Automated Tape Library Systems
Performance and Reliability Tests

Sun StorageTek SL500 with HP LTO-3 Tape Drives
vs.
Quantum/ADIC Scalar i500 with IBM LTO-3 Tape Drives

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Based on testing performed by and written by:

Percept Technology Labs
PRODUCT TEST AND COMPLIANCE EXPERTS

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Introduction

In today’s fast-paced business environment, data storage management has become increasingly important. More and more companies rely on tape libraries for their data backup, restore and archive. Automated tape libraries are designed to increase data capacity and simplify the data retrieval process.

Two of the most popular libraries that address this market today are Sun’s SL500 and ADIC’s i500. Both products are designed for the midrange marketplace and offer a similar feature set.

Percept Technology Labs, Inc., an independent test lab, evaluated the hardware design and ran a series of tests created to simulate real world operating conditions. The testing completed over a period of 4½ months, April 2006 – August 2006. All tests were performed at Percept Technology Labs’ test facility by Percept test engineers with new equipment. Both libraries were professionally installed by the respective manufacturer. The library test configurations of both systems were as follows:

- **Sun SL500 with HP LTO-3 Tape Drives**
  - Usable Storage elements – 158
  - HP Drive elements – 4
  - FC connections – 7

- **ADIC i500 with IBM LTO-3 Tape Drives**
  - Usable Storage elements – 128
  - IBM Drive elements – 4
  - FC connections – 6

The top three considerations when evaluating tape libraries include storage capacity, performance and reliability. Because storage capacity is simply a function of available storage elements, Percept focused its testing on the overall performance and reliability of these two products. The specific tests used to evaluate performance and reliability are listed below and will be described in detail later in this paper.

- Performance: Normal Operation Test
- Reliability: Dynamic Move Test
Product Design Observations

Despite the similarity of these two products, there are distinct differences in the basic design. Potential buyers should note these differences when making their decision in which product to purchase.

From an aesthetic point of view, the libraries tested are similar - the ADIC i500 occupies 14U of rack space while the Sun SL500 occupies 16U (Base module & Expansion unit). Closer investigation, however, reveals significant differences in the design of these products. The SUN SL500 is a true enterprise class system; constructed with metal panels and doors while the ADIC i500’s major component is plastic. Performance testing later proves the design of these two products have major implications on reliability and performance.

Robotic Movement and Cartridge Handling

One key area where the Sun SL500 and ADIC i500 differ is servo mechanical transmissions and cable axis transitions. The Sun SL500 is primarily a pulley driven system with belts and cables, whereas the ADIC i500 is exclusively a gear driven system. As a result, servo power is transmitted more smoothly within the SUN system. In contrast, the ADIC system generates more noise and is prone to accumulate debris from gear wear.

Another significant design difference between these two machines is the robot. The Sun SL500’s gripper lifts and places cartridges into tape drives and storage elements. The ADIC i500 gripper slides cartridges into elements rather than lifting them. Sliding the cartridge generates dirt and debris, which can introduce contamination to the system, including the robot gripper, servo elements and tape path. Potential results are robotic operation issues, tape path errors or data loss.
Figure 1: ADIC Scalar i500 Cartridge after 33,000 moves

Figure 2: Sun SL500 Cartridge after 52,000 moves

As you can see to the left, the cartridge used in the ADIC Scalar i500 exhibits debris, scoring and abrasion after 33,000 moves. The Sun SL500 is in unmarked and undamaged condition after 52,000 moves.

Library Topology

The Sun SL500 has a dedicated Fibre Channel (FC) node. There are no topology limitations and minimal impact to other devices on the same channel. The control and data path discovery is automatic. The ADIC i500 is a LUN 1 device, thus limiting the library’s control path through a specific drive and increasing configuration complexity. Library commands must be passed through one tape drive. There are two design issues with passing the commands through a tape drive:
1. Normally a library can continue to operate if a tape drive fails, but with the i500 a failure of the LUN 1 tape drive results in a system failure.

2. There is a significant performance penalty paid for using the data path for library control. This performance penalty will be shown later in this paper.

See the Input/Output (I/O) topology for each library below.

