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Whitney Technology:
The Second Generation Winchester

Amcodyne

Abstract

Whitney is the name commonly associated with the second-generation Winchester technology employed in the IBM 3370/3380 mainframe disk drives, first announced in 1979 and 1980. These products feature advancements in head suspension/low-mass slider, thin-film head technology and read/write encoding techniques. While the focus of mainframe disk technology is essentially to increase gross storage capacity and data transfer rates to accommodate higher-speed processors, the tradeoffs in microcomputer and microcomputer implementations are driven more by packaging, reliability and producibility considerations. Whitney technology fulfills these basic OEM requirements, and, in addition, provides substantial latitude for future capacity growth without system re-design.

Introduction

Areal recording density of rigid disk drives has increased 500-fold in the past 20 years, from 26,000 bits per square inch on the IBM 1301 to 12 million on the IBM 3380, the industry's most technologically advanced disk drive in high-volume production.

Improvements in areal density have been accomplished by increasing radial density (tracks-per-inch) and linear density (bits-per-inch). The evolution of radial and linear densities have required accompanying innovations in the mechanical design of head/disk assemblies, recording heads, media, encoding methods, and servo systems to realize read/write accuracy, improved seek time, throughput, and subsystem reliability.

The introduction of Winchester technology in 1973 on the IBM 3340 — followed three years later by the enhanced 3350 — combined a new HDA concept, reduced head flying height and the ushering-in of clean-room production. Winchester technology now dominates rigid disk drive design at all levels of computer system performance, from microcomputer to mainframe. The introduction of major new innovations in 1979 on the IBM 3370, followed shortly thereafter by the 3380, represents a significant maturing of Winchester performance as seen in the following table:

	Whitney*	Winchester**
Bits-per-inch	15,000	6,425
Track-per-inch	800	480
Areal density (b/in^2)	12,000,000	3,084,000
MBytes/spindle	1,260	317
Head flying height	10 μ in	18 μ in
Avg. Access Time	16 ms	25 ms
Transfer Rate	3 MB/sec	1.198 MB/sec

* IBM Model 3380
**IBM Model 3350

Head Suspension/Low Mass Slider

The system integrator and user of a disk subsystem will see the benefits of an improved head suspension in terms of read/write signal reliability, a function of the stability of the read/write platform. Reliability is advanced by:

- improving flying height stability;
- improving tracking accuracy (higher band-width servo systems); and
- reducing interfering signals from adjacent tracks, which in turn yield a higher signal-to-noise ratio.

The Whitney suspension is the most stable read/write platform in the industry. The purpose of the suspension is to hold the head rigidly in the plane of the disk over the track, while allowing it to follow variations in the surface topography, therefore maintaining consistent flying height.

Whitney stability and compliance are made possible by the geometry and reduced mass of the suspension assembly to which the recording transducer is attached (Figure 1). The greater stiffness of the air bearing and the suspension equates to fewer perturbations in head-to-disk spacing and track following.

It will be noted in Figure 1 that the Winchester side rails, which extend from the arm to the slider area, are about 7/8 of an inch long. By contrast, the Whitney side rails integrated into the tip of the load beam are about one-eighth of an inch. Since the stiffness of the beam varies with the cube of its length (and only directly with the lateral dimension), the Whitney beam is 350 times stiffer than that of the Winchester.

The Whitney load beam is similar in size and function to its predecessor. By eliminating the Winchester wings and streamlining the load beam, torsional resonance that plagues every Winchester suspension is also eliminated.

The Whitney load buttons are similarly located in the middle of the head above the center of pressure. Pitch and roll gimballing is achieved in the same manner—from deflection of the side beams. However, the Whitney suspension does not require the frame around the head, thus reducing the associated parasitic mass.

Air bearing stiffness, by rule of thumb, is the pre-load divided by the flying height. Given the same spacing, the Whitney pre-load is 15 grams versus the Winchester's 9.5 grams, yielding an approximate 50 percent improvement in stiffness. Reducing the flying height in half—as accomplished by the 3380 versus the 3350—increases that improvement to 300 percent.

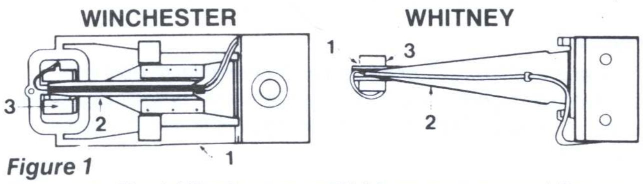

Figure 1
Elements of both Winchester and Whitney arm assemblies are compared in size and geometry: Side rails (1), load beam (2) and slider (3).

Stability of the flying height can be affected by mechanical resonances from shock, vibration and even disk rotation. On top of resonances encountered in the suspension are natural frequencies occurring from bounce (as the slider approaches the disk) and the pitching/rolling of the slider on its air bearing.

The Whitney low-mass slider (about 70 percent of the Winchester), combined with the smaller physical size of the suspension and a smaller air bearing, resist bounce, pitch and roll. When looking at mechanical vibrations of less than 10 KHz—the area where stability of the servo loop can be affected—the Winchester suspension has approximately 30, compared to less than 10 for the Whitney. Therefore, there are significantly fewer frequencies excited that could cause excursions by a Whitney head flying over a disk. The stable mechanics also create a higher band-width for the servo system, which enables more precise track following.

