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The Effects of Using Isolators for Mounting Disc Drives in PC Systems

Abstract

Seagate[®] has been investigating the effects of mounting disc drives on isolators to reduce the acoustic emissions of PC systems. This paper discusses the acoustic benefits of using isolators and their impact on system performance.

Our testing of PC systems showed that without fans running, isolators typically improve system idle acoustics by 5.5 dBA and seek acoustics by 8.5 dBA. With fans running, the improvements were 1.2 dBA idle, and 5.0 dBA seek. Improvements in the disc drive design alone cannot produce similar gains in system acoustics. Testing also showed that changes in disc drive acoustics had little effect on the overall system acoustics when they were solid mounted in the chassis.

The isolated mount negatively impacts seek arrivals for seeks greater than about 10 percent of the total stroke of the disc drive. This characteristic may cause performance degradation in some applications, but our testing indicates that the typical PC user will not experience any change in performance. Winbench testing currently shows little or no change in scores when disc drives are mounted on isolators. Because the Winbench tests change from year to year, there is also a chance that this result may change. Long seek arrival characteristics may pose a slight risk to data integrity, but our DMT and reliability testing has not shown this to be true with our drives.

Acoustic Noise Sources

The acoustic noise of a disc drive mounted in a chassis comes from two sources. The first source, airborne acoustics, is what all drive manufacturers currently specify as the sound power value. It is the sound that comes from the drive through the air to the observer. This value is measured with the drive suspended in space. The second noise source is generated from the drive's vibration during idle and seek. This vibration energy is transmitted directly to the PC chassis structure and causes the chassis to act as a speaker. This form of noise is called structure-borne acoustics. Until recently, we had not considered the total effect of drives on a PC system. Now we can show that structure-borne acoustics is the dominating source of disc drive-induced PC acoustics.

To separate the two acoustic sources, we tested PC systems without fans running. The fans act as a masking noise source and don't allow us to measure the acoustic emissions of the disc drive. The systems were run with the drives mounted in their normal solid mount and then with isolators. The tests were conducted in our semi-anechoic chamber according to ISO 7779 standards. The average improvement in the system idle acoustics with the drives mounted on isolators was 5.5 dBA sound power. The average improvement in the system seek acoustics was 8.5 dBA. A few systems saw a greater than 10 dBA improvement in seek acoustics. The drive used in this testing had an idle airborne emission level of 32 dBA with a seek level of 37 dBA.

When the drive is mounted on isolators, the emissions are almost exclusively airborne because the isolators have eliminated the structure-borne portion of the noise. We can calculate the amount of structureborne acoustic noise by subtracting the airborne acoustics (isolated results) from the total acoustics (solid results). Using our average system as an example, the idle value for a system with solid mounts was 32.5 dBA. With the drive mounted on isolators, that value was 27 dBA. The subtraction of these values (keeping in mind that this is a logarithmic scale) gives us a structure-borne value of 31.1 dBA.

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From this data, we learn two facts about PC system acoustics. First, on average, a PC chassis attenuates airborne acoustics by 5 dBA¹. This is no surprise because they are a partially sealed enclosure. Secondly, the structure-borne acoustics dominate the total acoustic emissions due to the chassis attenuation². Therefore, reductions in disc drive airborne acoustics will have little or no effect on the final PC system acoustics³. If we consider the masking effect of fans, the disc drive's contribution to system acoustics is even less.

For seek acoustics, this diminishing returns effect is even greater. Improvements in drive seek acoustics will be noticed even less, unless the structure-borne portion of the acoustic problem is addressed.

The following chart illustrates how two noise sources add when using the decibel scale. The values could represent the sound power values of a fan, and a disc drive, or airborne noise and structure-borne noise. If your source one is at 40 dB, you do not gain much by reducing your second source from 36 dB to 30 dB.

Source 1								
		34	36	38	40	42	44	46
Combined Loudness								
Source 2	28	35.0	36.6	38.4	40.3	42.2	44.1	46.1
	30	35.5	37.0	38.6	40.4	42.3	44.2	46.1
	32	36.1	37.5	39.0	40.6	42.4	44.3	46.2
	34	37.0	38.1	39.5	41.0	42.6	44.4	46.3
	36	38.1	39.0	40.1	41.5	43.0	44.6	46.4

2. The structure-borne acoustic value of 31.1 is significantly louder than the airborne value of 27.

^{1.} When measured in a open room, this drive's airborne idle value was 32 dBA. When placed in the chassis, it dropped to 27 dBA.

^{3.} Using our average PC system example, if we were to reduce the disc drive's idle airborne value by 2 dBA, the end-user would only see a 0.4 dBA improvement in system idle acoustics. This is without considering the additional masking effect of the system's fan.



Isolator Impacts on Seek Settling

The major problem created when mounting a drive on isolators is the additional motion in the drive's baseplate at seek settle. This condition is commonly called the *wind-up* mode. The isolators are springs that allow the drive's baseplate to rotate when the torque created during a seek is applied. The isolators "wind up" during a seek and then unwind when the actuator is trying to settle on track. This unwinding creates too much motion for the servo system to fully track, causing an offtrack condition to occur. This either causes delays in settling or causes the heads to come off track just after settling occurred.

When writing data, the first event causes a slow seek, the latter event is referred to as a *write retry*. The slower seeks usually cause delays on the order of 1 to 5 msec. The write retry can cause a delay in writing data equal to the time it takes for the disc to complete one revolution. As a whole, this settling problem is larger for writing data than reading data because the heads need to be kept closer to the track centerline during the write process.

