

Product Analysis

Hard Disk Drive



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1 Introduction

This Product Analysis defines what a Hard Disk Drive (HDD) is in relation to Hitachi Global Technologies (HGT) standards. This Product Analysis describes the technical aspects and the hardware challenges that Hitachi Global Technologies (HGT) overcomes in reliably designing and bringing large capacity HDDs to market. HDD Reliability and Capacity are its strongest selling points, and fortuitously, are HGT's strengths that must be exploited in bringing HDDs to market. A brief background, HDD definition, HDD significance, principles of operation, design challenges, and a look to the future round out this report.

This competitive but mature market with critical applications demands two seemingly opposite requirements – increased performance and leading edge technology combined with conservative reliability. HGT must address these opposing technical requirements to succeed in bringing the 5K 100 HDD series to market. See Appendix for 5K 100 specifications.

i Background

Hitachi Global Technologies is in an enviable world position. It successfully built on IBM's 48-year legacy of reliability and innovation in the HDD market – especially large capacity HDDs. Reliable HDDs hastened the introduction of real time online applications, such as airline reservation systems and online banking. HDDs made the previous storage media such as paper punched cards and tapes obsolete.

Competitors producing similar products include Maxtor, Fujitsu, Seagate, Western Digital and Winchester.

HGT is a world leader in hard disk drive technology and continues its evolutionary lead with the 3.5inch DeskStar 400 GB Storage King, where 3.5 inches is the disk diameter.

The laptop and music storage module market is to be addressed with the new 2.5 inch TravelStar 5K 100 series that maxes out at 100GB. See Figure 1 for internal photograph.



Figure 1. TravelStar 5K 100 HDD

2 Significance

HDDs are a crucial part of Information Technology (IT). HDDs, through changes in a magnetic field, semi-permanently store information, data, files, and operating systems that computers, servers, digital switches and devices such as music players and games players create and need in order to function reliably and respond quickly.

Individuals and companies replace their computers on an average of three to four years, so increases in capacity, speed and reliability continually drive HDD design in this very large, competitive and essential market.

Computers and their storage systems define how the world's economy functions, allow the world's largest communications environment, the Internet to exist, and to a lesser extent, define how society interacts with and entertains itself.

The only current digital storage medium that could be classed as permanent would be DVDs or CDs, which actually etch the information on plastic disks. With data being stored in such an ephemeral state, reliable HDDs are absolutely fundamental to the IT environment.

HDD failures can be catastrophic in the sense that years of information that could have immeasurable value can be lost or a real time essential function such as air traffic control can cease to function. Therefore the stakes are high for this product.

3 Definition

Classified as hardware, a hard disk drive is a small, electronically controlled, mechanical device that has a spinning disk stack and a set of read/write magnetic recording heads that position swiftly and accurately over the magnetic disk surfaces by an electromagnetic actuator. Data is read from and written to the spinning disk as the read-write heads float over it. Advanced HDD designs such as the TravelStar 5K 80 and 5K 100 series, the read-write heads, using "Load & Unload" technology, never touch the disk. See Figure 3. HDDs also have software and electronic components that control the position of the read-write heads and instruct the drive to either read or write information.



Figure 2. Hard Disk Drive Outline

ii Analogy

Imagine a very smart and fast record player/turntable – the vinyl Long Play (LP) record player that is coming back into vogue with audiophiles and never left vogue with the Urban Music DJs.

Except this record player is not limited to the swing arm following the one long eccentric track pressed into the LP disk for analogue for non-digital or analogue sound playback. As an aside, one can actually hear the sound as the needle sits in the track of that rotating LP. The electronics in this case convert the mechanical movement of the needle to an electric signal that goes to the amplifier and the speakers.

