TECHNICAL BRIEF

T9840C tape drive reliability

APRIL 2004

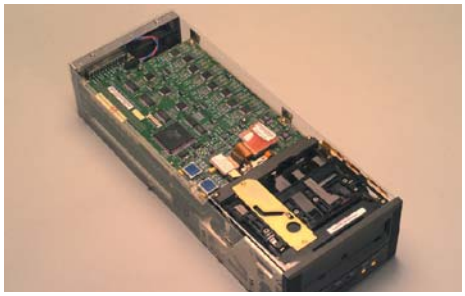

Figure 1.

1 INTRODUCTION

Reliability matters.

When you trust your valuable data to be stored on tape, you expect it to be there when you need it. The success (or failure) of storing and recalling data depends on the reliability of both the tape drive that writes the data and the medium (tape) it's stored on. Reliability is affected by the design of the data storage system, usage and environmental factors. There are many low-cost tape drives that can store data, but can they safely store the data in your high-usage, always-on business environment? And what are the potential consequences of using a tape drive that is not designed to operate 24 x 7 like your business?

How much is your data worth?

Data is often your most valuable business asset. The data on a single piece of media is often worth many times the price of the tape drive with which it's being written. That is the reason behind the T9840C tape drive design philosophy — a tape drive and media system where everything, by design, is optimized for ultimate reliability at high-duty-cycle usage.

You get what you pay for.

Any modern tape drive can be expected to reliably store data when used infrequently. However, as usage increases due to today's 24 x 7 business needs or shrinking backup windows, only tape drives and media designed for robustness in the most demanding environments can be counted on to safely store and retrieve data day after day. A fair analogy might be comparing an economy car with a race car. Both could reliably be counted on for trips to and from the grocery store, but only the race car is designed to provide the same level of reliability in a high-speed, long-distance race.

Businesses always need to balance price, performance and reliability. In low-usage applications, other tape technologies might provide a reasonable solution. Where high-duty-cycle usage is expected or ultimate data reliability is required, the T9840C tape drive is designed to provide the ideal solution with the fastest access time to data of any tape drive.

The T9840C tape drive, the third generation of the T9840 tape drive product line, doubles capacity to 40 gigabytes and increases native data rate 60 percent to 30 megabytes per second over StorageTek's T9840B tape drive. StorageTek® gained these improvements through our proven VR2 Partial Response Maximum Likelihood (PRML) technology, while utilizing the same 9840 tape cartridge as the T9840A/B tape drives to protect your media investment. First introduced on the StorageTek's T9940B tape drive, VR2 PRML doubles data reliability over the T9840A/B tape drives. (See Figure 1).

In addition to the increase in data rate and capacity, a variety of minor drive enhancements to further improve product reliability and data integrity were made.

In this paper, which assumes a general understanding of the T9840A/B tape drives, we will highlight and review the technical innovations and features of the T9840C system (drive and cartridge) and how they result in a new high water mark for streaming tape drive data integrity, reliability and robustness.

1.1 INCREASED RELIABILITY AND DATA INTEGRITY OF THE MEDIA, CARTRIDGE AND ERROR DETECTION/CORRECTION ALGORITHMS

Ensured media life and data integrity

Data integrity and long life are dependent upon advanced technology in the media as well as the tape drive. The T9840C tape drive uses the same cartridges you purchased for the T9840A/B tape drives. Users can read and write to the cartridges at higher capacity and speed, while still reading the original A and B formats. This provides a significant media investment protection.

The cartridge contains over 800 feet of advanced formulated metal particle (MP) media in a dual reel cartridge. As the cartridge is wound to the center of the tape to allow for fast access, the drive only needs to cover 200 feet in either direction on average to get to your data. In addition, since the entire tape path is contained in the cartridge, no threading of the tape through the tape path is required. This eliminates a potential source of media damage and leader block failures and provides the fastest load and search times of any computer tape drive on the market.

