The 5.25-inch fixed/removable disk drive

by DON M. MINAMI

DMA Systems Corporation
Santa Barbara, California

ABSTRACT

The fixed/removable 5.25-inch Winchester drive provides combined computer peripher al support functions, such as mass storage, input/output, and backup. The 13.5-MByte total capacity (6.75 MBytes fixed/6.75 MBytes removable) is packaged in a unit about the size of a shoebox.

Reliability has been the major factor in determining the design parameters of the fixed/removable drive. Not only has Winchester reliability been enhanced, but preventive maintenance has been eliminated.
INTRODUCTION

Reliable mass storage at a relatively low cost is the driving force behind the trend toward increased use of Winchester disk technology for small computer systems. Although the conventional Winchester drive offers high reliability due to its nonremovable media, it requires some form of data file back-up. One solution is to use a tape drive for backup; this allows adequate backup storage capacity, but it is too slow and not form-factoried for many small computer systems. Another solution is to use a flexible disk drive, but it does not provide sufficient mass-storage capacity without resorting to multiple diskettes.

A better solution is a Winchester disk drive for both fixed and removable media in a single unit that provides mass storage, input/output, and backup. The 5.25-inch Micro-Magnum 5/5 (see Figure 1) from DMA Systems is the first such drive with a fixed disk and a removable disk cartridge built to the proposed ANSI standard. The Micro-Magnum 5/5 offers significant reliability and performance advantages which include the following:

1. No preventive maintenance or head alignment required
2. Heads retracted from the media surface, thus preventing damage
3. The necessity of external backup devices and their controllers is eliminated
4. Reduced space and power requirements
5. Faster backup time because of a higher disk transfer rate
6. Reduced component count
7. Reduced overall system cost

The origin of the Micro-Magnum 5/5 and the product design specifications were derived from a market survey. This survey included inputs from system manufacturers, system integrators, component suppliers, and computer industry consultants. The result of this survey was a product specification which emphasized reliability in terms of product life, data integrity, data interchange, and freedom from preventive maintenance.

GENERAL SPECIFICATIONS

The Micro-Magnum 5/5 is designed with 6.75 MBytes (5.0 formatted) fixed and 6.75 MBytes (5.0 formatted) removable. The drive uses an ANSI-proposed 5.25-inch removable disk cartridge (see Figure 2) with 5.0 MBytes of formatted data. The front panel face is 3.25 inches high by 5.75 inches wide, which is typical of 5.25-inch Winchester drives.

The 5 MBytes per disk formats 306 tracks with 33 sectors...
(one spare sector) and 256-byte sectors on each surface. The recording density is 8600 fci using MFM encoding, and the track density is 450 tpi.

**TRACK FOLLOWING**

Accurate and repeatable positioning of the read/write heads is a necessity in the fixed/removable drive in order to maintain data interchangeability. The primary complication is the removable cartridge being used as a means for data interchange and transportability. The drive, in conjunction with the disk cartridge, must allow for mistracking errors, cartridge registration errors, temperature gradients, spindle runout, and head-track width tolerances. This mechanical error budget requires a track-following system which will compensate for these variations. The elimination of precise head alignment is also as important; the market survey indicated that any such field maintenance procedures would not be tolerated.

To overcome the errors due to thermal expansion, the problems of cartridge interchange, and the elimination of field maintenance, embedded servo positioning was selected for the Micro-Magnum 5/5. Embedded servo data (see Figure 3) is prerecorded during the manufacturing of the drive and the cartridge, and it is contained in the 26 bytes at the start of each sector. The embedded servo format has been submitted to ANSI for standardization. (A copy of the proposed servo format can be obtained by contacting DMA Systems or ANSI.)

![Figure 3—Embedded servo data](image)

Embedded servo positioning is a two-step process. First, course positioning allows the proper track to be located; second, the fine positioning locates the read/write over the center of the desired track. As the desired track is being sought, the course-positioning process is activated. The course-positioning process uses a Gray code for each track number and is prerecorded as part of a 26-byte servo format. As the desired track is approached, within half a track, fine positioning takes over. Prerecorded signal segments A and B (see Figure 3) define the fine-positioning servo bursts. The edges of A and B are along the centerline of the tracks, so that a head centered exactly on a track will read equal amplitudes from both segments. If the head is off-center, one amplitude will read higher and the other, lower. The difference is detected and used as an error signal to drive a linear motor positioner to seek a zero error to maintain the proper track centerline position.

**LINEAR MOTOR**

The linear motor, in conjunction with the embedded servo track-following system, provides not only fast access time (40 msec average) but also reliability. Figure 4 shows the Micro-Magnum 5/5 linear motor positioner assembly.