Imagine this swing arm apparently moving on its own, dropping down to pick up some shards of sound or record shards of sound again and again on that rotating disk – all without physically touching the LP disk. With playback and recording virtually un-interrupted to the ear. That is sort of how a HDD operates.

iii Basic Principles – How a HDD Works

Data in digital form is "written" on the disk or "read" from the disk by the read-write head changing or sensing the disk's magnetic coating's magnetic field alignment of a bit on a track, in a given sector. See figure 3. The smallest unit of data is a bit, which is represented by a zero or a one. Eight bits form a byte. A sector on the disk holds 512 bytes. The drive can have many sectors depending on its capacity. "Words" can be anywhere from one to eight bytes or more – depending on the computer. This information is not stored serially or in consecutive tracks, but randomly on the disk to minimize seek time and read-write time.

The disk is organized in concentric tracks that are then broken down into sectors. Software governs how the tracks and sectors are laid down on the disk and how each track and sector is addressed and how the information placed in a given track is addressed and placed. The models for this are beyond the scope of this analysis. See Figure 4.

The speed in which data is read from or written to the disk depends on the speed that the disk rotates, the speed in which the heads seek or find the correct place to read or write, and how scattered on the disk the information is distributed. The faster the disk rotates, usually the faster the response time. Software determines how much information can flow through the data bus from the HDD to the computer.

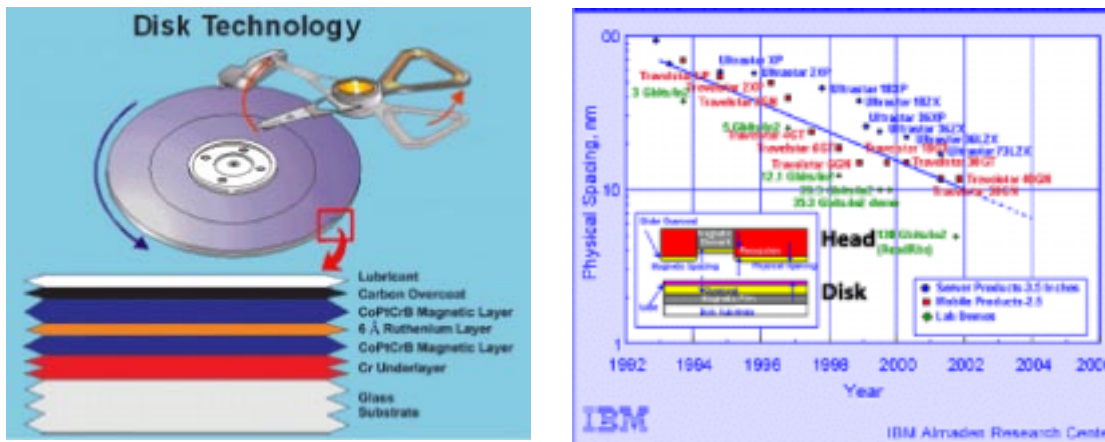
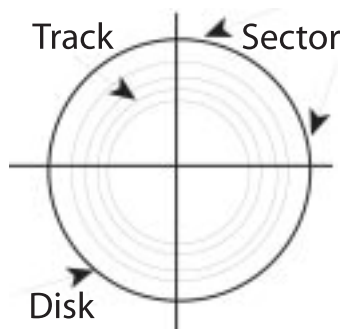


Figure 3. Disk & Read-Write Head Relationship Head – Disk Space in Nano-Meters



0001100010001000010001001100010000
 Track diagram with changes in magnetic field represented by the 1s and 0s.

Figure 4. Disk Data Layout and Track Schematic – MTB sketches

4 Design Challenges

Moore’s Law states that performance doubles every 18 months – whether it is larger, smaller, faster, less power. Consequently, HDD manufacturers are under pressure to produce disk drives that address four primary enabling factors: larger sizes in terms of capacity, greater power efficiency to lengthen battery life, retrieve or store information faster, and greater reliability with longer Mean Time Between Failure (MTBF) – all in the same size package. In 2000, a laptop HDD had a disk drive capacity of 12 GB. In 2004, capacities have reached 100GB. See Figure 3 for the head to disk space reduction trend.

