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TECHNOLOGY PAPER

FROM SEAGATE

INTELLIGENCE

Seagate's Sound Barrier Technology (SBT)

The Art of Quiet Disc Drives

Disc Drive Acoustics Defined

There are two types of acoustics measured for a stand-alone disc drive:

- **Idle Acoustics:** the audible noise emitted from a drive while it is spinning, but otherwise inactive
- **Seek Acoustics:** the audible noise emitted from a drive when the heads are moving (seeking)

For more information about the sources, measurement and characteristics of disc drive acoustics, please refer to Seagate's acoustics overview technical paper, *Disc Drive Acoustics* (TP-296D), published 4/00.

Reducing Disc Drive Acoustics with Sound Barrier Technology

Seagate's sound barrier technology (SBT) is a group of features that reduce audible acoustic noise from the disc drive. Some of SBT's features provide continued noise-abatement evolution, while others are new and take the drive into ever-quieter realms.

Idle Acoustics Reduction

The following SBT features all help reduce idle acoustics:

- **SeaShield®**—This protective cover for Seagate personal storage disc drives protects the drive and also dampens acoustic noise.
- **Dampers**—Seagate® uses several types of foam and other damping materials in its drives to reduce acoustic noise.
- **Resonance reduction**—Seagate's engineers continue to optimize the interplay of drive components to reduce harmonic resonance, vibrations and other sources of mechanical noise.
- **Mechanical and materials design optimization**—Seagate's engineers use sophisticated design and modeling techniques, such as finite element analysis, to choose the quietest possible combinations of parts and materials.
- **Motors**—Seagate continues to hold a leadership position in the design and implementation of ultraquiet fluid dynamic bearing (FDB) motors in its disc drives, as well as high-speed, state-of-the-art ball bearing motors.
- **Spin commutation**—Motor noise is further reduced by using shape-optimized positive/negative voltage-transition curve to the spindle motor stator with Seagate's sinusoidal driver current.

Dampers

Seagate personal storage drives include a top cover damper and a foam damper between the PCB and SeaShield. Seagate's enterprise products use combinations of dampers with increasing levels of damping:

- Damped metal laminate (DML) top covers provide sound-proofing.
- Whirl dampers absorb motor vibration by connecting the motor and the cover with an elastic material that isolates the motor from the cover.
- Ring dampers work with the whirl dampers to further reduce top-cover vibration.
- Double DML covers increase the damping loss factor by placing visco-elastic damping material at locations susceptible to vibration and by further increasing the cover mass to reduce vibration amplitudes.