![Figure 4—Carriage head and linear motor](image)

The reliability features of the linear motor positioner are the following:

1. The heads are allowed to be fully retracted off the disk surface and latched into position inside the drive.
2. Contamination control is improved due to the smaller cartridge and drive-door openings.
3. Head gaps move in a radial line, giving the best possible tolerance for cartridge interchange.
4. The structural resonance is better controlled.
5. Manufacturing of the head-carriage assembly is simplified.

**HEAD-MEDIA CONTACT**

Two problems can result from head-media contact; the head and/or the media surface can be damaged. Therefore, optimal data reliability can only be obtained by making it impossible for the head to ever make contact with the media. In the Micro-Magnum drive, the heads are never allowed to make contact with the disk. This is achieved by a patented head design (see Figure 5) which allows a Winchester air bearing to be loaded dynamically onto a spinning disk. (Forty-thousand load/unloads have been successfully completed with no damage to head or media.) The heads are also retracted completely off the media when the drive is shut down.

Reliability is significantly enhanced using a dynamic load/unload head design. Avoided are reliability compromises that exist with typical Winchester drives, which allow heads to
start/stop on the media. Eliminated problems are the following:

1. The heads wringing onto the media
2. The heads landing on top of contaminants even after a purge cycle
3. Heads and/or media being damaged during transit, during shipment, or when the system is transported from one desk top to another

CONTAMINATION CONTROL

In typical office environments, contaminants such as smoke and dust can cause severe damage to the heads and media. Contamination control is therefore a very important reliability consideration. Figure 6 shows the Micro-Magnum's high-capacity closed-loop air system.

The closed-loop air filtration system is designed so that an impeller generates sufficient system air flow to move a volume of air through the recirculating filter once per second. (The filter has a design life of five years, with no filter change required in a normal office environment.) During a purge cycle, this allows efficient removal of contaminants that may have been introduced during the cartridge insertion.

The Micro-Magnum 5/5 drive, as well as the cartridge, have self-sealing doors to preclude contaminants from entering their respective compartments. The drive has a door that seals the head port opening and keeps contaminants from entering the drive's clean air compartment. It is not necessary to take any precautionary measures to assure that the cartridge insertion door is secured and closed. The cartridge also has a door that closes the head opening and a clamp that secures the hub against the cartridge to prevent contaminants from entering the cartridge. Because the drive compartment is sealed and not accessible, the total volume of contamination that can enter the clean-air system is limited to the cartridge at the time of insertion.

ELECTRONIC SYSTEM

The electronic packaging of the Micro-Magnum 5/5 was no minor task, considering all the electronic functions that had to be housed in a 3.25-inch by 5.75-inch by 10.50-inch volume. Complicating the design was the necessary circuitry for the embedded servo and voice-coil positioner.

The Micro-Magnum's electronic block diagram is shown in Figure 7. A dual-microprocessor system was employed to conserve space and partition functions in order to make firmware design simpler. MPU1 is dedicated to the interface and status functions that include all controller input and output lines, front panel functions, safety checks, and fault algorithms. MPU2 receives embedded servo information from the servo decode circuit (LSI2). This serves the basic servo functions, such as track follow, seek, re-zero, load, and retracking of the heads.

To achieve the required packing density, two CMOS gate array custom IC's were developed. LS1, a 200-gate array, is used to control spindle servo. LSI2, a 500-gate array, is used to perform decoding of digital information in the embedded servo fields.

An all-important electronic function is the control of the write operation to prevent overwriting the embedded servo fields. Overwriting the embedded servo field could result in the loss of removable and/or fixed data. The Micro-Magnum 5/5 drive, therefore, has a series of hardware and software safety checks that are performed before a write operation is allowed. Hardware functions are gated directly to the write current enable function of the head read/write chip. Also, all the following conditions must be true simultaneously before the logic circuits allow write current to be enabled:

1. Spindle speed must be within 0.1%.
2. Heads and head circuits must be in a safe condition; i.e., no shorts or opens, only one head selected, MFM data being received.
3. All power supplied must be in tolerance.
4. Power must be safe, spindle must be on, write gate signals must be enabled on the interface, and the drive must be selected.
5. The previous embedded servo field must be decoded properly, including a correct sector/index field and clock-shift check code.
6. Servo system must indicate that the head is within the "on track" limits as determined from the fine position information.
7. A redundant spindle-speed check circuit must indicate that the spindle is within the allowed 0.5% of normal.
8. The write protect switch for the disk to be written must not be activated.

REDUNDANCY

There is always a possibility that data errors can occur during system operation. Therefore, the disk drive must have the capability to provide data redundancy and error correction in a manner that is transparent to the user. This can be achieved by providing spare sectors and alternate tracks on the disk, as well as data formats that allow the controller or host computer to provide user-transparent correction techniques.

