



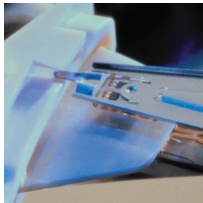
Ramp Load/Unload Technology in Hard Disk Drives

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Overview

Load/unload technology was discovered in the mid-1990s as a viable alternative to Contact Start-Stop (CSS), a method where the sliders which carry the Read/Write heads in hard disk drives land on the disk media at power down, and remain stationed on the disk until the power up cycle. Although still used by some



vendors in non-mobile platform drives, CSS has inherent limitations which are addressed by load/unload technology. HGST was the first hard disk drive manufacturer to implement load/unload technology, and found the wear durability benefits proven in early large hard drives incorporating the technology worthy of further research and development efforts. These activities gave rise to enhancements in the mechanics of load/unload, as well as lead to innovations in other areas of hard drive design. Today's load/unload implementation relies on a ramp mechanism which provides numerous

benefits including greater durability, more efficient power utilization and superior shock resistance.

Stiction

When not in use, the sliders in CSS-based drives rest on the disk surface. One of the most significant drawbacks to this direct physical head-media contact is the exposure to stiction where two smooth surfaces, the disk and slider in this case, adhere to each other making their separation extremely difficult without causing significant damage to the components.

To avoid the negative affects of stiction, the surfaces of the disk media in CSS-based drives are roughened in a precision manufacturing process called texturing. Texturing can be uniformly applied over the disk surface or centralized in the inner diameter of the media specifically dedicated to the starting and stopping of the heads, known as the start/stop zone. While such texturing techniques have been satisfactory in the past, the desire to pack more data into the same surface area requires using disk media with ultra-smooth surfaces.

Due to the stiction issue, however, the usage of extremely smooth media is difficult in CSS-based hard drive designs. Limiting texturing to the landing zone area produces other complications, such as the challenge of ensuring the Read/Write heads fly high enough over the texture bumps to minimize contact upon their ascent and descent. The inability to clear the bumps could result in significantly degraded reliability of the head/disk interface.

The mechanics of load/unload

Ramp load/unload technology involves a mechanism which moves the sliders off the disks prior to power-down, and safely positions them onto a cam-like structure. The cam is equipped with a shallow ramp on the side closest to the disk, giving ramp load/unload its name. During a power-on sequence, the Read/Write heads are loaded by moving the sliders off the ramp, and over the disk surfaces when the disks reach the appropriate rotational speed. The air current from the rotating disks acts like