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Motors

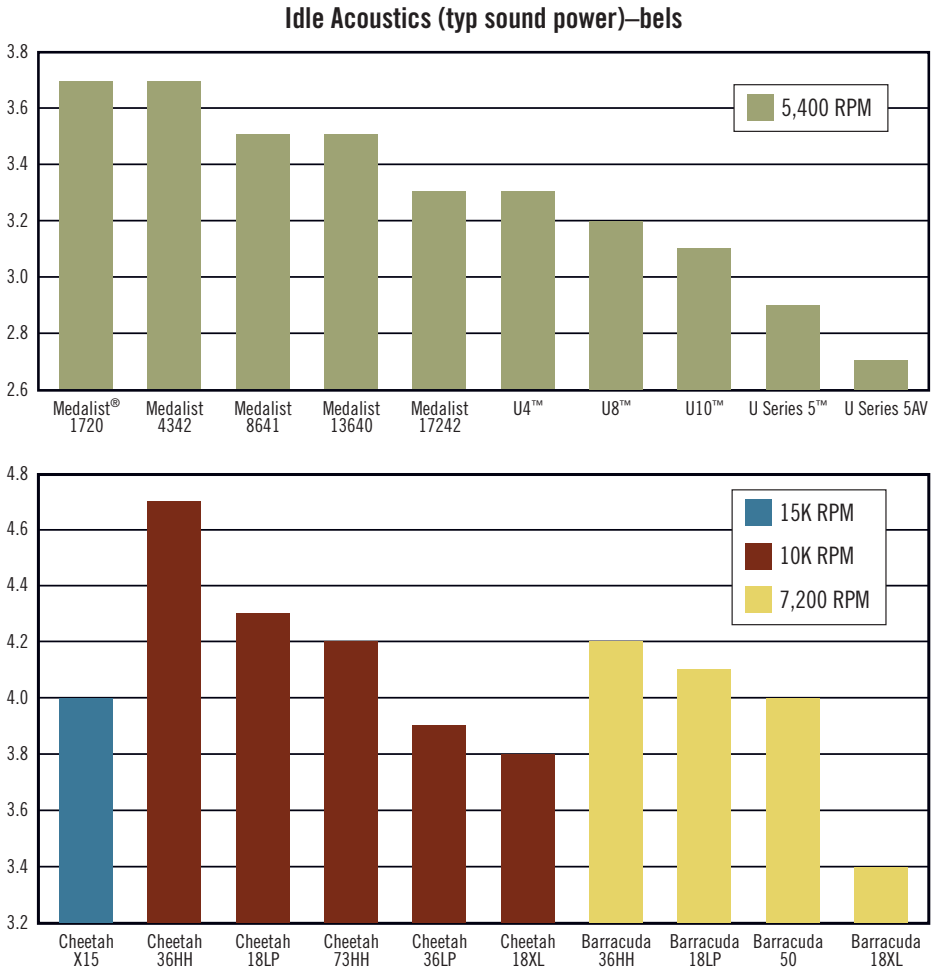
Seagate leads the disc drive industry in motor design and implementation.

RACE Motors (Reliability with Advanced Control and Efficiency)
Seagate's advanced high-efficiency stator in its 15K RPM RACE motor reduces the high-frequency tones due to motor commutations, lowering the overall acoustics of the drive. The RACE motor also uses ceramic ball bearings instead of metal alloy. The ceramic balls result in less vibration and noise. These technologies allow 15K RPM motors to spin 50 percent faster than 10K RPM motors without increasing the acoustic output of the drive.

Fluid Dynamic Bearing (FDB) Motors
Seagate is the only disc drive manufacturer currently shipping its third generation of fluid dynamic bearing motors, which are significantly quieter than ball bearing motors. Acoustic performance of fluid bearing motors is substantially improved because of the elimination of metal-to-metal contact. Fluid dynamic bearings provide a smoother, more perfectly circular spin with very little vibration and nearly silent operation. They are also more resistant to damage during manufacturing or consumer handling that can increase the noise and vibration produced by ball bearings.

Reduction Trends

Over the past several years, idle acoustics for Seagate's disc drives have been reduced dramatically, and the reduction trend continues in new and upcoming products:



Seek Acoustics Reduction

Seagate also focuses on reducing seek acoustics across its product lines. Most of the features that help reduce idle acoustics also result in lower seek acoustics. Additional specific SBT features that *reduce seek acoustics* include:

- **Dampers**—absorb sound from seek-specific movements during drive servo operations
- **Support for Automatic Acoustic Management (AAM)**—interface specification for ATA-interface drives
- **Quiet ("silent") seeks**—various methods of reducing noise during seeking

Automatic Acoustic Management (AAM)

AAM is a standardized means of setting limits on allowable acoustics from a drive. The interface standard is defined in the ATA/ATAPI-6 specification and has been adopted by the ANSI X3-T13 Committee of the National Committee on Information Technology Standards (NCITS).

AAM works by limiting the allowable acoustics from a drive and results in a drive that performs seeks in either *quiet seek* or *performance seek* mode. Quiet mode typically results in decreased seek performance, and performance mode is typically noisier.

The drive provides AAM support information to the host through the Identify Device (ID) command, which defines whether the drive supports AAM, and if supported, defines whether AAM is enabled/disabled, and if enabled, defines the current level and the "vendor's recommended acoustic management value" (VRAMV). The VRAMV allows the drive to recommend a level between quiet and performance, which can result in the drive being faster than the quietest mode and quieter than the performance mode.