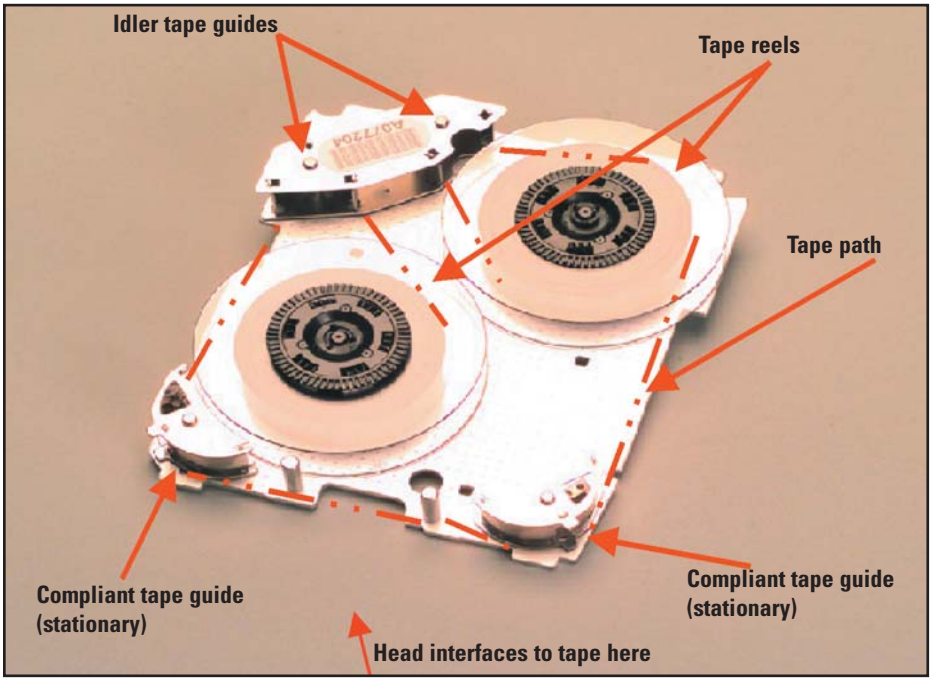

Figure 2.

Cartridge design

The entire tape path, excluding the head, is contained in the cartridge. Designed for maximum durability and data integrity, the 9840 tape cartridge is based on a 0.1-inch aluminum plate, flat to 1/1000 of an inch. The entire tape path length from reel to reel is about 18 inches, significantly reducing the edge guiding force needed to position the tape on the head, as compared to the shorter tape path lengths of other tape drives. See Figure 2. The tape path design uses two compliant tape guides that edge-guide the tape so that it is precisely positioned relative to the head. These guides use a finely tuned compliant spring to keep the tape positioned properly as shown in Figure 3. In addition, no customer data is stored on the first meter of tape in each direction from the center of tape position. This is done to ensure that customer data is not compromised if the cartridge were to be dropped during handling or transport, possibly causing edge damage to the exposed unwound tape.

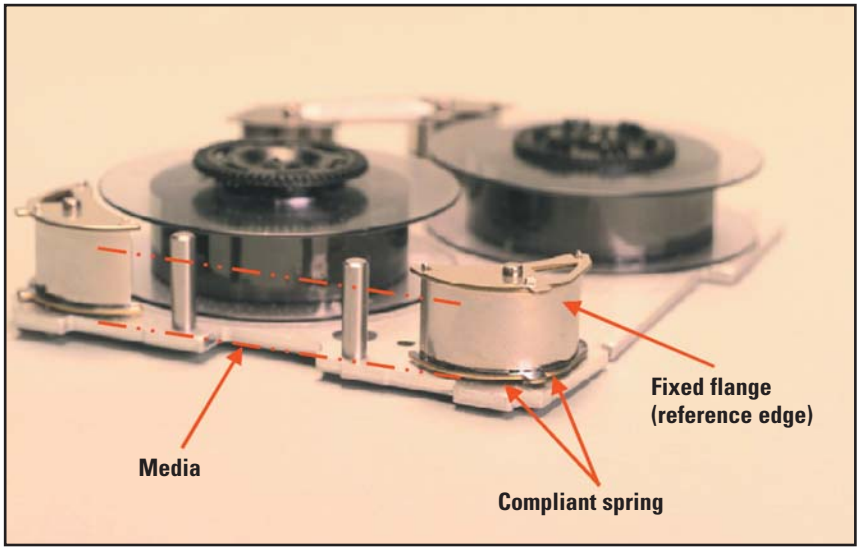

Figure 3.

Media uniquely designed for reliability

The media employs a unique durable back coating that is rugged yet smooth and flexible. This is critical to preventing damage to the magnetic coating caused by trapped debris or other surface imperfections. Wrap imprinting can occur when debris or surface imperfections leave an impression on the magnetic coating of subsequent wraps of tape. A durable back coating minimizes this source of data errors.