In the Micro-Magnum 5/5, one spare sector per track and five spare tracks per surface are provided to replace those found to be defective. This allows 4.5% media redundancy for the accommodation of defects. The defect-tolerant system is further enhanced by provisions for CRC (cyclic redundancy checking) and ECC (error-correction coding) in the data formats.

Error-correcting technology serves to verify header and data field accuracy, plus providing the capability for correction of errors. Most errors can be corrected by the combination of CRC and ECC techniques, and no data will be lost. This is accomplished by using an intelligent controller or the host computer in conjunction with the CRC and ECC formats of the Micro-Magnum system.

Defective track correction can be handled in two ways by the intelligent controller of host computer. These are:

1. After a seek to a defective track has been completed, the Bad Track Flag in the first sector tells the controller that an alternate track has been assigned. The data field information is then read and a new seek is issued to the assigned alternate.
2. Alternatively, the alternate track catalog can be read and stored by the controller upon the initial spindle-up sequence after a cartridge is installed. If a seek to a bad track occurs, the controller automatically issues a seek to the assigned alternate track. The same algorithm can be implemented by the host computer.

"Hard" errors can usually be corrected to protect data, using the error-correction techniques. If a defect cannot be error-corrected, it should be mapped into the defective sector category and spared out by the appropriate method. If the sector is spared while it is still a correctable defect, no data will be lost.

When a new defect is spared and an alternate track is required, the alternate-track catalog must be updated along with the data field information on the bad track.

DATA TRANSPORTABILITY/INTERCHANGEABILITY

Use of a removable cartridge using embedded servo permits a reliable mass-storage system that is transportable and inter-
changeable with other similar systems. The disk cartridge has been accepted as a proposed ANSI standard for the mechanical configuration of the removable cartridge; this allows the mechanical standard to be used in all similar systems. However, no standard has yet been established for the data formats on the 5.25-inch fixed/removable Winchester drive. With the hope that a standard can be established that provides data file compatibility, the following information on the data formats for the Micro-Magnum 5/5 is presented.

Using MFM (modified frequency modulation) encoding, the disk is organized into tracks of 10,890 bytes each of unformatted capacity. Each track is divided into 33 sectors of 330 bytes each. When formatted, each sector contains 256 bytes of data, 48 bytes of format information, and 26 bytes of embedded servo information. Figure 8 shows the organization of each sector. It is detailed below:

1. **Embedded Servo Field**—Track and sector location information is embedded in 26 bytes.
2. **PLO (Phrase-Locked Oscillator) Sync**—Consists of 12 bytes of 000's transmitted for data separator synchronization.
3. **ID and Data Address Marks**—A 1-byte address mark, made unique by omitting the clock transition between bits 4 and 5, precedes both the ID and Data Addresses. The 1-byte, FE (hex), identifies the ID Address Mark; and the 1-byte, F8 (hex), identifies the Data Address Mark.
4. **Write Splice**—This byte is provided between the ID field and Data field PLO Sync to turn on the write current if data is to be recorded in the Data field.
5. **Data Pad**—To guarantee data integrity, a 1-byte pad is provided between the final ECC field and the speed buffer area.
6. **Speed Buffer**—A 5-byte buffer at the end of the sector accommodates spindle-speed variations up to ± 0.75%.
7. **Sector Interleave**—As recorded at the factory, a Sector Interleave factor of 4 is applied to the sector ID field. This sequence of sector ID fields is as follows: 0, 8, 16, 24, 1, 9, 17, 25, 2, 10, 18, 26, etc.
8. **CRC**—This 2-byte field is used to implement the CITT CRC polynomial, \((X^{16} + X^{12} + X^5 + 1)\), for error detection in both the ID and Data fields.
9. **ECC**—A 3-byte field reserved for appending an error correction code to both the ID and Data fields.

The three bytes associated with format information provide additional data:

10. **Cylinder/Head/Sector**—Provision is made to address up to 1024 cylinders, 8 heads, and 64 sectors. The head byte also contains the two MSBs of the 10-bit cylinder code and three 1-bit control flags listed in the following items (11 and 12).
11. **Write-Protect Sector Flag**—A ONE set in this bit location indicates to the controller that this sector is "write-protected" and cannot be overwritten by the host computer.
12. **Bad Sector/Bad Flag Track Flags**—These 1-bit flags alert the controller that either a bad sector or a bad track has been detected; this allows them to be replaced by space sectors or tracks.

**CONCLUSIONS**

By virtue of its relatively low cost, high data reliability, and small volume, the Micro-Magnum 5/5 5.25-inch Winchester disk drive is destined to be a widely used mass-storage device for small computer systems. The drive employs a number of proven, mature technologies that are integrated for the first time to provide a capability never before available. The only remaining consideration is the establishment of standard data formats that will allow universal interchangeability and transportability.