**Figure 3: Sun SL500 I/O Topology**

<table>
<thead>
<tr>
<th>SL500 Library</th>
</tr>
</thead>
<tbody>
<tr>
<td>HP LTO-3</td>
</tr>
<tr>
<td>HP LTO-3</td>
</tr>
<tr>
<td>HP LTO-3</td>
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<tr>
<td>HP LTO-3</td>
</tr>
</tbody>
</table>

**Figure 4: ADIC Scalar i500 I/O Topology**

<table>
<thead>
<tr>
<th>i500 Library</th>
</tr>
</thead>
<tbody>
<tr>
<td>IBM LTO-3</td>
</tr>
<tr>
<td>LUN 1</td>
</tr>
<tr>
<td>IBM LTO-3</td>
</tr>
<tr>
<td>IBM LTO-3</td>
</tr>
<tr>
<td>IBM LTO-3</td>
</tr>
</tbody>
</table>

The design related differences Percept Technology Labs, Inc. noted between the machines during testing in include:

- No contamination visible on the Sun SL500 vs. contamination on the cartridges, gears, servos, storage elements and surfaces of the ADIC i500
- No cleaning requests were required during our testing on the Sun SL500 vs. 3 cleaning requests were required for the ADIC i500 for the same testing.
- Fault-tolerant firmware on the Sun SL500 vs. non-tolerated faults resulting in manual interventions for the ADIC i500
- Easy accessibility to the Sun SL500 elements vs. no accessibility to the base module of the ADIC i500. While not normally an issue, this did present a problem due to the manual interventions experienced during the Library Performance testing.
- ADIC’s LUN 1 configuration negatively affects all devices on the same channel. Test results show ADIC’s streaming tape I/O slows down with cartridge move requests. This is not an issue for Sun’s library that does not rely on a LUN 1.
Management Tools

The management tools of the two libraries were compared for robustness and ease of use. For each library, management tools are accessible via the network or the front panel LCD. The ADIC i500 management tools are located directly on the library while the Sun SL500 requires a software install on a host computer. The SL500 can be managed only from a computer containing the installed software. The i500 library can be managed from any networked computer by pointing a browser at the library. However, the i500 management application did provide very slow response times – it ran much slower than the SL500 SLC remote management application.

ADIC offers a robust feature set on the Scalar i500. All IT issues can be addressed through the touch-LCD or network interface. Configurability is ADIC's strength. Unlike the Sun SL500, the ADIC i500 can be configured to send e-mail event notification and the library can be partitioned. Another configuration parameter required by the i500's design is a control path designation. Conversely, the SUN SL500 interface offers few configuration options and its management tools function principally as a diagnostic and reporting tools.

Performance and Reliability Testing

In order to get an accurate feel of how these two devices compare in the real world situations, a series of tests were performed to simulate normal system operation as well as how the libraries handle adverse situations using exception testing. The following server configurations were used for all comparison testing:

- Dell PowerEdge 2800 1 GB RAM
- (2) Qlogic FC HBA QLA2310F
- Windows 2000, Service Pack 4
- FC Switch Qlogic SANbox

Performance: Normal Operation Test

The primary way to improve performance is to maximize data transfer rate, which has the effect of minimizing the time it takes to store and/or retrieve a given amount of data. Write/read tests were performed to assess data throughput by timing write and read operations. Each write operation transferred 20 GB of data in the form of a different compressible pattern. The write operation was followed by read commands. Each write/read was performed with specific block sizes in order to measure the effect of data block size on transfer rate.

Normal operational testing was accomplished by simultaneously executing library move commands while streaming data to tape drives. This simulates a real-world load concurrent with tape drive data. Figure 5 below shows the comparative...
throughput performance of the HP LTO-3 tape drive (in the Sun SL 500 library) vs. the IBM LTO-3 tape drive (in the ADIC i500 library). The tests results show that, in the most common block size range (64KB to 512KB) the Sun SL500 offers the fastest data transfer rate.

**Figure 5: Results of the Tape Drive Operation Testing**

![Graph showing throughput performance of HP and IBM tape drives](image)

Under an operational load the ADIC Scalar i500 design topology inhibits the performance of the tape drive. This deterioration applies to library activity as well as drive Input/Output. The ADIC Scalar's LUN 1 communication interface is the primary contributor to this performance decline.

**Reliability: Dynamic Move Test**

The primary purpose of an automated library system is to provide a means to store, consolidate and retrieve data. The library system’s reliability depends mainly on the robotic mechanism, which moves the cartridges throughout the various locations in the library. Percept performed an element interchange test, which tested the robotic systems’ ability to cycle cartridges between the various elements (i.e. Drive, Storage, EEpport) and allowed Percept to assess robotic movement, timing and reliability.

The Sun SL500 completed the entire interchange testing process twice without error. The ADIC i500 required numerous manual interventions (library operation comes to a complete stop when manual intervention is required), and never
completed the test in a single pass. During testing, ADIC provided a firmware upgrade for the ADIC i500. Even with the upgrade, the ADIC i500 could not complete the test without reported errors. Uninterrupted performance is an expected function of these systems. With the ADIC i500, that was never achieved.

