# Refining head design in high-density minifloppies

OTTO BUTSCH, Micro Peripherals, Inc.

*Advances in several parameters cope with the problems that surface when track density doubles*

There has been a significant evolution in the past year in the design of 5¼-in. floppy-disk drives. The number of tracks per inch has risen from the industry standard for minifloppies of 48 tpi to 96 or 100 tpi. Doubling track density doubles capacity but also leads to design problems. More closely spaced tracks call for more precise head placement or data are lost. The solution to the problems involves changes in magnetic heads and cores, data tracks and guard bands, ferromagnetic material and head rotation. The systems builder must be familiar with the interactions and trade-offs of these parameters to make an intelligent choice among minifloppy drives.

Fig. 1 shows a magnetic recording head assembly of the type used with double-sided floppy-disk drives. The upper side 1 head is gimballed; the lower side 0 head is rotationally fixed and is known as a button head. In earlier two-sided floppy disk drives, both heads were gimballed, resulting in misalignments that caused excessive diskette wear. The asymmetric design illustrated eliminates that problem (MMS, May, p. 159). The use of special lapping processes to polish and shape the heads and to round sharp edges and corners helps prevent medium wear, increasing diskette life by a factor of three or four.

The erase core of the read-write element (Fig. 2) is structurally similar to the read-write core. The erase core trims the edges of a written track while the drive is in its write mode to prevent crosstalk between tracks. In the past, the erase core lacked a backbar—the magnetic yoke section connecting the pole pieces on the side opposite the gap—to increase flux density through the core. It was eventually determined that improved erasure and noise reduction made it worthwhile to use a backbar in the erase core as well as in the read-write core, and now that is standard.

A special filler is inserted between the core sections

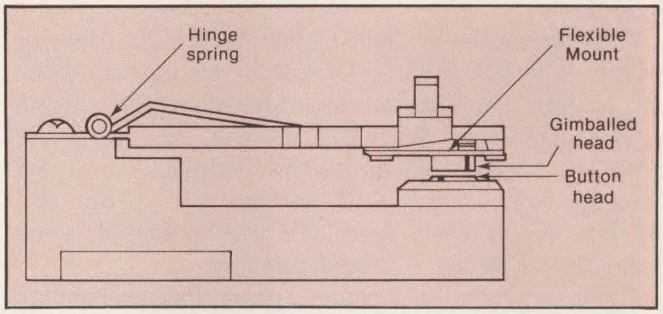


**Fig. 1. The magnetic head assembly** *for double-sided minifloppy drives now uses gimballed head above, flat-surfaced button head below. This asymmetric design eliminates the excessive diskette wear that resulted from the previous design, in which both heads were gimballed.*

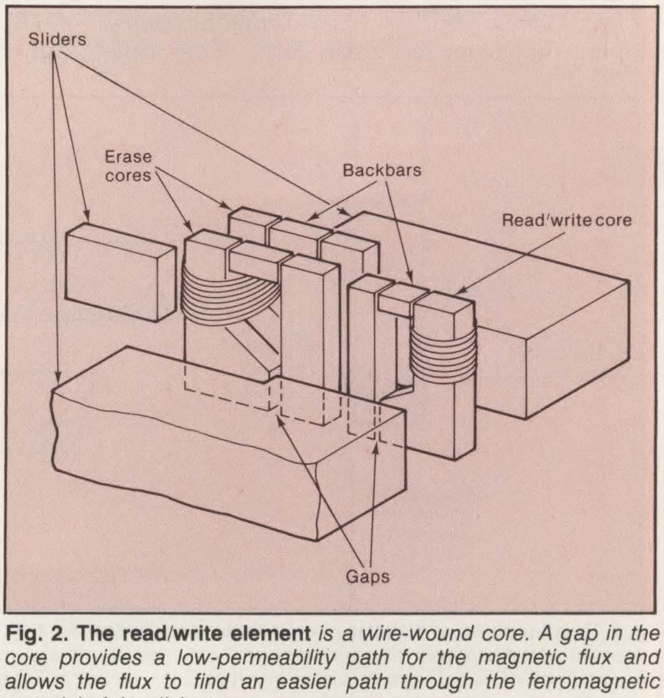


**Fig. 2. The read/write element** *is a wire-wound core. A gap in the core provides a low-permeability path for the magnetic flux and allows the flux to find an easier path through the ferromagnetic material of the diskette.*

*The erase core of the read/write element is structurally similar to the read-write core.*

to keep the magnetic properties of the gap constant and to protect the gap from contaminants that would change the flux density. Both of these goals are achieved by "bonding" the magnetic poles with a low-permeability material, usually glass. The same material is also used to bond the magnetic cores to the head (Fig. 3).

