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# The MAMMOTH Project

**Tim Gerchar**
Senior Product Manager
EXABYTE, Corp.
1685 38th Street
Boulder CO 80301
Phone: +1 (303) 447-7342 FAX: +1 (303) 447-7501
e-mail: timger@exabyte.com

## What is MAMMOTH?

On the surface MAMMOTH is a high performance 5.25-inch half-high 8mm helical scan tape drive that records a native 20 Gigabytes of data on Advanced Metal Evaporated media at a sustained throughput of 3 Megabyte per second over a high speed SCSI interface, that is scheduled for production in the second half of 1995. But it's much more than that. Inside its custom designed sheet metal enclosure lies one of the greatest technical achievements of its kind. Exabyte's strategic direction is to increase throughput and capacity while continuing to improve drive, data and media reliability of its products. MAMMOTH adheres to that direction and the description of its technical advances is described in this paper.

MAMMOTH can be broken down into four main functional assemblies: high-performance integrated digital electronics, high-reliability tape transport mechanism, high-performance scanner, and advanced metal evaporated media. All this technology is packaged into a standard 5.25-inch half-high form factor that dissipates only 15 watts.

## High Performance Integrated Digital Electronics

There has been some confusion in the industry over what commonality Exabyte's 8mm products and 8mm video technology share. The only similarity between 8mm video technology and MAMMOTH is the cartridge shell dimensions.

MAMMOTH employs a single processor design anchored by the AMD 29200 processor. The top-down design methodology of MAMMOTH results in a highly-integrated system that includes seven unique custom ASICs. The low parts count lends itself to a highly reliable system. The electronics are surface mounted onto three printed circuit boards. The MRF (MAMMOTH Rigid Flex) is an 'L' shaped board that contains the processor and its supporting circuitry. The digital data path section which contains two large digital ASICs, RAM and its supporting circuitry are also mounted on the MRF. Also contained on the MRF are the electronics for servo control, which include driver ICs and a custom mixed signal ASIC. The MRC (MAMMOTH Read Channel) is a rigid board that supports the read and write operations of the drive. It contains custom ASICs and all of the discrete filter functions. The MAMMOTH SCSI interface offers a configuration of one of four different SCSI variants; single ended narrow (8 bits) and wide (16 bits), differential narrow (8 bits) and wide (16 bits).

Firmware design is accomplished by the use of 'C' code wherever possible. The code is stored in EEPROM that is programmable, by the use of a code load tape, over the SCSI interface, or with an Exabyte proprietary diagnostic program. The code is designed with an eye towards the future; many of the SCSI 3 features already exist and the layered firmware allows for easy migration to other interfaces such as serial SCSI and fiber channel. The SCSI code is a special area of focus for the MAMMOTH designers. It is optimized for high performance, minimal bus hogging and improved error recovery. This will provide for fast average and predictable worst-case timing values.

In keeping with EXABYTE's strategic direction of constantly improving reliability, the engineering design criteria has been more stringent than the product specifications allow. These criteria include such things as power supply margins, operating temperatures and component tolerances. All this adds up to high performance, highly reliable tape drive electronics and firmware.

**High Reliability Tape Transport Mechanism**

MAMMOTH's tape transport mechanism can be broken down into three subassemblies: the solid aluminum deck casting, the innovative capstanless design and the cartridge loading mechanism.

Exabyte's MAMMOTH drive uses a one-piece aluminum deck casting with a belt-drive system to load the tape path. The one-piece deck casting affords a very high degree of rigidity and precision tolerances for greater reliability. The belt drive tape loader mechanism that operates the two streamlined trolleys uses an angled motor/worm shaft to optimize gear mesh and reduce axial loads. The integrated overdrive springs eliminate any timing errors between the trolleys. The trolleys have been designed to hold very tight tolerances by insert molding the guide pins into the arms. The use of large 6mm tape guides and rollers aid in producing a very simplified and low stress tape path. The tape path can be manually unloaded without damaging the media in an emergency situation.

The innovative capstanless reel-to-reel design used in the MAMMOTH tape transport mechanism incorporates the circuitry for the supply and take-up motor controls and a custom motor driver chip. This is all packaged on a rigid flex mounted on a metal base plate to minimize interconnection and electrical noise. The take up motor's gear ratio allows accurate speed control at low tape speed. This ratio also provides for increased efficiency and low power consumption. The supply motor tightly maintains tape tension through a closed loop control system. The assembly is designed to effectively handle not only component tolerances but cartridge tolerances such as hub roundness.

The capstanless design used in MAMMOTH provides many benefits. Among those are minimized edge damage by using fewer edge guides and lower edge forces when recording on long thin smooth tapes such as AME, tape life is also extended by using fewer large diameter guides. The capstanless design also provides for faster backhitches, improved high speed search performance and faster load to ready times. By removing the capstan debris is not pressed into the media by the pinch roller, also there is less debris generated in the capstanless system.

