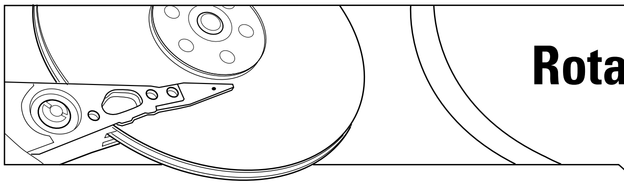


Rotary Acceleration Feed Forward (RAFF)

Rotational Vibration Cancellation Technology in WD Raptor™ Serial ATA Hard Drives

Designed for enterprise environments, the new WD Raptor high performance, high availability hard drives employ Rotary Acceleration Feed Forward (RAFF) technology to maintain the highest possible data transfer performance in the high Rotational Vibration (RV) environments commonly found in servers and storage arrays. Hard drive (HD) performance is degraded when an HD is exposed to vibration induced by one or more of its neighbors in the chassis. This induced vibration shakes the head off a track that is currently being read from or written to, resulting in retries and serious performance consequences.

The Growing Menace To Performance

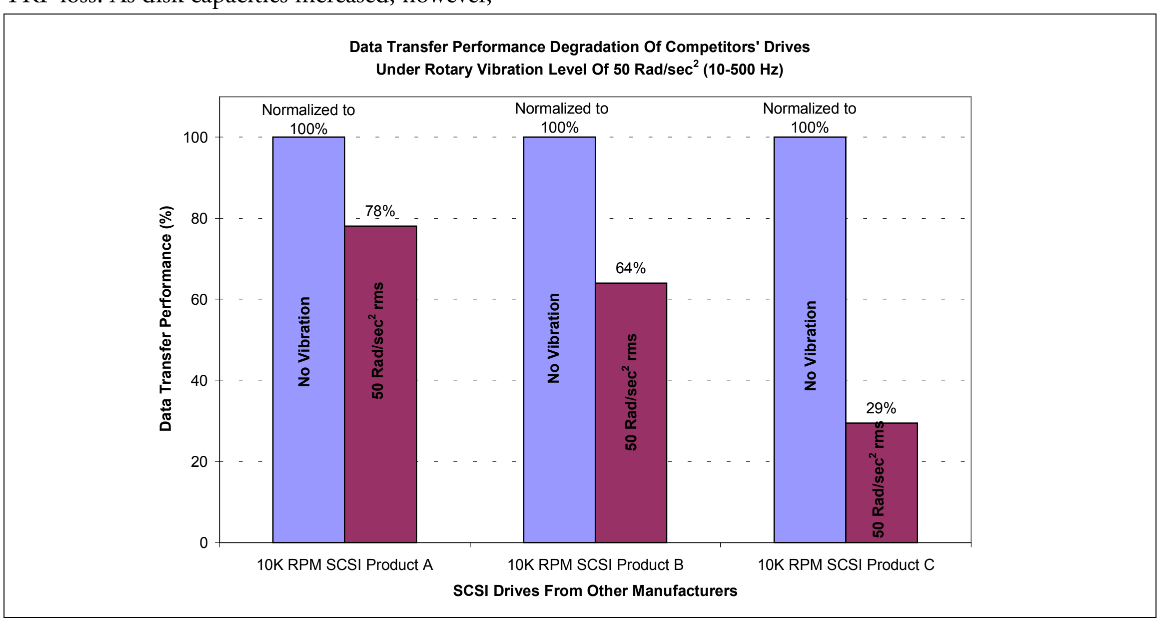
The most important performance metric of a disk drive is the rate at which data can be transferred to/from a host. This performance is called Data Transfer Rate Performance (DTRP) and can be measured by a test.

A few years ago, drives in servers operated without any significant DTRP loss. As disk capacities increased, however, tracks were squeezed closer together. Additionally, higher spindle speeds (10,000 RPM, for example) generate higher vibration levels in servers and storage arrays. These two factors make HDs operating in server environments more susceptible to DTRP degradations.