### Data tracks and guard bands prevent erasure

The position of a magnetic recording head relative to a rotating diskette (Fig. 4a) is critical in preventing accidental erasure on adjacent tracks. Fig. 4b illustrates a tunnel-erase configuration, in which a data location on the diskette passes the central read/write core, and then passes the two flanking erase cores. In the write mode, the erase cores trim the edges of the data track as it is written, although with a slight lag relating to the distance, L, between read/write and erase gaps.

This lag causes a slight reduction in data capacity because a length equal to L must be left unused at the end of each data section. The "straddle-erase" design corrects this loss. With this method, the two erase cores are exactly adjacent to the read/write core, and the gaps are also adjacent, so that L = 0. But this efficient arrangement sees little use because it is not compatible with the industry standard.

The guard band (G) includes a strip that lies beneath the erase head, plus an additional tolerance called a safety margin. This margin allows the head assembly to experience a positioning error normal to a data track, without the erase head reducing the flux in the adjacent track.

The strips of width F are the regions occupied by the fringing flux from the erase cores. They cause slight additional reductions in the width of the data track, in addition to the erasure within the guard band that occurs directly beneath the erase core. In the specifications of drive manufacturers, these fringes are required

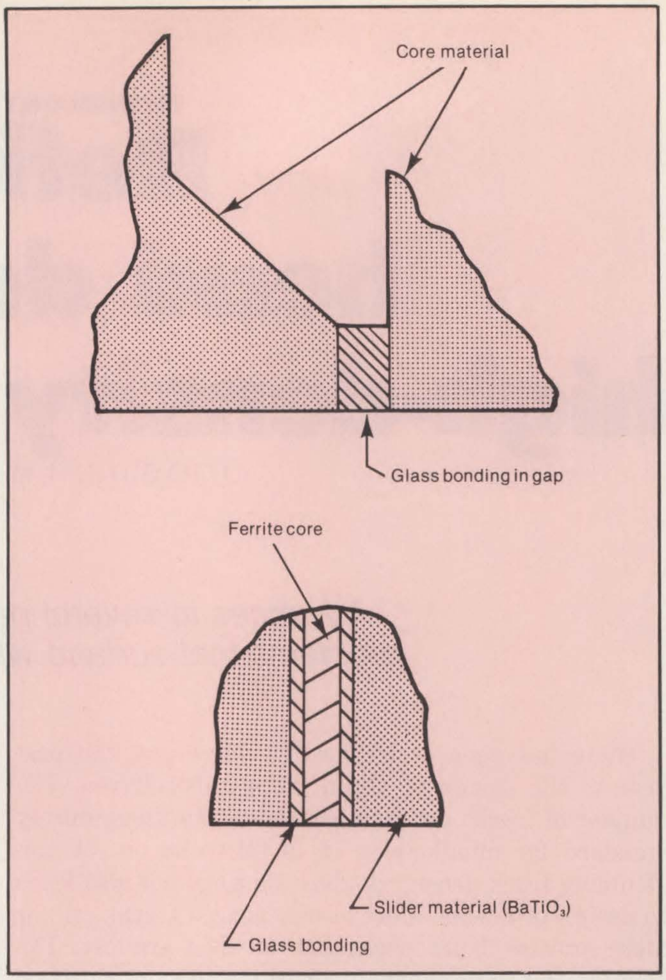


**Fig. 3. Glass bonding** *keeps gap dimensions constant and protects the gap from contaminants that might affect its magnetic properties. Glass bonding is shown in the gap of a read/write or erase core (top panel) and between the ferrite core and the slider material (bottom panel).*