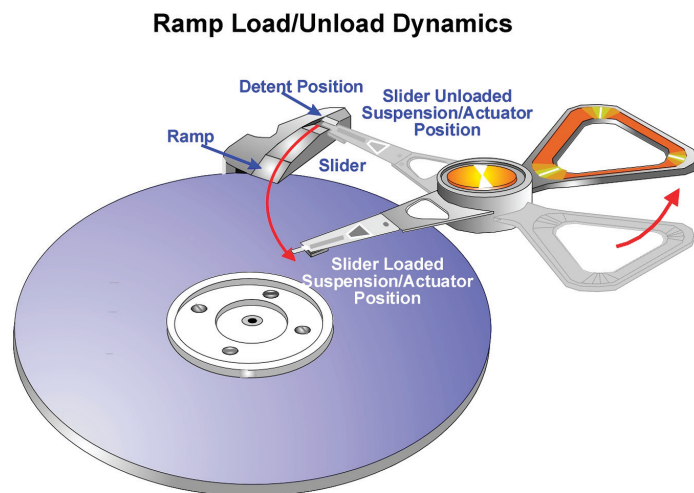


Figure 1. Ramp load/unload dynamics

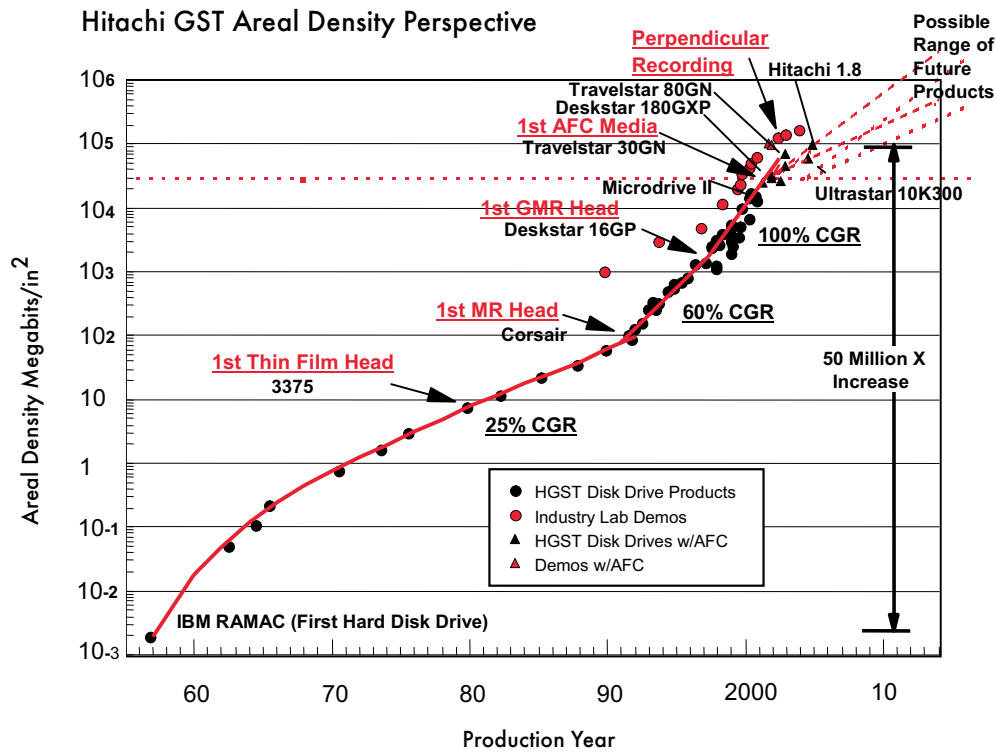


Figure 2. Areal density growth over time

a cushion between the sliders and disks, keeping the two surfaces separated by a designed distance, called the flying height.

Higher storage capacities

By physically parking the heads off the disk surface, the problem of stiction is avoided, and the usage of very smooth recording media is enabled. Smoother disk surfaces also allow for closer head fly heights, contributing to improved signal to noise ratio during read and write operations. The combination of load/unload technology and the advent of giant magnetoresistive (GMR) heads made possible significant increases to the track and bit densities on the recording media.

The product of bits per inch multiplied by tracks per inch is commonly referred to as areal density, which today exceeds 80 Gbits per square inch in HGST Travelstar® drives, 92 Gbits per square inch in the Deskstar® T7K250, 78 Gbits per square inch in the Microdrive® 3K6, and 61 Gbits per square inch in the Ultrastar® 10K300 server drive. HGST's early use of these technologies accelerated the areal densities offered in the company's line of hard drives, outpacing the storage industry for many years.

Greater durability

During the start-up cycle, the sliders in CSS-based drives rest directly on the disk surface until air generated by the spinning disks allow the aerodynamically designed heads to lift off and fly above the disk platter at the designated flying height. Direct contact of the sliders to the disk surfaces in CSS-based designs subject these components to wear. This can compromise the service life of the drive, especially in applications where large numbers of start/stop operations are performed. Systems which power off the drive between

data accesses to maximize battery life are examples of such applications.

By eliminating direct contact between the heads and disks, load/unload hard drive designs are exposed to less wear and usually tolerate more start/stop cycles than their CSS counterparts. This has been demonstrated in HGST Travelstar drives which carry a 300,000 cycle specification and have successfully passed long-term endurance testing beyond 1,000,000 load/unload cycles—both well beyond the limits of hard drives designed with CSS. Overall drive reliability is significantly improved due to the prevention of start-up wear, head-to-disk interaction, and decreased exposure to heat through more efficient power utilization techniques used in ramp load/unload drives.

Lower power consumption

The ability to reliably increase the number of start/stop cycles gave rise to new innovations in power utilization. HGST's early usage of load/unload in small form factor drives including the Travelstar 2.5- and 1.8-inch series, and Microdrive, enabled the company to pioneer various power management modes, referred to as Adaptive Battery Life Extender™ (ABLE).

Parking the heads on the ramp, or “unloading” the heads, became the foundation of advanced power management modes including Active Idle, Performance Idle and Low Power Idle, implemented under Enhanced Adaptive Battery Life Extender™ (Enhanced ABLE). Usage of Enhanced ABLE can provide as much as a 20 percent reduction in power consumption at the drive level.

In HGST Ultrastar server drives, load/unload technology enabled the implementation of intelligent Power and Standby modes which are triggered by Read and Write operation inactivity. These modes significantly decrease power usage by Ultrastar drives resulting in reduced energy costs, extended drive service life, and a more environmentally friendly high-end storage solution. Ultrastar products are the only server-class hard drives that utilize ramp load/unload to park the heads, greatly reducing drive failures caused by improper handling during system integration in addition to the energy saving benefits derived from load/unload technology.

Enhanced shock tolerance

Ramp load/unload technology greatly minimizes the effects of shock damage by safeguarding against head/disk contacts. This is especially important in small-form-factor drives which are more exposed to shock events due to their portability. Several methods are used in HGST drives to ensure the heads never contact the disk surface.