To maintain their DTRP under high RV environments, the WD Raptor drives employ Rotary Acceleration Feed Forward (RAFF) technology through an adaptive feed-forward compensation scheme. RAFF is implemented in 74 GB and higher WD Raptor drives beginning with the 74 GB, EL74 drive family. RAFF is not available on 36 GB EL36 drives.

Sizing the Problem

Figure 1 shows considerable DTRP degradation in SCSI drives from other manufacturers when exposed to 50 rad/sec^2 rotational vibration as compared to their normalized DTRP in isolation. The measured DTRP degradation under rotational vibration is from 78 to 29 percent!



What is Rotational Vibration?

RV is induced in a hard drive as a result of other drives' spinning and seeking in the same chassis. RV can also be induced by external forces on the rack or chassis containing the hard drives. Even linear vibrations applied on a chassis may get converted to RV at the drive level if a chassis is not designed appropriately. An example of this would be a drive bay structure that is not rigidly attached to a chassis.

RV produces the effect of making a hard drive vibrate about an axis. The effect of this vibration on hard drive is a loss of data transfer rate performance. In an RV environment, a hard drive head is prevented from settling on a data track quickly to start reading or writing data and/or is shaken off a track while reading or writing is in progress. Once the head is outside of a safe operating region over the track, either of these conditions will cause the drive to delay its scheduled operation. Until the head returns to and stays within the safe operating region, the drive will not return to normal operation. These unscheduled delays degrade the data transfer performance rate of the drive. Therefore, an RV management system is required to maintain the DTRP required of enterprise class drives.

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How RAFF Works

Rotary Acceleration Feed Forward (RAFF) overcomes the effects of RV on a hard drive by sensing RV disturbance and controlling head position to keep the drive heads within the safe operating region during read and write operations.

The RAFF implementation has three major components:

a. RV sensing

b. RV control effort feed-forwarding

c. Adaptation to environmental conditions

RV sensing in the RAFF implementation is accomplished by using two relatively inexpensive linear accelerometers placed on the printed circuit board assembly (PCBA). The sensor locations are optimized for separation distance and PCB mounting conditions. The accelerometers produce signals due to vibration. The two signals are subtracted from each other to generate a Differential Sensor Signal (DSS). This signal is proportional to the vibration magnitude.

RV control effort feed-forwarding is achieved by digitizing the DSS. The digitized DSS is sent to the microprocessor. The microprocessor generates a control effort signal by processing the digitized differential sensor signal according to a sophisticated control algorithm. This feed forward control effort is in addition to the conventional servo control approach in hard drive operations (see Figure 2).

Adaptation to environmental conditions is a key component to deliver the benefits of RAFF. The Western Digital design selectively adapts to individual drive parameters to mitigate RV interference and maintain maximum performance in the hard drive.

