Technical White Paper

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Iomega® REV™ Drive
Data Transfer Performance

Understanding Potential Transfer Rates and Factors Affecting Throughput

iomega REV™

Introduction

Iomega's revolutionary Removable Rigid Disk (RRD) technology provides the speed, reliability, and ease-of-use of a hard drive with the portability and expandability of tape and optical media. While based on standard hard drive components, the removable Iomega RRD disk contains only the magnetic media and spindle hub and motor for greater durability – all the sensitive drive heads and electronics remain in the drive itself. Both the drive and disks are sealed by a unique shutter mechanism designed to keep the heads and media in a virtual "clean room" environment. Advanced air filtration, automatic head cleaning, and robust two-stage error correction are employed to ensure high data integrity and reliability.

The Iomega® REV™ 35GB/90GB* drive system is the first of the company's RRD-based family of products. With its high speed, capacity, and removable media, the Iomega REV products are the ideal solution for desktop and server-level backup as well as high-capacity, portable storage applications.

Iomega has gone to great lengths to ensure that the REV drive is among the fastest technologies, thereby reducing backup times and increasing overall productivity. This paper discusses the potential transfer rates of the Iomega REV drive and the factors that can influence the system's data transfer throughput.

Maximum Sustained Transfer Rate

Maximum sustained transfer rate is defined as the highest data transfer rate for reading and writing large blocks of user data. This includes the time to seek, settle and continue the transfer on an adjacent track when the data transfer exceeds the capacity of a single track. It does not include any overhead from the host operating system or access time to begin the transfer.

Maximum transfer rates are achieved at the outer diameter of the disk. The transfer rate will decrease as the heads move from the outside diameter (OD) to the inside diameter (ID). This variation is due to the amount of data contained on each track. There are more data sectors on the outer tracks; therefore, more data is transferred on each rotation of the disk. As the heads move from one data zone to the next, the transfer rates change in a predictable stair-step pattern.

While it is unlikely that most drives will achieve their theoretical maximum transfer rates, Iomega believes that the REV drives will perform very close to these maximum rates under typical user conditions.

* Compressed capacity assuming 2.6:1 data compression with "high" compression on Iomega Automatic Backup Pro software. Capacity may vary and is data and software dependent.

Track Format Specifications for 35GB REV Drive:

- 864 sectors/track (OD)
- 432 sectors/track (ID)
- 512 Bytes/sector
- Error Correction Code (ECC) uses six sectors for every 128 sectors of user data (user data ratio = 128/134)
- 4,200 RPM
- 2.38 ms track-to-track skew

Theoretical sustained transfer rate at OD:

$$\frac{\left(864\ \frac{\text{sectors}}{\text{track}}\right)\cdot\left(\frac{128\ \text{sectors}}{134\ \text{sectors}}\right)\cdot\left(512\ \frac{\text{Bytes}}{\text{sectors}}\right)}{\left(60\ \frac{\text{seconds}}{\text{minute}}\right)\cdot\left(\frac{1}{4200\ \ \text{RPM}}\right)+0.00238\ \text{seconds}} = 25.4\times10^{6}\ \text{Bytes/second}$$

Theoretical sustained transfer rate at ID:

$$\frac{\left(432\ \frac{\text{sectors}}{\text{track}}\right)\cdot\left(\frac{128\ \text{sectors}}{134\ \text{sectors}}\right)\cdot\left(512\ \frac{\text{Bytes}}{\text{sector}}\right)}{\left(60\ \frac{\text{seconds}}{\text{minute}}\right)\cdot\left(\frac{1}{4200\ \text{RPM}}\right)+0.00238\ \text{seconds}} = 12.7\times10^{6}\ \text{Bytes/second}$$

These rates are theoretical maximums and do not include overhead from the operating system (OS) or application software. They also do not include any time for defect management, such as flagged sectors, flagged tracks or retrying of soft errors. The overall time added by defect management should be very small on a typical drive/disk system.

Burst Transfer Rate

The burst rate of the drive is determined by the maximum transfer rate supported across the host interface. The AT Attachment Packet Interface (ATAPI) drive supports Ultra Direct Memory Access (UDMA) Mode 5 and is capable of transferring data across the interface at a rate of 100 MB/s. The Universal Serial Bus (USB) interface drive supports USB 2.0 and can transfer data across the interface at 60 MB/s. The burst rate is the rate at which the data can be transferred into or out of the drive's electronic data buffer.

Factors Affecting Performance

Many factors act together to result in actual system level performance. Generally, these factors decrease actual throughput from the maximum sustained transfer rate. This decrease from the theoretical maximum occurs because various factors act as data transfer bottlenecks. The factors can be categorized under three headings: host related, drive related and application software related. The host and application software issues are not under control of the drive.