How large a performance problem is this?

When testing our drives with Winbench99, we see no difference in either the business or high-end test scores when the drives are mounted on properly designed isolators. Even when the drives are mounted on poorly designed mounts, we only see a 1 percent to 2 percent drop in the business scores and nothing in the high-end scores. This is to be expected because 95 percent of the seeks involved in the current Winbench test are shorter than 30 tracks. Our drives today have over 12,000 tracks, so the motion required to perform the Winbench is small and doesn't cause much wind-up in the isolators.

Our testing has shown that it takes a seek length of about 10 percent of the full stoke of the drive before we see the amount of write retries increase. We conducted performance testing using a random seek profile over the entire surface while transferring 10 blocks of data and found a 20 percent reduction in write-throughput rates. However, when doing reads, we saw no reduction in the throughput when the drive was mounted on isolators. The performance impact the customer sees depends on the length of seeks that are performed in the typical PC applications. *See the following topic for a discussion on our testing of seek lengths involved in booting PCs.*

What if future Winbench tests change to using longer seeks?

We asked Ziff Davis, the creators of Winbench, this question. They indicated that future Winbench disc drive tests will emphasize "activities that make you wait on your PC." Because we don't know what future Winbench tests will do, we mapped the seek activity that makes us wait for our PCs, namely booting and opening applications. We mapped a typical Windows 95 operating system used at our facility and special fully loaded Windows 98 and Windows NT operating systems. These special systems included versions where the Microsoft Office products where located on a second partition to purposely move them halfway across the disc drive. The first thing we noticed was that the size of the operating system defined the longest seek possible during the boot process. We know that isolators start to affect performance for seek lengths greater than 10 percent of the total seek stroke. This equates to about 10 percent of the disc drive's capacity⁴. So, as a general rule of thumb, we can say that if the operating system occupies less than 10 percent of a drive's capacity, then isolators will not affect the time it takes to boot the system.

^{4.} The relationship between percent of capacity and percent of stroke varies from the ID to the OD of the disc. At the OD where the operating system is located, 10 percent of the drive's capacity occupies less than 10 percent of the stroke.





The following graph shows the distribution of seek lengths involved in booting a Windows 95-based operating system. The test was conducted on a typical operating system at our Longmont facility. The size of the operating system and various applications was a little over 400 Mbytes, and the drive used had a 4.3-Gbyte capacity. The total number of cylinders on this drive is just over 12,000. The read-to-write ratio observed during the boot process was 3 to 1.

The Windows 98 and NT systems used in our tests were over 600 Mbytes long. Even with the Office software located on the upper partition, half way across the disc, 90 percent of all seeks involved in booting were less than 10 percent of stroke on a 4.3-Gbyte drive. If you look at the write seeks only, this number climbs to about 95 percent.

Our tests show that 60 percent of the seek lengths involved are less than one third of the operating system size and that there are three times as many read operations performed as write operations⁵.

Because we have tested only a few operating system configurations, we feel that system suppliers should investigate the seek length distributions involved in the boot processes for the operating systems they ship.

^{5.} This ratio is affected by the caching efficiency during the boot process. It varied between values of 1 to 1, and 6 to 1 reads to writes.



Are there any data integrity problems created with the use of isolators?

There are many factors involved in disc drive design that pertain to maintaining customer data integrity. These include: disc magnetic parameters, head magnetic parameters, head-flying characteristics, spindle runout characteristics, servo characteristics and drive operating environments, to name a few. Most of these factors must be at the end of their distributions to cause a problem. Statistically speaking, there is a higher chance of a data-integrity problem occurring when a higher write retry rate occurs in a disc drive.

Our DMT and reliability tests are conducted in an environment that produces an equal, if not higher, write retry rate than we see when the drives are mounted on isolators. Our specified DPPM reflects this test condition. Therefore, we know our drives can operate on isolators without seeing a higher failure rate for data integrity than what occurs in our test processes. Nevertheless, future Seagate products will offer optional drive code that will maintain acceptable write retry rates across all seek lengths when drives are mounted on isolators. With this approach, we can absolutely ensure the data's integrity while minimizing the performance loss to the customer.

Are there any other problems created when disc drives are mounted on isolators?

The one other problem that isolators could create is an increase in the imbalance shaking force from the disc drive. If the isolator natural frequency is chosen so it is close to the rotation speed of the disc, then the imbalance force of the drive will be amplified. This could cause a noise problem if the chassis has a vibration mode at the rotation speed of the disc. The converse is also true, in that a force coming from the chassis can get amplified and may cause a drive tracking problem. Seagate's recommended isolator design uses a highly damped rubber compound that minimizes this amplification. This design can keep the amplification to less than a factor of two in the frequency range that causes the most problems. In the PC chassis we tested, we never saw an increase in noise due to the amplified imbalance force. We believe that PC chassis designers should be aware of this problem, but that its occurrence will be rare.

Conclusion

The dominance of structure-borne acoustics over airborne acoustics in today's PC chassis has created a diminishing returns effect when it comes to reducing disc drive acoustic emissions. Reductions in disc drive acoustics no longer produces a significant improvement in the end-users acoustic environment. If PC systems need to improve their acoustic quality related to disc drive noise, then isolator mounting is necessary to achieve any significant change. The possible performance impact due to using isolators should be reviewed by each system supplier. If they agree with our conclusion that long seeks play a small part in today's PC operation, then the use of isolators should provide a very cost-effective way of reducing acoustic levels.