The highlights of this test include:

- The Sun SL500 completed approximately **163,000** cartridge moves requiring no intervention
- Due to the numerous manual interventions, the ADIC i500 completed only approximately **90,000** cartridge moves during our testing.
- The ADIC i500 requested three drive cleanings during this test. This is potentially the result of debris build-up on cartridges, from being dragged across storage elements. Dirt in the tape path results in corrupted tapes and data loss.
- The Sun SL500 tape drives required no cleanings during complete test. Despite completing 80% more moves than the i500, there is no evidence of debris build-up in the SL500.

Additionally, testing indicates that cartridge cycling time increased with usage in the ADIC i500. This problem is most likely caused by gear wear and/or cartridge dragging or the debris buildup noted in the ADIC system. The cartridge cycling time remained constant in the Sun SL500 throughout the testing process.

The results of this testing indicate that the Sun SL500 design provides significant reliability and performance advantages. The ADIC i500 experienced more problems and therefore may require more maintenance throughout the system’s lifespan.

**Exception Testing**

Exception testing is designed to show how the units operate under adverse activities. Percept put the systems through a wide variety of exception tests. The results provide an analysis as to the product’s robustness, reliability and recoverability. For most exception scenarios the two systems handled the conditions very similarly.

One significant difference between the systems was noted – how the systems react to a stuck cartridge.

- The Sun SL500 handles this problem routinely. It abandoned its efforts to extract the cartridge, disengaged the cartridge and sent an error message. The cartridge was then accessed through the front door, the robot ascended to the “park” position and the cartridge was easily removed.
- The ADIC i500 robot did not release the cartridge as expected, even once the front door was opened. To retrieve the cartridge, it was necessary to remove the top cover of the library to gain access to the cartridge. The cartridge was manually removed by lifting the robot sled up to relieve pressure and hand turning the gripper servo gears.
• With the i500, if there are additional modules installed with the library, each module installed above the control unit will need to be uninstalled in order to access the stuck cartridge.

Conclusion

Capacity, performance and reliability are the most important aspects when evaluating an enterprise library system. Although both the Sun SL500 and the ADIC i500 offer similar feature-sets and are both designed for the mid-range marketplace, independent testing shows significant differences. From the test results that were collected over a span of several months, it can be concluded that the Sun SL500’s performance and reliability far exceed that of the ADIC i500 and will last longer and require less maintenance over its lifespan.

Additionally, the robust reliability of the Sun SL500 gives the user confidence that data backup will complete as scheduled without numerous issues to deal with. The Sun SL500 performed all tasks with minimal user attendance, while the ADIC i500 was problematic and required excessive user intervention.
The following comments are from Sun Microsystems and do not represent the findings or conclusions of Percept Technology Labs.

**Sun Microsystems Comments**

As expected, the SL500 performed well in the Percept tests. The SL500 is a highly reliable library, sharing many designs and components that are used in the Sun’s enterprise class StorageTek SL8500 Tape Library. After the Percept tests were completed, Sun tape library engineers were able to inspect the Quantum/ADIC i500 library and add additional insight into the design differences between the SL500 and the i500 that may have contributed to the Percept test results. Sun engineering’s findings were primarily related to Robotic design and performance.

**Encoder Disk**

One of the differences between the SL500 and the i500 not noted in the Percept tests is in the encoder disk design. The encoder disk is used to determine the positioning of the robot in the library and is important to the performance and reliability of the robot. Errors in the encoder counts will cause missed pulses from the encoder. This will give position errors.

The SL500, designed for 24x7 use as an enterprise library, uses a fully enclosed encoder disk while the i500 encoder disk is exposed. By not enclosing encoder disk ADIC is exposing the disk to debris which can eventually cause problems with determining the position of the robot. Positioning errors will degrade performance as the robot needs additional time to determine its position. Unless cleaned, the problems will progressively worsen and performance will continually degrade. Eventually the component will need to be replaced.

Figure 6 shows a picture of the i500 encoder disk after completion of the Percept tests. Debris can clearly be seen covering the entire disk. In addition, there are significant wear marks on the disk. It is uncertain if the wear marks were caused by the debris or if there is another design flaw causing the wear in the disk. Regardless of the cause of the wear, this wear can contribute to the robotic positioning problems being caused by the debris.
As mentioned in the Percept test results, the i500 drags cartridges from cell locations, which creates debris within the library. But the cartridge dragging is not the only source of debris in the library. The encoder disk for the motor that performs robotic reach, wrist, and track is also creating debris. Figure 6 shows the scratch marks on the disk that is the cause of this extra debris and also shows debris on the disk. Debris on the encoder disk can lead to position errors in the robot.