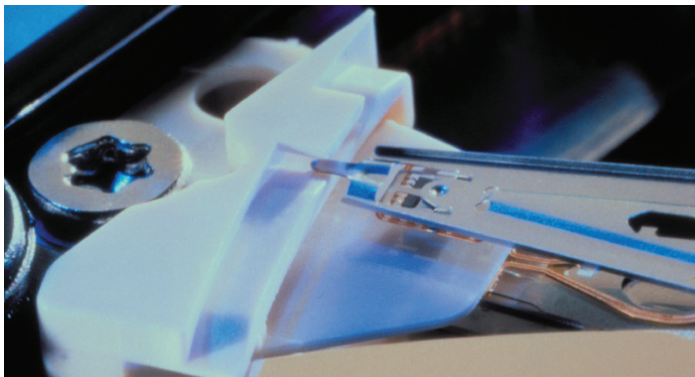


Figure 3. Read/Write heads parked on the ramp using lift tab technology (HGST patent US 6,288,876)

Configured in the aerodynamic design of the heads in a ramp load/unload drive is a lift tab on each head suspension assembly, (see Figure 3). The lift tab fits into a groove in the ramp which guides the heads into the park position.

In the event of power loss to the drive, HGST invented a fault-tolerant retract system to move the heads to the park position by extracting energy generated from the spinning disks through

a high-efficiency retract circuit. This circuit directs the current from the spindle motor back-EMF to the actuator assembly, enabling the sliders to move off the disk area to the ramp in a controlled fashion during an unexpected power down situation. In February, 2000, HGST was awarded the patent to this invention (US 6,025,968), which is used in all HGST drives and any hard drive incorporating load/unload technology.

HGST's technology leadership in the usage of load/unload is further reflected in the shock tolerance supported by its products. The 2.5-inch Travelstar drives are the most rugged mobile drives in the industry. All drives in the Travelstar 7K100, 5K100 and 4K40 series withstand 1,000 Gs of non-operating shock. The 6GB HGST Microdrive 3K6 takes this further, with the ability to withstand 2,000 Gs of non-operating shock.

Benefits of Load/Unload Technology

Improved reliability	»»	Eliminates Stiction No CSS wear—longer flying lifetime Greater shock resistance Lower heat dissipation
Increased areal density	»»	Thinner overcoats Smoother disks—lower flying height
Reduced power consumption	»»	Enhanced power management modes More start/stop cycles for low power applications

Figure 4. The many benefits of load/unload technology

Legacy of usage

Introduced in 1956, the RAMAC (Random Access Method of Accounting and Control) drive was the world's first magnetic hard disk drive. With RAMAC, the company now called HGST initiated many of the principal product technologies still used by the storage industry. This includes load/unload, which was implemented in the RAMAC drive using a pneumatic mechanism. The product's success led to further drive generations and enhancements to the load/unload mechanism.

Due to its anti-stiction properties and elimination of wear durability problems frequently seen in CSS-based drives, load/unload was selected as the start/stop solution in the enterprise-class Model 3390 drive which used 10.5-inch disks. The product entered the market in 1991 and holds the record for the lowest failure rate in the hard disk industry. Today, the 3390 can still be found operating in many customers' server installations. Its reliability is largely attributed to its load/unload-based design.

Ramp load/unload affords additional benefits of superior shock durability as a result of the protection against direct head-disk contact. The size and weight of small-form-factor drives make them particularly suitable to portable applications, greatly increasing their exposure to shock. In the 2.5-inch hard drive arena, the Travelstar 4GT and Travelstar 3GN were first to adopt ramp load/unload technology. The revolutionary 1-inch, 340MB Microdrive soon followed in 1998, incorporating a miniaturized ramp load/unload structure as an intrinsic part of its innovative design.

The integration of ramp load/unload into 3.5-inch hard disk drives began in 2000 with HGST's launch of the Deskstar 75GXP, a 76.8GB desktop drive, and the enterprise-class Ultrastar 36ZX and 18LZX drives. Since that

time, over five generations of HGST Deskstar drives have been designed using ramp load/unload, which is now the start/stop method used in all HGST drives.

An enabling technology

Ramp load/unload has proven to be an important breakthrough technology. In addition to the advantages of increasing areal density and overall storage capacity, load/unload provides significant benefits in lowering power consumption, improving shock robustness, and increasing drive reliability. All of these attributes are critical parameters in the design of hard disk drives.

To the system integrator, the energy savings and increased reliability provided by hard drives incorporating ramp load/unload technology can be invaluable in the reduction of overall maintenance costs and extended service life of the drive. Ramp load/unload is especially suited to small disk drives that are typically used in applications requiring frequent power on and power off cycling such as handheld devices, consumer electronics and battery operated systems. As HGST learned early on, load/unload provides tangible benefits for the disk drive as well as the end products which incorporate drives designed with the technology.



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One GB is equal to one billion bytes when referring to hard drive capacity. Accessible capacity will vary depending on the operating environment and formatting.

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