The ability to make tracks smaller and smaller along with the ability to reduce the distance between the read-write head and the disk brings increased data storage densities up to the current TravelStar 5K 100 areal density of 86 Gbits/sq. inch. Increased rotational disk speeds and software improvements can realize a maximum data transfer rate of 150 MegaBytes per second using the 100 Ultra DMA mode-5 interface.

iv HDD Main Components

This performance increase is achieved by designing the read-write heads to read data on tracks that are laid closer and closer together on a disk that spins faster. This requires design and manufacturing technologies that can design very flat disk surfaces coated very evenly with the magnetic material so changing the magnetic alignment or re-alignment of a bit does not affect more than one track or more than one bit on the disk. This also requires machining and assembly techniques and operating conditions that work in the micron and even in the angstrom range. Parts of

the magnetic coating of current HDDs are but several angstroms thick – several atoms thick. A human hair falling on an operating HDD would bring it to a crashing halt.

Figure 5 illustrates the major components and the potential mechanical and performance bottlenecks any HDD design must address. Hard Disk Drive main components are listed below.

- Disk and its magnetic substrate – magnetic physics is the limitation here – obviated with Pixie Dust Technology
- Read-Write head -
- Swing arm and suspension interconnect – addressed with Load & Unload technology
- AE electronics
- Flex Cable
- Electronic components – Disk electronic board, chips on the board, AE Electronics – fewer chips and parts in the electronics reduce probability for failure.

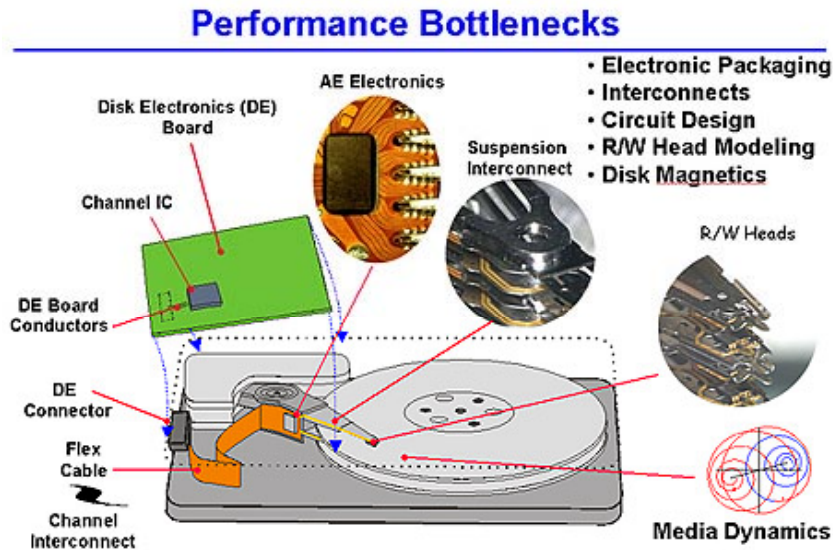


Figure 5. Major Components that Affect HDD Performance

Some HDD designs use Contact Start/Stop (CSS) head management where the read-write head is in contact with the surface of the media when at rest and is in sliding contact with the media when starting and stopping the disk spindle. The head flies or floats above the disk only when the disk spindle speed is above several hundred RPM. However, the risk of surface disk damage with its attendant loss of data is much higher than with HGT's touchless Load & Unload head management. Load & Unload Head management actually parks the read-write head on a ramp- physically away from the disk when it is not actually writing or reading data. See Figure 6.

v HDD Hazards

While relatively robust, HDDs are sensitive to mechanical shock such as being dropped, vibration from the environment found on aircraft, trains, buses or industrial installations. HDDs are sensitive to internal wear over time. Disk spindle and read-write head arm bearings can wear, which allows disk and head alignment to exceed the submicron tolerances required for reliable writing and reading of data stored on the disk.

HDDs are very sensitive to electrical conditions such as static discharge if they are handled without being properly grounded. Variations in the disk's magnetic coatings as well as manufacturing variations in the read write head can affect the integrity of stored data. Electronic components such as the circuit board, and its components can fail.