The host sets the AAM level through the system BIOS, applet, or utility using the Set Features command. The command protocol is defined in the ATA/ATAPI-6 specification.

Automatic Acoustic Management Levels

Level	Sector Count Value
Reserved	FF_H
Maximum performance	FE_H
Intermediate acoustic management levels	81_H–FD_H
Minimum acoustic emanation level	80_H
Retired	01_H–$7F_H$
Vendor-specific	00_H

If the host wants the drive to operate in its quietest mode, the host should set the AAM level to 128 (80 hex). If the host wants the drive to operate in the fastest mode, it should always use AAM level 254 (FE hex). If the host chooses a value in the intermediate range, then a supporting drive will operate in between the two extremes.

Quiet Seeks

There are a number of seek noise contributors:

- Speed
- Acceleration (torque)
- Arrival (deceleration, stop)

There are various methods for controlling these variables:

- Velocity-limited seeks
- Acceleration-limited seeks
- Shaped seeks
- JIT seeks

Each Seagate product may use a different combination of methods for achieving quiet seeks. The measured tradeoff between performance and acoustics is 0–3 percent performance decrease and 2–3 dB acoustic noise decrease (improvement).

Velocity-Limited Seek Method

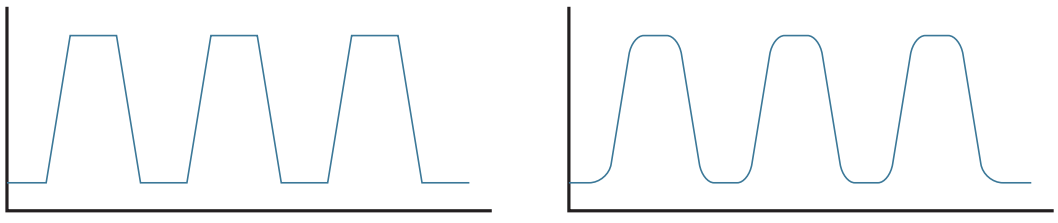
During a long (high-velocity) seek, the drive generally wants to get the heads over the data track as fast as possible for best performance. The faster the seek, the more noise is emitted from the drive because more energy is applied to the actuator. Maximum noise can be lowered by limiting maximum seek speed during a long seek. The limit can be set to minimize performance impact while also reducing audible noise, although some performance tradeoff is necessary using this method.

Acceleration-Limited Seek Method

During a long (high-velocity) seek, the drive generally wants the heads to accelerate to maximum velocity as quickly as possible by using the highest possible torque. The higher the torque (more sudden movement), the more noise is emitted from the drive. Maximum noise can be lowered by lowering torque, which limits acceleration. Limits can be set to minimize performance impact while also reducing audible noise, although some performance tradeoff is necessary using this method.

Shaped Seek Method

During a long (high-velocity) seek, generally the drive wants the heads to accelerate to maximum velocity as quickly as possible by using the highest possible torque. When the heads reach the required track, the drive wants to slam on the brakes (decelerate) as late as possible while still stopping on time. This sudden acceleration and deceleration causes more audible noise, which can be reduced by shaping the acceleration/deceleration current to be smoother. Shaped seeks often help improve performance by reducing overshoot.