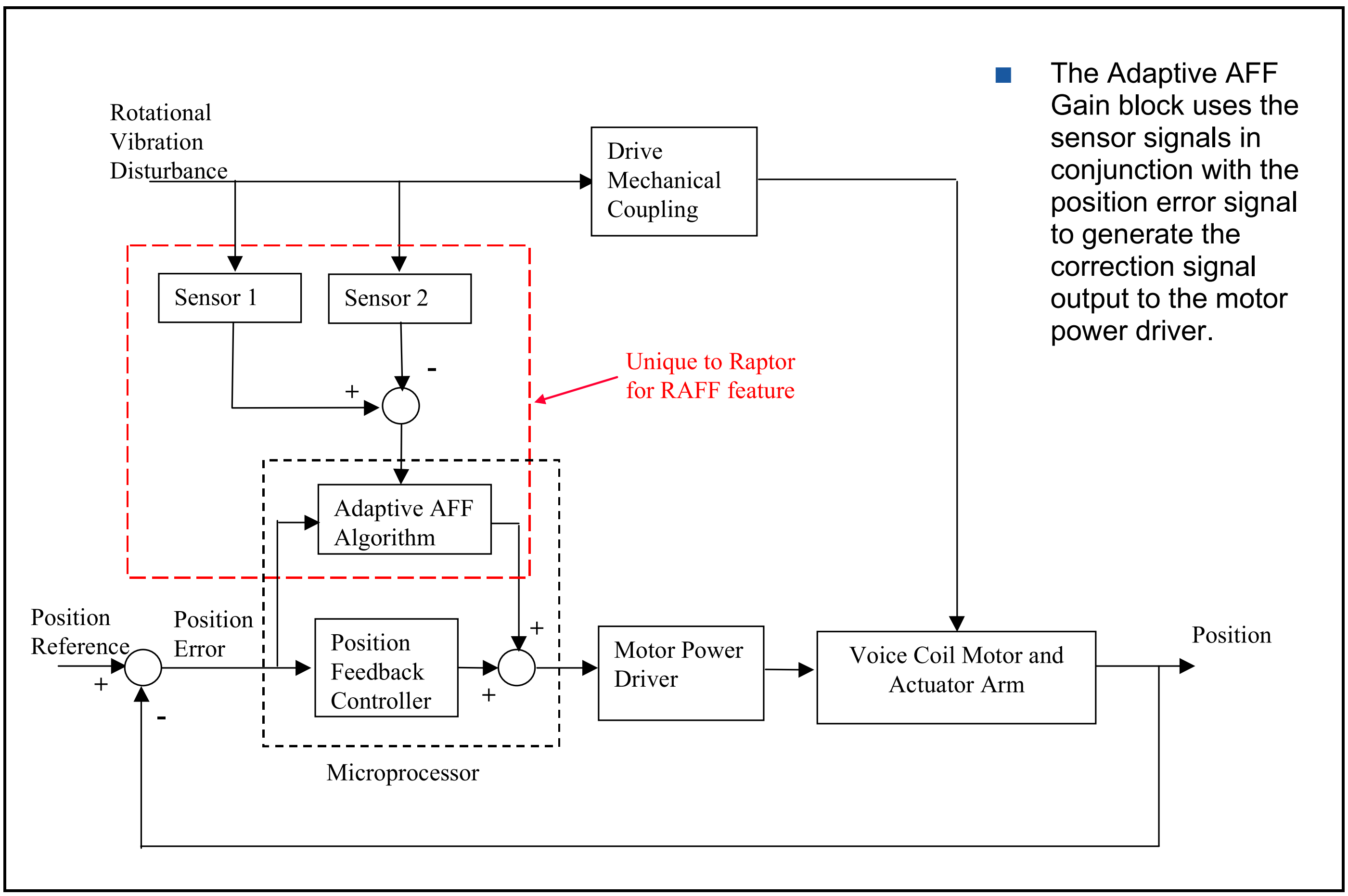

Figure 2. Dual Linear Sensor Rotational Acceleration Feed Forward (RAFF) Functional Block Diagram

Results

Data collected from WD Raptor drives showed that drives maintain their high DTRP even under high RV levels. For example, under 50 rad/sec^2 RV level WD Raptor drive data transfer rate degraded only by 4 percent. See Figure 3 for a comparison including WD Raptor drives.