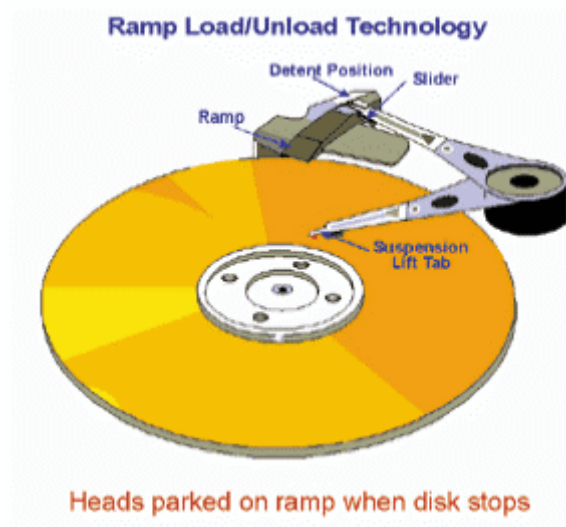


Figure 6. Read-Write Head in use / parked

vi Technical Solutions

HGT's materials and component design and manufacturing processes minimize these risks using Load & Unload read-write head management technology, Fluid bearing actuator motors to drive the swing arm back and forth along with fewer chips in the controlling electronics. Fewer chips means fewer parts that could conceivably fail.

HGT through IBM's legacy developed Pixie Dust or AFC technology that allows for very small track widths. An AntiFerromagnetically Coupled (AFC) media is a multi-layer structure in which two magnetic layers are separated by an extraordinarily thin – just three atoms thick — layer of the nonmagnetic metal, ruthenium. This precise thickness of the ruthenium allows the magnetization in each of the magnetic layers to be coupled in opposite directions – anti-parallel. This eliminates magnetic charge orientations from bleeding into adjacent tracks. See Figure 7.

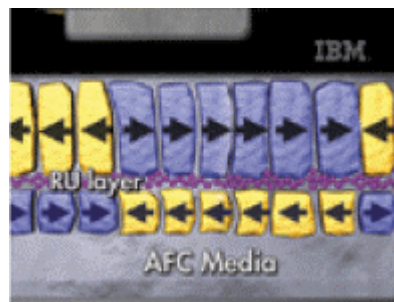


Fig. 7 Pixie Dust Disk Magnet coat

5 Operating Scenario

The HDD – on command from the computer – reads or writes data from the disk and delivers it to the CPU for processing, whether the computer is powering up and going through its bootstrap where the operating system and its drivers that allow the HDD, CPU, Display and input devices such as keyboard and mouse to communicate with it need to be loaded or for an application needing to retrieve or send data to the disk.

A signal goes to the HDD with a request for data. Internal addressing systems direct the read-write head to the correct sector(s) on the spinning disk. The data is either written to the disk or is non-destructively read from the disk.

6 Conclusion

Hitachi Global Technology can lever its current HDD technology- to successfully design and bring to market the largest capacity reliable laptop disk drive, 5K 100.

Refinements in reliability or MTBF through Load & Unload technology and Pixie Dust coatings along with software refinements to increase data throughput will maintain HGT's laptop HDD technology and pave the way for further evolutionary or even revolutionary advances in HDD design and manufacture.

References

All of the facts stated in this report were taken from the Hitachi Global Technology on line library and the following sources. HGT also used legacy IBM HDD documents and research.
All URLs functional as of 18 Oct 2004.

Hitachi Global Technology

<http://www.hitachigst.com>

The research and technology library link.

http://www.hitachigst.com/portal/sitehgst?epi_menuItemID=fcb84918655f65f694d64eb7bac4f0a0&epi_menuItemID=f3422d6ea3268f8d5f5a530560e4f0a0&epi_baseMenuID=22f0deefa8f3967dafa0466460e4f0a0

The various papers came from this portal

Others

<http://www.waea.org/tech/techdocs/harddisk.pdf>

Robert G. Kaseta. **Ruggedized Disk Drives for Commercial Airborne Computer Systems**. Vice President, Engineering Miltope Corporation.

Graphics

Unless stated otherwise, all illustrations came from the Hitachi research and IBM legacy documents. The Report Cover used HGT's diagram in the computer screen.