**Gears versus Belts**

As mentioned in Percept’s findings, the i500 robotic control mechanisms are all gear driven; there are six gears plus one drive screw. ADIC’s use of gears is a key design difference from the SL500. Gears are less desirable than belts because gears can cause three problems in a modular tape library.

- Gears require proper alignment between modules. Over time, the alignment will require adjusting to compensate for gear wear. If the gears are out of alignment it can cause additional wear on the gears, creation of debris, and inaccurate positioning of the robot.
• Gears can be a cause for debris within a library. This is particularly true if the gears are not properly aligned.
• Gear backlash is the amount of clearance between mated gear teeth in a gear pair. Backlash equates to lost motion due to clearance or slackness when movement is reversed and contact of the gear teeth is re-established. Backlash is an unavoidable property of all reversing mechanical couplings. This lost motion makes the robotic positioning and targeting less accurate. The library can compensate, but it becomes more difficult to compensate over time as the gears and track continue to wear. The result of backlash is degraded performance over time and increased service costs due to an increase in the parts needing replacement.

The SL500 uses belts to drive the Z movement of the robot. Sun/StorageTek has been using belt technology in their libraries for decades and prefers to use belts wherever there is room because they are more reliable than gears and do not require any periodic maintenance. The SL500 launched in mid 2004 and has shipped well over 5,000 libraries. To this date Sun has not experienced a single failure in any of the belts used in the SL500.

Dragging versus Lifting

Debris within the library causes significant reliability and performance problems as discovered during the Percept testing. The SL500 robot hand uses a gripper to grab and lift the tape cartridge while the i500 design uses hooks to drag the cartridge from its location. As the Percept results indicate, dragging the cartridge is a source of significant debris. The SL500 robot gripper eliminates the cartridge and cell wear and tear caused by the constant dragging of the i500.

Exposed versus Protected Targeting Mechanism

The i500 uses an infrared sensor for targeting; this sensor is located below the robot hand and is exposed to all the debris created by dragging the cartridge. The location of the sensor combined with the creation of debris is a bad design because debris interferes with the infrared sensor identifying targets. Problems with identifying targets will degrade performance as the sensor requires more time to accurately identify targets. These problems were demonstrated in the Percept findings. The SL500 scanner used to identify targets is mostly protected in the hand assembly. While the SL500 does not create debris, the position of the SL500 scanner significantly reduces the probability of debris collecting on the scanner.

Slip Ring and Rotary Connector versus Z-Loop

The design of the Z flex cable is used for sending communications to the robot. It moves with every robot move and is a key component in determining the reliability of the robot. The SL500 uses a Z loop design for this cable, which is virtually impossible to wear out. A Z loop design does not contain any moving parts and the
loop provides enough slack in the cable to allow the robot to move up and down with the robot.

The i500 uses a slip ring and rotary connector design for the Z flex cable. This design uses a complex counterweight and spring mechanism much like a tape measure. The cable is wound and unwound with each robot move. This design requires many additional moving parts and is a key point of failure in the i500 design. As with most mechanical systems, the more moving parts, the faster it will wear out. The use of a slip ring design increases the probability of library failure that is not present in the SL500 library.

**LUN 1 versus Dedicated Control Path**

As described by Percept, the i500 sends control path commands through a tape drive. The SL500 has a dedicated control path through a FC interface card. The difference between these designs can affect library performance as the Percept findings describe. In addition to the performance problems this design can create, there is a significant reliability risk with this design.

Tape drives are highly mechanical devices and have a higher probability of failure than any other component in the library. The use of a tape drive for control path communications reduces the reliability of library to that of a tape drive. Normally a library can continue to operate if a tape drive fails, but a library cannot continue to operate without control communications. While the i500 control path can be moved to another drive in the library, it requires manual intervention for the library and possibly configuration work for the backup application.

Generally speaking, every component added to a library reduces library reliability. Since the SL500 contains a FC interface card that the i500 does not have, it's logical to assume that the SL500 is less reliable in this area. However, the addition of the SL500 FC interface card actually increases the relative reliability of the SL500 compared to the i500. While the i500 uses fewer components for control path communications, it uses the least reliable component in the library. Sun field reliability data shows that a FC LTO3 tape drive is 23 times more likely to fail than the SL500 FC interface card. It is more likely that multiple tape drives will fail before the SL500 FC card fails.

**Final Sun Comments**

The SL500 has significant robotic design advantages over the ADIC i500. In a tape library the robot design is the critical component in determining tape library performance and reliability. These design advantages can be seen in the results of the Percept product testing where the SL500 was proven to be much more reliable and provide a higher level of operational performance.