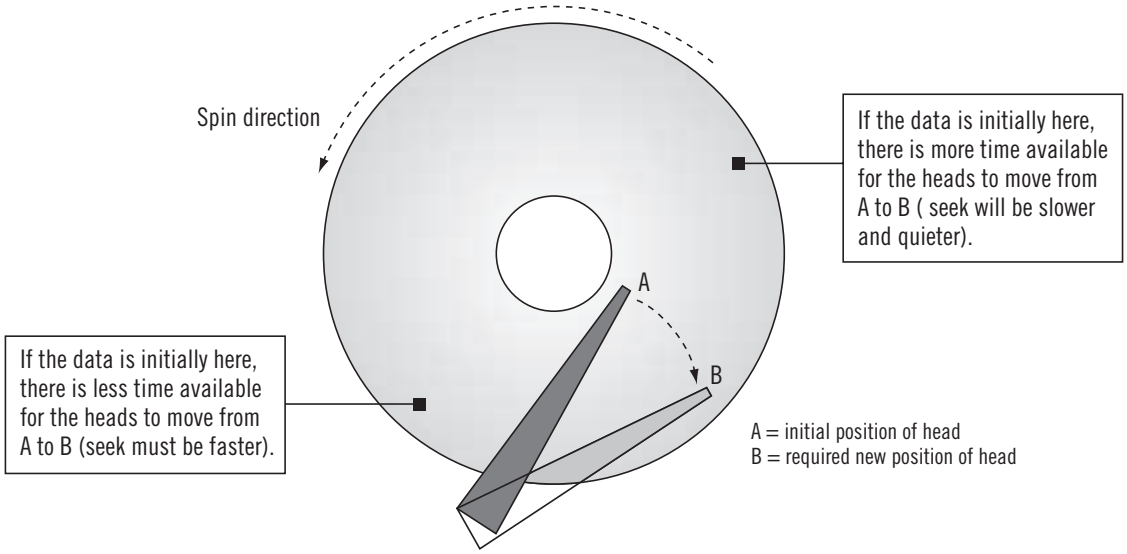


Standard seek

Shaped seek

Just-in-Time (JIT) seek method

This computation-intensive seek method calculates how much time is available until the requested data rotates around to be under the head. It adjusts the speed of the seek to use the amount of time available (faster if the data is close by, slower if the data is nearly a full revolution away). The slower seeks are quieter than standard seeks. This method of reducing noise also has no impact on seek performance, and may also reduce power consumption. See diagram below for further clarification.



SBT Applications

PC Systems:

In traditional PCs with fans, the fan is typically louder than the idling drive, which drowns out all but the most prominent tones (if any) and the seek acoustics. As fans and systems get quieter, *OEMs building traditional PCs are looking for drives in the sub-30-dB acoustic range at idle, and for minimal differences between idle and seek (ideally within 3 or 4 dB).*

Higher-performance systems, which are often running in office environments or as game machines in homes, do not have such stringent acoustic requirements. High spindle speeds are more important in these applications, and *7,200-RPM drives should have sub-35 dB sound power acoustics.* SBT results in dramatic reductions in Seagate's 7,200-RPM acoustics starting with the Barracuda ATA® III, which is expected to have idle acoustics of a mere 3 bels (comparable to many 5,400-RPM drives).

New small form-factor PCs do not have fans. For these systems, *drives should be in the mid-20-dB range, with seeks preferably less than 2 dB louder than idle.*

New Consumer Devices:

Internet appliances and consumer electronics systems (personal/digital video recorders, electronic jukeboxes, electronic game consoles, etc.) may have no fans and may be operating in quieter environments than typical PCs. For example, a PVR may be recording in the bedroom in the middle of the night, or an electronic jukebox may be playing in a family room. For such applications, the drive must be inaudible, including seeks. *The drives going into these consumer electronics systems must be in the mid-20-dB range, with seeks preferably less than 2 dB louder than idle.*

Enterprise systems:

Acoustics has become an increasingly important feature in enterprise systems. Many systems have scaled in size to accommodate increasing numbers of drives to keep pace with system performance. The additive nature of acoustics points to the need for individual drive acoustic emissions to decrease from generation to generation. At the same time, smaller systems, such as performance workstations that are in the office environment, are incorporating faster drives and require acoustics appropriate for the office environment.

SBT Summary

As the existing and new segments of the market continue to require quieter systems, Seagate is leading the industry in providing exceptionally quiet drives with SBT. These efforts are resulting in ever-quieter disc drives from Seagate in both Idle and Seek modes, which ultimately results in more satisfied customers and end-users.