technology requires that the fly height be greater than 1.0 micro-inch.

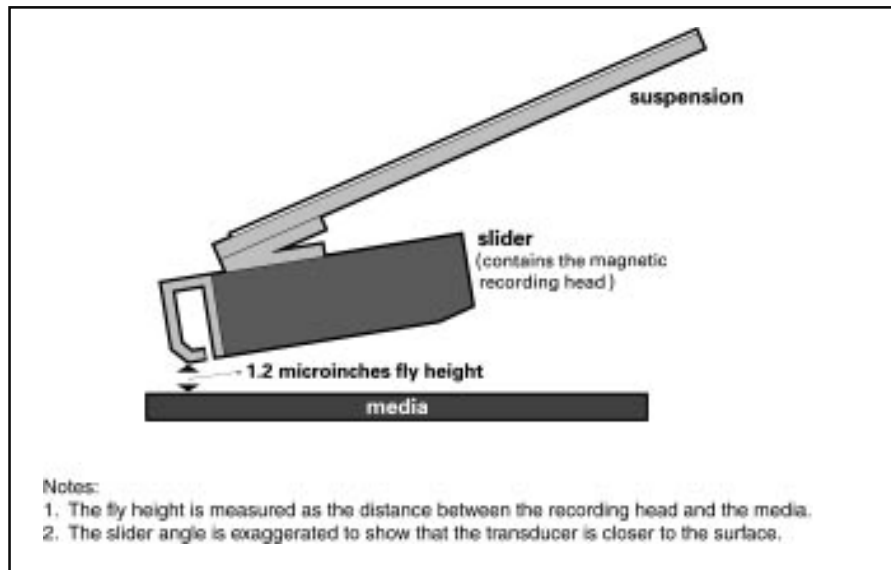


Figure 1. Flying Height of Hard Drive Heads

There are several conditions that create disturbances between the airbearing and the disk surface that can change the fly height. These conditions are altitude, temperature, and contamination. An extreme in any of these conditions will degrade the error rate performance of the drive. These conditions are taken into account during the development of the airbearing designs. Instantaneous change in fly height is the only factor that is not controllable. With the implementation of Western Digital's Fly Height Monitoring System, this potential failure mode is reduced.

If the recording head flies higher than intended, even for a short period of time, the magnetic field available may be insufficient to reliably write to the media. This is referred to as a "high fly write." External shock, vibration, media defect or contamination may cause this. If the result is a soft error, it can be corrected by the hard drive's Data Recovery Procedure; but if it is a hard error, it is unrecoverable.

Before Western Digital's Fly Height Monitor, excessive variation in flying height could degrade the write process and not be detected. Write verification was not typically performed because it would cause a reduction in throughput. As a result, the hard drive was not able to ensure that the information was written reliably. Western Digital's new Fly Height Monitor resolves this shortcoming in hard drives.

► HOW THE FLY HEIGHT MONITOR WORKS

The Fly Height Monitor is essentially a write condition detector that suspends write operations if the transducer's flying height deviates from its nominal condition. The flying height is constantly monitored during normal write operations to determine if deviations to an unsafe flying height condition occurs. Monitoring the flying height improves the integrity of the data without degrading throughput.

The monitoring process circuitry is embedded in a custom integrated circuit that is connected to the write fault circuit. This circuitry is compatible with all Western Digital's

user interfaces. The circuitry continuously determines the ratio of the magnetic pulse area to the magnetic pulse peak. As a head flies higher, this pulse ratio increases, creating a measurable and repeatable relationship for each head. Table 1 presents typical parameters for nominal and unsafe flying heights for a typical hard drive.

Reference Signal	Nominal Flying Height	Unsafe High-Flying Height (+40% Deviation From Nominal Flying Height)
PW50	8 ns	11.2 ns
Area	.6 v	.84 v
Peak	.8 v	.8 v
Area: Peak Ratio	.75	1.05

Table 1: Parameters for Nominal and Unsafe Flying Heights

The normal distribution of fly height requires the circuitry to be calibrated during the drive manufacturing process. Then during normal operation, both prior to and after a write operation, the monitor measures the Pulse Ratio and compares it to the stored value to determine if it is within the acceptable range of variation. If it is, the fly height is accepted and the write operation proceeds.

If the monitor detects an unsafe condition (high fly), the write process is interrupted and the recovery procedures are invoked. This procedure may involve one or more retries of the write process. If the high fly condition is transient and disappears during a retry, the write operation continues normally. However, if the high-fly condition is still present for subsequent retries, then the data is reallocated to a new region of the disk, thereby preventing data loss.

► **MAJOR BENEFIT: HIGHER RELIABILITY AND DATA WRITING INTEGRITY**

The Fly Height Monitor was developed specifically to increase reliability and reduce unrecoverable errors. The Fly Height Monitoring circuitry has enhanced the reliability margin and reduced the unrecoverable error rate significantly over older products.

The Fly Height Monitor enhances the reliability and integrity of the writing process, and significantly reduces the Hard Error Rate. It increases the overall reliability of Western Digital drives.