



HP ultrium  
tape drive

Data Rate Matching  
technology overview

## Introduction

As tape drive technology progresses and the data transfer rates possible increase with each new generation one of the challenges to be faced is the need to reposition or stream-fail when the host is not capable of supplying data to the tape drive fast enough. This can result in additional wear and tear on the drive and stress on the media, which in turn leads to reduced reliability and potentially early mechanical failure. Just having a larger buffer is not the answer as this cannot prevent stream fails as the drive and host speeds will still be mismatched. Something better is needed, and that is the real time Data Rate Matching feature that is unique to the HP Ultrium LTO tape drive family.

The Data Rate Matching or DRM feature in the HP Ultrium LTO tape drives uses two methods to overcome the streamfail problem; these are Adaptive Tape Speed and Buffer Management. The Adaptive Tape Speed or ATS function works by adjusting the speed of the tape so that the rate the drive is writing or reading data exactly matches the rate the host computer is supplying or receiving the data. The ATS function does this by continuously monitoring the data throughput of the drive, and adjusting the speed of the tape drive in real time to match the host data transfer rate. In most applications the ATS function completely eliminates the need for the tape drive to reposition. Below the range of the ATS function the HP Ultrium LTO tape drives use Buffer Management to ensure uninterrupted data flow to or from the host and minimize tape repositions.

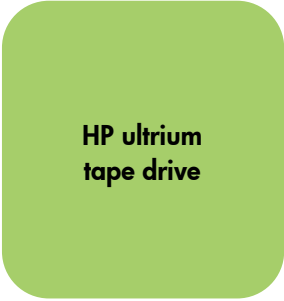
## What happens during a reposition?

Each reposition a tape drive has to perform not only causes additional wear the drive mechanism, but also puts additional stresses into the media. During a reposition the tape drive will be required to perform the following steps all in the space of less than 2 seconds: -

- Slow down both reels to a full stop whilst maintaining the proper tension control of the media.
- Reverse the direction of rotation of each reel motor.
- Speed up both reels with the proper tension control to move back down the tape.
- Slow down both reels to a full stop again still maintaining the proper tension control.
- Reverse the direction of rotation of each reel motor again.
- Speed up both reels again to the full tape speed still with the proper tension control.
- Reposition the heads to get back on track.
- Then continue writing from where it left off

The above process needs to be repeated every time a drive performs a reposition. All of this will not only put additional wear and tear into the mechanism and obvious stress into the media, but will also require a lot more power to slow down and speed up the reels so quickly. Repeated repositions can also significantly affect the tape packing within the cartridge leading to additional problems.

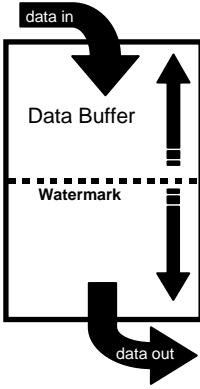
For the family of HP Ultrium LTO tape drives any data transfer rate within the ATS range requires no repositions. The drive will continue to stream write or read and adjusts the tape speed so that the drive data transfer rate exactly matches that of the host, clearly this puts much less stress on the mechanism and media and requiring only a fraction of the power.



### HP LTO Adaptive Tape Speed fundamentals

The ATS system works by monitoring the amount of data in the drives buffer 1000 per second. In steady state (streaming) operations, the buffer is maintained at half full. If the amount of data in the buffer starts to increase or decrease, the tape speed is adjusted, and as the density of the data written to tape always remains unchanged, the effective transfer rate of the drive is therefore changed. This brings the level of data in the buffer back to the control point (watermark).

To maintain the data transfer during a write operation, as the drive approaches the end of a wrap the ATS system will empty the buffer. Whilst the drive performs the end of wrap turnaround and the head assembly locks onto the next wrap, the buffer is allowed to fill. After the drive starts writing again on the new wrap the amount of data in the buffer is reduced back to the watermark level.



- Data buffer fills up:
- Increase tape speed (backup)
  - Reduce tape speed (restore)
  - Managed at end of wrap (restore)

- Data buffer empties:
- Reduce tape speed (backup)
  - Increase tape speed (restore)
  - Managed for end of wrap (backup)

Figure 1: ATS Operation

During a read operation the reverse happens. The buffer is allowed to fill as the drive approaches the end of a wrap; it can then continue to send data to the host whilst the wrap turnaround is executed.

In order to maintain full format compliance and interchangeability it is essential that the density of the data written to tape remains unchanged by these tape speed adjustments. This is achieved by deriving the write clock from the servo signal off the tape. In this way the write clock is always perfectly tuned to the tape speed, and any physical change in the tape speed automatically adjusts the write clock timing keeping the data density absolutely constant. Hence after a tape is written there is no way to tell at what speed it was written and it is still fully format compliant and interchangeable. This feature allows the tape speed to be infinitely variable within the entire ATS range, totally eliminating any repositions.

One of the most impressive features of the ATS system is the huge range of data transfer rates that it can accommodate whilst still streaming the tape drive. The table below shows the transfer rate ranges of the ATS system for the entire HP LTO tape drive family.

HP LTO tape drive	ATS data transfer rate ranges	
	native transfer rate	2:1 compression
HP LTO1 tape drive	6 to 15 MB/s	12 to 30 MB/s
HP half height LTO1 tape drive	6.6 to 16 MB/s	13.2 to 32 MB/s
HP LTO2 tape drive	10 to 32 MB/s	20 to 64 MB/s
HP half height LTO2 tape drive	8 to 24 MB/s	16 to 48 MB/s
HP LTO3 tape drive	27 to 80 MB/s	54 to 160 MB/s
HP half height LTO3 tape drive	27 to 60 MB/s	54 to 120 MB/s
HP LTO4 tape drive	40 to 120MB/s	80 to 240 MB/s



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Throughout the entire streaming host transfer rate range the Adaptive Tape Speed system monitors the amount of data in the drives buffer 1000 times a second and adjusts the tape speed accordingly to perfectly match the host transfer rate. This vastly reduces the need for repositioning, thus improving reliability and increasing throughput.