Thin-film Transducer

Winchester heads are made of a monolithic ferrite slider, which forms half of the head magnetic circuit. The core that forms the other half of the magnetic circuit is glass-bonded on the back of the slider and is hand-wound with a conductor. The IBM 3340—the first Winchester drive—introduced the first successful batch fabrication of heads, although in quantities of less than 20 per batch. The 3340 was further an innovation in head production in that it reduced the number of components from more than a dozen (as in the 3330 head) to two.

Among the Whitney innovations on the 3370/3380 disk drives is the first implementation of thin-film transducer heads, which allows the read/write transducer to be directly fabricated on the slider by using semiconductor deposition processes. It successfully introduced fabrication in batches of up to 500.

Thin-film heads have been in development for more than 10 years, but only recently has the yield-per-wafer begun to approach a level of economic viability. As processes are further refined, substantial cost advantages will accrue from mass production, as indicated by reported yield improvements from 15 to 60 percent in the past two years.

The most notable performance characteristic is a 15 to 20 percent improvement in resolution, which will enable increases in linear density beyond that possible with ferrite heads. A vertical side-wall construction, as constructed with the angled side wall of monolithic Winchester heads, results in less fringing with adjacent tracks during read operations and a better signal-to-noise ratio. A significant bandwidth improvement can be achieved over ferrite heads by virtue of materials and construction techniques.

The finite pole tip geometry of the Whitney head (Figure 2) enables magnetic tuning of the head to bit cell size, which provides the improved resolution over Winchester semi-infinite poles.

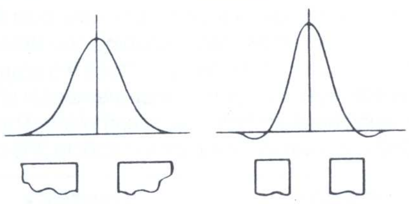

Figure 2

Conventional ferrite transducers with semi-infinite pole tips produce the signal wave form at left. A higher amplitude signal (right), is produced by the finite-length pole tip structure of a thin film head.

Encoding Techniques

Considerable work has been done in the past 10 years on encoding techniques, resulting in a class of codes known as run length limited code (RLLC). The name literally means encoding techniques that exhibit a limited number of non-transition lengths, which permit self-clocking. The technique enables optimization of read/write encoding to a particular application. Given a particular media, for example, transducer and bit density parameters can be predictably manipulated to achieve desired results.

1000000010000000100000001001001001

Figure 3

Two-of-seven run length limited code is illustrated by the minimum and maximum number of non-transition locations (represented by 0), between transitions (represented by 1).

The Whitney RLLC is designated "2 of 7." The number 2 refers to the minimum number of consecutive clock cells (½ bit cells) without a transition, and the 7 represents the maximum number of consecutive clock cells without a transition (Figure 3). The advantages of Whitney RLLC versus the Winchester technique include:

- a 50 percent increase in bits-per-inch with respect to flux changes-per-inch;
- limited bandwidth due to run-length limitations;
- self-clocking; and
- optimization for use on present head and disk technologies.

Self-clocking is significant in that it enables a phase-lock-loop synchronized to the data to determine bit lengths. By defining the minimum and maximum ratio of wave lengths and by defining the detection window that is suitable, it is possible to define a ratio of BPI to FCPI. The Whitney compaction ratio is 1.5 to 1 for improved linear density. The limited bandwidth of 8 to 3 preserves signal fidelity.

Whitney Technology at Amcodyne

Amcodyne Inc. commenced development in 1981 of an 8-inch rigid disk drive that would bring the benefits of Whitney mainframe technology to OEM minicomputer and high-performance microcomputer systems.

The principal difference in implementation on the Amcodyne Arapahoe 7110 subsystem is the use of a mini-composite ferrite head, rather than a thin-film transducer. This decision was based on cost and availability from multiple sources—two essential criteria in designing for the OEM market. The mini-composite head features a reduced mass and a nearly vertical side wall with approximately 85 percent of the efficiency of thin-film transducers. It also has superior overwrite characteristics.

The Arapahoe 7110 has a track density of 555 TPI and a bit density of 10,859 BPI, to yield an areal density of 6.02 million bits per square inch, or about 50 percent of the IBM 3380 areal density.

The Arapahoe 7110 is a fixed/removable cartridge drive with a total capacity of 50 megabytes. The removable cartridge concept, while an ideal solution to nagging industry concerns with data backup, off-line storage and program loading, is far more difficult to implement than a fixed-only drive. It is, at this time, a product driven by demonstrable reliability, a situation that is particularly suitable to the Whitney innovations.

Future Whitney products will be influenced by developments in head and media technology. Even without these benefits, however, system integrators are assured of a considerable margin for growth.

Amcodyne Monograph No. 1

Amcodyne Inc.
1301 South Sunset Street
Longmont, Colorado 80501
(303) 772-2601

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