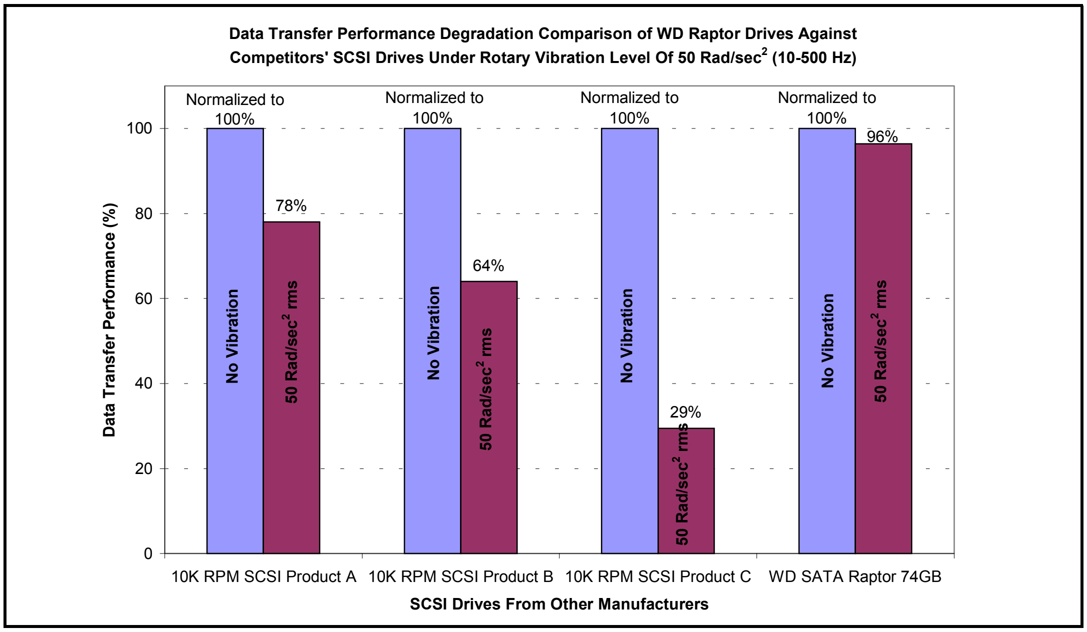

Figure 3. DTRP of WD Raptor Drive and its Competitors vs. RV Comparison Chart Under 50 rad/sec^2 Rotational Vibrations.

RAFF improves DTRP of WD Raptor drives for all rotational vibration levels. Figure 4 shows the DTRP of four sets of drives from WD and 10K RPM SCSI products by other manufacturers.

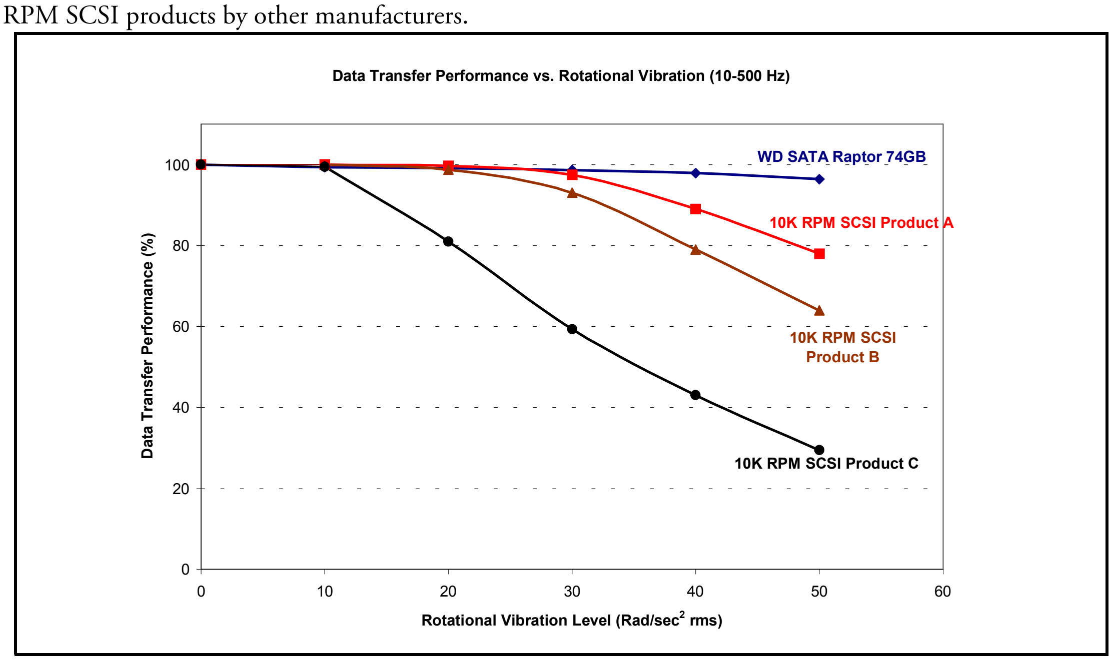

Figure 4. DTRP vs. RV Comparison Chart of Various Drives Under Different Levels of Rotational Vibration.

Conclusion

Rotary Acceleration Feed Forward (RAFF) technology provides a significant performance advantage in high RV environments, considerably surpassing SCSI drives from other manufacturers.

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