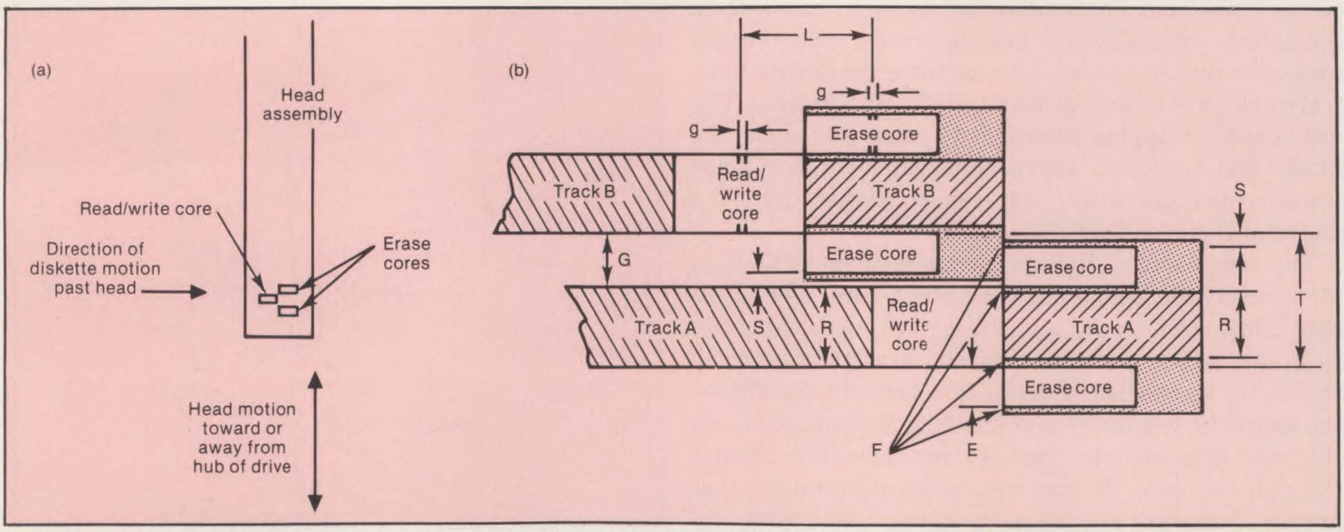


**Fig. 4. Relationships of diskette components** *to each other are critical. Fig. 4a is a broad view of the relative positions of one set of magnetic read/write and erase heads on one track of a diskette. Fig. 4b shows this in detail, as well as the relationship between the core sets of two adjacent tracks. Positioning errors of as much as 2 mils can be tolerated. L is the spatial lag between the operation of the read/write and erase heads. The parameters of the other lettered dimensions in b are given in Table 1.*

| Parameter (in mils) \ Drive type | 48 tpi | Wide-head 96 tpi | Narrow-head 96 tpi |
|---|---|---|---|
| Track spacing, T | 20.8 | 10.4 | 10.4 |
| Read/write core, R′ | 13 | 6.25 | 5.25 |
| Data track, R | 11.7 | 5.63 | 4.73 |
| Erase fringe, F | 0.65 | .31 | .26 |
| Erase core, E | 6 | 3.5 | 3 |
| Safety margin, S | 1.8 | .65 | 2.15 |
| Guard band, G | 7.8 | 4.15 | 5.15 |
| Effective read width, $R_r$ | 9.7 | 3.63 | 2.73 |
| Reduced write width, $R_w$ | 11.5 | 4.28 | 4.73 |
| Combined reduced width, $R_{rw}$ | 9.5 | 2.28 | 2.73 |

**Table 1. Typical head/diskette** *parameters as a function of drive type.*

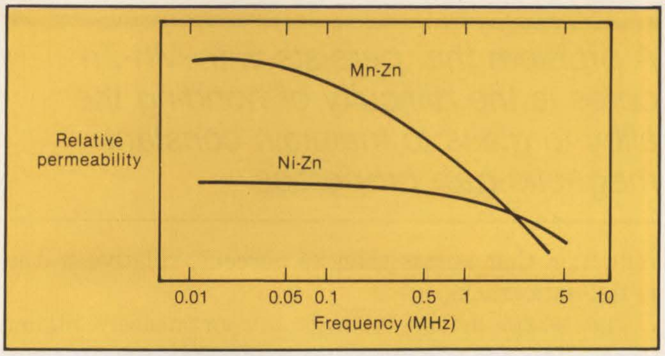


**Fig. 5. Magnetic effectiveness** *of manganese-zinc alloy is greater than that of the nickel-zinc alloy in the frequency range for minifloppies, which is from 0.25 to 0.5 MHz.*

to restrict data track reduction by no more than 10 percent. The fringes also help prevent accidental erasure in adjacent tracks by representing the leading edge of the erase field.