High duty cycle tape path

Data reliability is strengthened even further because T9840C tape drive guides only contact the media on the tape's backside instead of on the magnetic side where data are stored. This eliminates the potential problems of data loss resulting from accelerated wear of the magnetic coating, especially during start-stop operations.

The value of hydrodynamic tape guide bearings

Even though the T9840C tape drive guides only contact the backside of the tape, opposite the data, we go even further to avoid generating debris that can contaminate the magnetic side of the media.

Our solution uses hydrodynamic tape guide bearings made of a precision-formed aluminum. T9840C tape literally floats on a film of air when it is moving, so wear on the back coat of our tape is significantly reduced. In addition, our patented hydrodynamic air-bearing tape guide design provides a uniform air bearing under the tape. This ensures that the bearing surface has the tight tolerance shape needed to keep the air bearing from collapsing at the edges and causing edge wear.

StorageTek's hydrodynamic air bearing guides have an added benefit. Any small debris buildup will be carried through the air bearing and out of the way by positive air pressure, a design characteristic unavailable from metal roller bearings.

Bi-directional, high integrity head carriage assembly

The T9840C tape drive has a "three-bump" head design that allows for read after write in both directions, providing very high data integrity. The T9840C read/write head is designed for a long life; it is designed to maintain specified levels of high reliability and performance for a long time.

Head life defines how long the head will reliably read/write until reaching its design limit for wear-out. The higher the specification, the longer the head is expected to go without contributing to read/write errors due to natural wearing mechanisms. At 50 percent tape motion duty cycle head life is predicted to be 12 years. This is nearly twice the design specification of other tape technologies which commonly specify 30,000 hours to head wear-out. At 50 percent tape motion, other tape heads reach their wear-out specification at 6.8 years.

To provide high data reliability, the T9840C tape drive has a cleaning brush built into the head assembly to automatically clean the head when a cartridge is loaded or removed. This nonabrasive cleaning cycle causes no head wear. The brush also has the unique ability to perform a multistage cleaning in the event of a read/write error. Working under fully automated control, the tape is backed away from the head, which is then cleaned multiple times by the brush to remove any debris.

The T9840C tape drive features a tape head with 16 read/write elements and requires only 18 full-length passes to fill all of its 288 data tracks. Other "serpentine recording" tape drives use heads with fewer read/write elements, requiring more full passes to fill a tape. T9840C tape drive's advantage is that it fills a tape with fewer passes thus ensuring longer media life and reducing the possibility of data errors due to media wear.

The T9840C tape drive uses a closed-loop, track-following servo system to keep the read/write head elements precisely aligned with the data tracks while the tape is moving. This is accomplished by specialized servo track reader elements that read servo information pre-written in five servo zones on each 9840 tape cartridge. (See Figure 4).

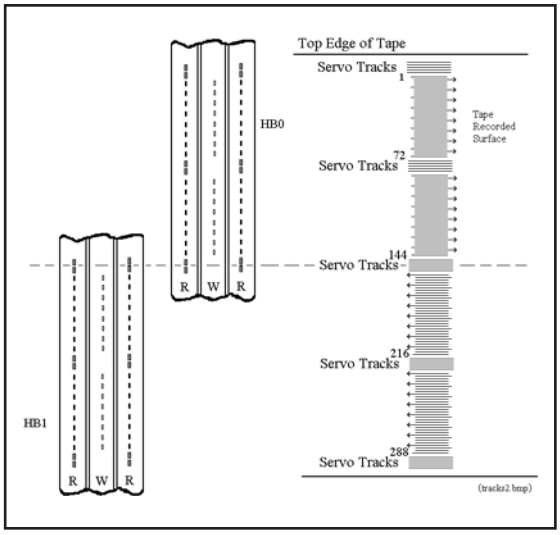

Figure 4.

As the head travels, it reads three of its five servo zones simultaneously for redundancy. The head will still remain on track to write if one of the servo tracks becomes damaged and continues to function during read operation if even two of the servo tracks are damaged.

When the head travels in the opposite direction, it moves to the bottom three servo zones as shown. Other tape drives have five recorded servo zones too, but only read two zones at any time. T9840C drive's added redundancy makes it less prone to off-track errors (with resulting data loss) if a cartridge becomes damaged.

With the T9840C drive, head and media wear are eliminated during high-speed (eight meters per second) searches and rewinds. This is done by unloading the head from the tape; a function unique to the T9840 and T9940 tape drives. Although the head is not loaded or reading during a search, the T9840C tape drive knows precisely where it is on the tape by counting tachometer marks from the reel motor's precision tachometer. Once the desired data is reached, it will slow down and load the head.