For host transfer rates below the ATS range, the Data Rate Matching function uses Buffer Management. The data buffer in all the HP LTO tape drives can hold enough data to allow uninterrupted data transfer to or from the host. Less buffer memory is required because of the lower transfer rate at which the drive can start streaming because of the ATS system, and also because the reposition takes significantly less time to complete due to the lower tape speed. The result is a system that matches the data throughput of the system at all host data rates whilst minimising the repositions required.

### HP LTO Data Rate Matching design objectives

The design objectives of this unique function were:

- Increase the drives reliability by reducing the number of repositions needed.
- Minimise the wear on the mechanism as a result of repositioning.
- Minimise the stress on the media as a result of repositioning.
- Minimise the power requirements for the drive by reducing the number of repositions needed.

The data rate matching functionality unique to all the HP LTO tape drives satisfies all the above objectives as it greatly reduces the need for tape repositions, hence wear and tear on the mechanism and stress on the media is reduced, and the life span of both is increased. Every time a tape drive performs a reposition it increases the probability of a failure. The HP LTO Data Rate Matching functionality significantly reduces this probability.

### Advantages of data rate matching over drives with large buffers

The clear advantage of the data rate matching function over the use of a large buffer is the reduction in the number of repositions that a drive needs to perform. If a drive has no DRM function and only a large buffer then it will continue to streamfail at all data transfer rates up to the drives nominal data transfer speed. This will dramatically increase the number of repositions required as is the case with the IBM LTO1 drive which has no DRM function. The IBM drive still needs to reposition right up to the full streaming transfer rate of 15MB/s whereas the HP LTO1 tape drive will stop repositioning all together at any transfer rate over 6MB/s.

For LTO2 tape drives and later generations the affect is not so dramatic because after the release of the HP Ultrium LTO1 tape drive with the unique DRM feature; the other drive manufacturers realized the power of data rate matching and attempted to implement a similar function in their tape drives.

### What about other manufacturers?

The power of the HP Data Rate Matching feature in all the HP Ultrium LTO tape drives was recognised by the other manufacturers and they have attempted to implement a similar feature in their drives. The main differences between the HP implementation and the others manufacturers are that with the HP DRM feature the data transfer speed of the drive is infinitely variable over the entire ATS range, and that the HP implementation does real time speed adjustments so that the data transfer speed of the tape drive is constantly matched to that of the host. The other manufacturers have a stepped speed version in which the tape drive has only a few discrete speeds that it can run at and these speeds cannot be selected without interrupting the data transfer with a reposition or at end of wrap.



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### **Infinitely variable vs. stepped response**

The HP DRM feature provides an infinitely variable data transfer rate over the entire ATS range; however the IBM and Quantum implementations use a stepped system. What this means is that the HP Ultrium LTO tape drives can stream at any speed what so ever within the ATS range, whereas the others have only a few discreet speeds they can select from. One of the main design requirements of the HP DRM system was to reduce and if possible eliminate the need for the drive to do any reposition. To do this the drive must be able to run at what ever speed the host is supplying or taking data. In a stepped implementation this is not possible as host transfer rates fluctuate constantly, hence if the drive picks a speed below that of the host then the drives buffer will fill up and the drive will have to hold off the host to give it time to catch up; slowing overall system performance. If the drive picks a speed above that of the host then the drives buffer will empty requiring the drive to do a reposition in order to give the host time to catch up. This will put extra wear and tear on the drive and media and is the very thing we are trying to avoid.

So whilst the number and frequency of repositions is reduced with the stepped implementation they have not been totally eliminated as they have with the HP implementation at any host transfer rate within the ATS range.

### **Real time adjustments vs. reposition adjustments**

The HP implementation provides real time adjustments of the drives data transfer rate as the tape drive checks and adjusts its speed 1000 times a second. In this way the drive will exactly follow what ever the host is doing, irrespective of how fast or slow the host transfer rate is changing. As the host speeds up or slows down the HP drive will respond immediately to match. In a stepped speed system like that in the IBM and Quantum tape drives the drive is faced with a dilemma. If it responds immediately it must perform a reposition in order to pick a new speed and the tape speed will jump up and down as the drive struggles to match the host and the number of repositions will increase. If the IBM and Quantum drives don't respond immediately then there is the chance the drives data buffer will empty, again causing a reposition, or fill causing a drop in overall system performance, both of which are undesirable. In the HP implementation the speed adjustments are real time and continuous and no repositions are needed clearly putting much less stress on the drive and media.

### **Conclusion**

The real time infinitely variable data rate matching system unique to the HP LTO drives continuously adjusts the tape speed matching the drives effective data transfer rate to that of the host. Repositions are greatly reduced, and in many systems completely eliminated. This significantly reduces the physical wear and tear on the drive mechanism, the stress on the media, and the power required by the drive. The probability of errors is therefore greatly reduced and the data transfer is streamlined. The durability and reliability of the product are therefore improved and the overall efficiency is maximised.

In addition the real time infinitely variable data rate matching system offers significant advantages over a stepped speed implementation as speed changes are continuous rather than big jumps and can be achieved without the need of a reposition or waiting for the end of wrap. The HP drive can respond immediately to any speed changes from the host rather than having the possibility of continued repositions, or worse, degrading system performance.