Table 1 lists head/diskette parameters for a 48-tpi drive, a 96-tpi drive with a standard 6¼-mil head and a 96-tpi drive with a 5¼-mil head. Head-positioning error is 2 mils (a reasonable maximum value). The values underlined are the independent design variables —track spacing, widths of read/write and erase cores and fringing-flux width. The other values are derived from these. For example, the safety margin, S, can be derived (using the notation of Fig. 4) as $S = T - R' - E$, all three terms on the right being design variables. Some results are immediately apparent from the table: The 48-tpi drive provides wide margins for error with negligible reduction in write width and a read-width

## GLOSSARY

**Backbar**—The yoke element of a magnetic recording or erase core.

**Bonding**—Joining of the pole pieces of a magnetic core with a low permeability material that fills the gap; glass or epoxy can be used. The same material is also used in bonding the core to the magnetic recording head.

**Button head**—A curved or flat magnetic recording head having no freedom of rotation.

**Cocking**—A design modification in which the magnetic head is rotated by approximately ½ degree relative to the radius of the diskette, parallel to the plane of the diskette. The purpose of the rotation is to ensure even erasure of inner tracks.

**Erase cores**—The magnetic cores on a recording head that erase data and noise from the diskette.

**Fringing flux**—The magnetic flux that extends beyond the lateral boundaries of the magnetic core that is causing the flux. It is particularly significant in relation to erase cores.

**Gap**—The separation between the poles of a read/write or erase core where reading, writing and erasure of data occur.

**Gimballed head**—A magnetic recording head having two axes of rotation, allowing it flexibility in its contact with the diskette.

**Guard band**—The unused space between data tracks on a disk or diskette that safeguards against crosstalk and accidental erasures of adjacent tracks while writing.

**Lapping**—The fine-polishing of magnetic recording heads to reduce diskette wear.

**Manganese-zinc** (Mn-Zn)—A ferromagnetic alloy having superior properties for magnetic read/write and erasure, but difficult to bond.

**Nickel-Zinc** (Ni-Zn)—A ferromagnetic alloy that has been standard in magnetic recording heads, but which is facing replacement by Mn-Zn.

**Positioning error**—Error in location of magnetic-recording head and, therefore, of read/write and erase cores when a data track is accessed. The error is in a radial direction (toward or away from the hub of the drive) and can result in reduced sensitivity in reading a track or accidental erasures of adjacent tracks while writing.

**Read-write core**—The magnetic core on a recording head that reads or writes data on the diskette.

**Safety margin**—The tolerance width within a guard band. A positioning error that remains within the safety margin will not cause accidental erasures of adjacent tracks during the write mode.

**Side-1 head**—The magnetic-recording head on the upper side of a two-sided drive. On a floppy or minifloppy drive, this is generally a gimballed head.

**Side-0 head**—The magnetic-recording head on the lower side of a two-sided drive. On a floppy or minifloppy drive, this is generally a button head.

**Sliders**—Sections of a magnetic-recording head that contact the diskette surface while supporting the cores.

**Straddle erase**—A design in which there is no lag between the action of the read/write core and the trimming action of the erase cores. The erase cores are adjacent to the read/write core with gaps aligned.

**Track spacing**—The space between adjacent data tracks on a disk or diskette. Track spacing can be measured between any corresponding points on adjacent tracks, such as between center lines or between their inner or outer edges.

**Trimming**—The action of the erase cores in erasing the edges of data tracks to avoid crosstalk between adjacent tracks.

**Tunnel erase**—A design in which the two flanking erase cores are placed so that they follow the read/write core relative to points on the rotating diskette. The lag distance between the read/write and erase gaps slightly reduces available data storage capacity, but this design is the industry standard.

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reduction that is less than 20 percent, relative to the initial data track.

The 96-tpi drives undergo proportionately higher losses. The use of a narrower read/write core protects adjacent tracks from the effects of positioning errors during write operations. The narrower core leaves a greater margin for safety between data tracks—2.15 mils—so that a 2-mil positioning error does not affect an adjacent track.

However, the narrower core, while offering this additional safety margin, is not superior to the wider core in every respect. The signal (flux through the read/write gap) that can be read is directly proportional to the width of the data track, and, if no positional error occurs during the write operation, the available signal will be stronger with the wider core. This is shown in Table 1, in the larger values of R and $R_r$ when the 6¼-mil core (rather than the 5¼-mil core) is used.

Assuming that erase-core properties remain constant, there is a critical position error above which the 5¼-mil read/write core would yield better results and below which the 6¼-mil core would yield better results. A simple calculation shows that this breakpoint occurs for a position error of 1.55 mils.