Because today's heads are manufactured using thin metal film technology, they are susceptible to corrosion, especially if the media is used outside of traditional data center environments. The T9840C tape drive resolves this issue by leaving the head charged at half power to keep the head surface heated and dry when the drive is not in use. Since water must be absorbed on the surface for corrosion to start, this extra step reduces any chance of this occurring. This is another reliability-enhancing function unique to the T9840 and T9940 tape drives. The media is also protected from any possibility of thermal damage by lifting the head off the tape when the media stops moving.

Robust loader mechanism reduces failures

Using state-of-the-art design and technology to maximize robustness, the T9840 loader is designed for automation and the high duty cycles demanded by most of today's customer applications. The loader, drive and media were designed together to take the high acceleration/deceleration loads subjected to in high-speed enterprise-class automated libraries. A unique locking mechanism holds the cartridge in place, eliminating a common cause of load failures in other types of tape drives.

Unprecedented error correction

StorageTek's primary design objective for the T9840C tape drive was providing data integrity. To accomplish this, we combined a sophisticated error correction code (ECC) and cyclic redundancy data check (CRDC) to provide the highest level error detection and correction in the industry. The ECC is a 32-byte Reed-Solomon code of order eight. Each code word is also spread out over all 16 tracks that are being simultaneously written or read and spread along the tape for a length of over 1000 microns. This is done to reduce error sensitivity to media defects. With this capability, you could lose four of the 16 tracks being read for an indefinite length of time and still recover your data. This ECC is so powerful you could still read the tape with a one millimeter hole punched through the media.

Such attention to detail results in an impressive set of bit error specifications for the media.

Undetected bit errors: 1×10^{33}

> Based on the mathematical probability for uncorrected errors after ECC and CRDC checking are applied.

Uncorrected bit errors: 1×10^{18}

> The calculated number of bits of data read between uncorrectable media-induced bit errors. The T9840C tape drive will not send detected but uncorrected data to the host unless the host requests it. It will post a hard read error instead.

2 RELIABILITY SPECIFICATIONS

Electronics

The T9840C tape drive exploits much of the already proven and highly reliable T9840 tape drive's component design and innovation. With its proven design and demonstrated reliability, the T9840C's mean time between failure ($MTBF_H$) is calculated at 290,000 hours at 100 percent power on duty cycle.

Loader mechanism

The T9840C loader mechanism is designed for 100,000 loads with no failure. This results in an $MTBF_L$ of 240,000 hours at 10 loads per day.

Tape path

The tape path has a calculated $MTBF_T$ of 216,000 hours, also with a 70 percent TPM and, again, more than 16 hours per day of continuous tape motion.

Head

Head life is calculated to exceed 8.5 years at a TPM of 70 percent. (See Figure 15.)

2.1 THE FASTEST, HARDEST WORKING, MOST RELIABLE TAPE DRIVE FOR YOUR TAPE APPLICATIONS

Offering design enhancements over previous generations of tape drives with already outstanding reliability records, StorageTek's new T9840C tape drive is an exceptionally robust, reliable, high-capacity tape drive. Designed for nearly continuous operation of 16 hours per day, it is capable of doing three times more work than that of typical midrange tape. Perhaps more important, it is a drive and cartridge system designed to protect your data. In fact, the T9840C tape drive provides a corrected BER of 1 in 10^{18} — 10 times that of other contemporary tape drives.

With numerous patents granted or applied for, the T9840C tape drive is also a strong testament to StorageTek's continued technological advances and will surely result in our customers' high confidence in the drive and the integrity of the data that it stores — which is exactly our intention.

All of which is why we call the T9840C tape drive the fastest, hardest working, most reliable tape drive for your tape applications.

ABOUT STORAGETEK®

Storage Technology Corporation (NYSE: STK), a $2 billion worldwide company with headquarters in Louisville, CO, has been delivering a broad range of storage management solutions designed for IT professionals for over 30 years. StorageTek offers solutions that are easy to manage, integrate well with existing infrastructures and allow universal access to data across servers, media types and storage networks. StorageTek's practical and safe storage solutions for tape automation, disk storage systems and storage integration, coupled with a global services network, provide IT professionals with confidence and know-how to manage their entire storage management ecosystem today and in the future.

StorageTek products are available through a worldwide network. For more information, visit www.storagetek.com, or call 1.800.275.4785 or 01.303.673.2800.

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