Integrally mounted in the deck casting is the cartridge loader. It has been designed with a sturdy metal frame for smooth quiet motion of the cartridge, and doesn't allow the cartridge to be misloaded in the drive. The cartridge loader can also be manually operated for media removal without damage. The cartridge loader was designed for fast load/unload times

which are required in an automated environment. This allows for complete and simple library integration without modification of the drive.

The deck assembly is shock mounted to the three piece sheet metal enclosure to help in isolating the deck casting and tape path from the host system's enclosure. The electronics are mounted along the side and rear top of the casting to help in cooling and prevent particulate contamination from entering the tape path. The sheet metal enclosure has been designed to facilitate cooling while minimizing any susceptibility to external radiating sources. The SCSI interface is easily changed by removing one screw to remove the sheet metal cover.

All of the tape transport mechanism design features add up to provide a low stress tape path, tight control over tape speed and a library-ready cartridge loader which in turn offers not only a highly-reliable tape drive but one which also extends media reliability. The design also affords a simple, reliable and predictable manufacturing process.

High Performance 8mm Rotating Scanner

With the purchase of the Grundig scanner division, now known as EMG (Exabyte Magnetics Gmbh) Exabyte now controls another piece of the core technology required to effectively compete in the tape drive industry. Exabyte had been working with that division for more than two years before the acquisition to develop the high-performance scanner used in the MAMMOTH product.

The 47mm scanner was designed to maximize the utilization of tape area. The scanner's rotational speed of more than 5600 RPM, along with a proprietary upper drum design, provides precise airfilm control over the 4 dual azimuth read/write heads throughout the scan. The high head-to-tape speed allows the drive to easily attain the 3 MB/sec. sustainable transfer rate while reading and writing the MAMMOTH format. The 4 dual azimuth read/write heads employ the same type of read-after-write strategy that has been an EXABYTE trademark since the EXB-8200, Exabyte's first product. Head design and media characteristics combine to give the long head life Exabyte's 8mm products have traditionally enjoyed. The motor technology that drives the scanner is a three-phase brushless DC motor.

One of the very innovative features of the MAMMOTH scanner is the rotary transformer. This advanced proprietary transformer technology affords a much higher coupling coefficient than previous designs. This coupling coefficient not only makes the high data rates for MAMMOTH achievable but allows for easy migration to higher performance follow-on products. The transformer configuration also allows for excellent noise isolation to boost the SNR.

All of the design features incorporated in Exabyte's MAMMOTH scanner will provide for high data reliability while achieving a very high level of performance in an easy-to-manufacture product.

**Advanced Metal Evaporated Media**

MAMMOTH will utilize 160 meters of a high-performance advanced metal evaporated media to store 20 Gigabytes at a rate of 3 Megabytes per second. MAMMOTH will be able to read 8200, 8500, and the 8500c formats of the 8mm Metal Particle tape recorded by previous Exabyte 8mm tape drives.

The AME media is being developed by SONY Corporation in concert with the drive mechanism. The development goal is to meet or beat all previous Exabyte reliability specifications. In our internal testing the durability and archivability of the media are meeting and or exceeding expectations. That results in an initial specification of at least 1500 passes, and a storage life of at least 30 years. Exabyte is very confident that the media will meet expectations due to all of the design features built into the MAMMOTH tape transport mechanism.

**Summary**

MAMMOTH accomplishes Exabyte's strategic direction of increasing throughput, performance, and capacity while improving reliability by utilizing design features such as high-reliability tape transport system, high-performance digital electronics, a high-performance scanner, and the use of AME media.

It furthers Exabyte's commitment to the tape industry by extending 8mm technology. The first Exabyte product, the EXB-8200, was first produced in 1987. It gave the tape industry the shot in the arm that has brought about a multitude of new products and technological advances in the existing technologies. Exabyte followed the 2.5GB EXB-8200, that when released was specified at 20,000 mean time between failure hours, with the 5GB EXB-8500 in 1990. The EXB-8500 had a transfer rate of 500 KB/s and a MTBF specification of 40,000 hours, in that same year the EXB-8200's MTBF specification was doubled to 40,000 hours. In 1992 Exabyte introduced its second generation of products which were half high versions of the EXB-8200 and EXB-8500. The EXB-8205/8505 were designed in a co-developement with our deck supplier to provide additional drive and media reliability. As a result the EXB-8205/8505 were released with double the MTBF specification: 80,000 hours. Exabyte has recently released the 'XL' versions of the EXB-8205/8505 that again double the MTBF specification to 160,000 hours, and extend the capacity to 3 and 7 GB respectively. Along with the drive reliability specifications doubling, the head life expectation also has been increased to at least 16,000 hours.

I equate the MAMMOTH tape drive to the EXB-8200 - - it will also cause a resurgence of tape technology being utilized in many of the non-traditional tape applications such as video-on-demand and hierarchical storage management systems. MAMMOTH also establishes a new level of performance and reliability that is directly due to the technological advances described above. It will initially have reliability of at least 200,000 hour MTBF, and a large library population ready to upgrade to its capacity, performance and reliability level.