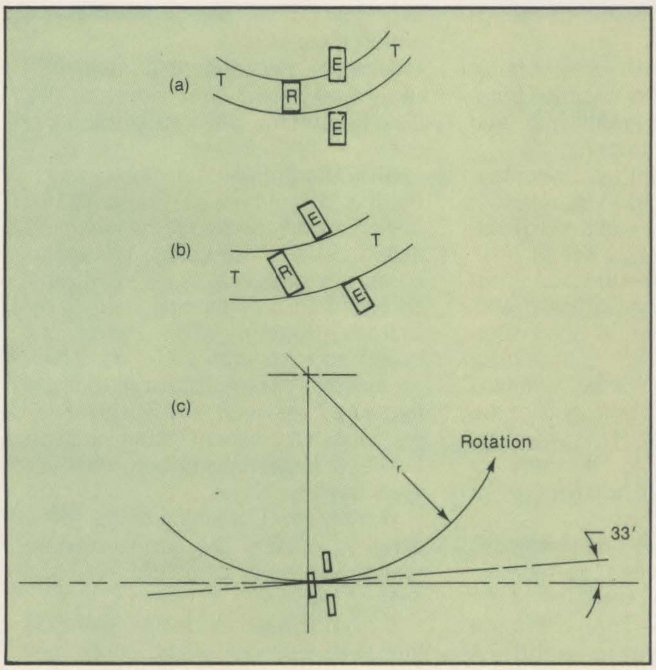


**Fig. 6. Inter-track curvature** *causes erase distortions resulting from asymmetry. Diagram A shows the positions of the read/write gap (R) and the erase gaps (E and E′) relative to inner data track (T). Because of inner-track curvature, erase gap E cuts too deeply into the track, and erase gap E′ separates from the track. In B, the magnetic cores—and therefore the gaps—have been rotated to correct this effect. The correction used by many manufacturers is about ½°. Diagram C presents this same situation in a less exaggerated form, where r = inner-track radius. Here, the manufacturer has corrected the distortion with a 33′ of arc head rotation.*

### Choosing the right ferromagnetic material

Designers use a manganese-zinc alloy rather than the nickel-zinc alloy used previously for read/write and erase cores. Mn-Zn combinations provide better magnetic properties. The flux density available at the gap for writing data is 67 percent greater than for the nickel-zinc cores, and the sensitivity in reading data is 40 percent greater. The Mn-Zn core loses its advantage over the Ni-Zn core at data rates higher than 1 MHz. However, the frequencies for minifloppies lie between 250 and 500 KHz (Fig. 5), so this effect is not a significant liability for the Mn-Zn core.

The use of the Mn-Zn alloy in these recording heads was previously impractical because it had porosities that would lead to reductions in field, bad definition and chipped gaps. However, a new process, in which the alloy is produced under higher pressures, has reduced porosity.

A problem that persists with Mn-Zn cores, however, is the difficulty of bonding the alloy to glass to maintain constant magnetic-gap properties. Bonding must occur in an inert atmosphere, usually nitrogen. This requires new equipment and techniques. Some manufacturers have used epoxy as a bonding material to circumvent this requirement, but most epoxies or adhesives "creep," or change dimensions with changes in temperature and humidity, imparing—long-term stability. Therefore, many manufacturers are staying with Ni-Zn cores until new equipment is available, at which point they will convert to Mn-Zn with glass bonding.

### Head rotation

The innermost tracks on a disk or diskette are subject to erase distortions because the curvature of these tracks presents the head assembly with asymmetries. The erase core closer to the hub of the drive suffers excessive overlap of the data track (Fig. 6A), while the other erase core experiences a comparative lack of overlap (Fig. 6b). To correct this effect, one manufacturer has rotated the head by 33′ of arc, making the inner tracks symmetrical (Fig. 6c). Asymmetries in outer tracks, on which data densities are greater, are not a liability when this strategy is employed. It is unclear whether head-cocking will diminish compatiblity with drives from other manufacturers and whether rotation improves performance.

Performance and compatibility requirements will be more severe in all parameters affecting minifloppy-head design as future drives move to higher track densities. The availability of the improved drives is bound to place greater stress on all of the primary structural factors, which will lead to further evolution in minifloppy-head design. ■

**Otto Butsch** is vice president of R & D at Micro Peripherals, Inc., Chatsworth, Calif.