Host Related Issues

1. **64KB boundaries**
   Data on the disk is written in 64KB blocks, with an additional 3.5KB of ECC data to protect the user data in case of errors when trying to read it back. Whenever any data within that 64KB block is written, the ECC data must be recalculated and rewritten. Transfers onto the disk are most efficient when data from the host starts and ends on 64KB address boundaries. Transfers that are not aligned to block boundaries require the drive to take additional time to read information off the disk before being able to calculate the ECC data and write it back onto the disk.

2. **Host configuration**
   If the ATA interface in the host computer is not configured to support high-speed UDMA transfers, then any ATAPI drive on the interface runs significantly slower. Although Iomega tools optimize this configuration when customers install the REV System Software, it can be changed subsequently by the user, operating system and other applications.

3. **USB plug-in cards**
   Most USB 2.0 plug-in cards are not as fast as the USB 2.0 interfaces that are built onto motherboards. In most cases, the transfers are being broken in 512-byte blocks with a delay between each block of data. Iomega expects that the manufacturers of these cards will eventually fix this problem.

4. **Host overhead**
   In a backup application, the operating system or software could cause delays that allow the drive's buffer to run dry between write commands. If this happens, the maximum transfer rate of the drive cannot be achieved. The same problem occurs during read operations if the host delays emptying the drive's buffer and allows it to become full.

Drive Related Issues

1. **High error rate**
   Unusually high soft error rates can cause delays in writing or reading from the drive. When reading data from the disk, the ECC on the drive is capable of correcting 24 bytes of data on the fly in each sector without affecting performance. Defects as large as seven sectors in length in each ECC 64KB block can also be corrected, but not without affecting data transfer performance. Defects beyond these limits require additional disk revolutions and retries to retrieve the data, thereby slowing the overall data transfer rate.

2. **Write-Behind-Cache turned off**
   Write-behind-cache means the drive tells the host that the transfer has completed successfully once the drive has received all the data into its buffer. Sending completion status to the host before the data is written onto the disk keeps the drive's data buffer filled and avoids taking extra disk rotations while waiting for data from the host. The only way to guarantee that the data can be successfully transferred to the disk without failure is to have spare locations where the data can be moved if a problem is found in the normal data area. Normally, the data caching by the drive is turned on by default. Caching is turned off by the drive when it is determined that insufficient spares are available to guarantee that data can be written to the disk successfully. Iomega REV disks are designed with a large number of spares to make this occurrence highly unlikely.

3. **Shock and vibration**
   Drives placed in areas that receive periodic shocks or continuous vibration will take longer to seek and settle. If every seek takes an extra rotation of the disk because of increased settling time, a large sequential data transfer could take nearly twice as long to complete.

4. **Reallocated sectors**
   Occasionally a sector becomes either unreadable or unwriteable. When this happens, the drive will reallocate the sector automatically to another physical location (typically on a different track). A small delay occurs whenever this address area is accessed during future data transfers because the drive must seek the spare sectors and then seek access to the remaining data. Whenever a format command is completed by the drive, all sectors that had been reallocated are restored into sequential order.

Application Software Related Issues

Transfer rates, as measured at the application level, are primarily affected by how fast the application can acquire data and then writes this data to the drive. In order for an application to produce maximum transfer rates, the application must be capable of sending data to the drive at or above the maximum transfer rate of the REV drive. In addition, data must be sent to the drive in 64KB data blocks. Writing large files is also much more efficient than writing small files because of the associated file structure overhead.

1. **Drag-and-drop with Microsoft® Explorer**
   Drag-and-drop performance is primarily affected by the size and number of files to be transferred. Dragging and dropping small files (less than 64KB) results in much lower data transfer rates because of the associated file/directory structure overhead. Appendix A provides a comparison of drag-and-drop performance by file size for the Iomega REV drive and a 4x DVD+RW drive using the UDF file system and external 2.5″ 4200 rpm ATA hard disk drives using both NTFS and FAT32 file systems.

2. **Backup applications**

Backup application performance is affected primarily by how fast the application can read data from the source drive and prepare that data for writing to the REV drive. The application must be able to read, prepare and transfer the data quickly enough to keep the drive buffer from running dry between write commands. Backup applications that write data in 64KB data blocks and then write the backup data to a large file will see the highest data transfer rates. Using a software compression option in the backup software typically will decrease the application's maximum sustained transfer rate. Appendix B highlights the results of a comparison of backup application transfer rates to the REV drive and other HDDs.

Conclusion

As shown, the maximum theoretical transfer rate for REV drives is 25.4 MB/s, although this transfer rate does change as the heads move from the outside diameter of the disk to the inside. The maximum theoretical rates vary from 25.4 MB/s at the OD to 12.7 MB/s at the ID. The actual speeds experienced by users will vary, depending where on the disk the data is being accessed and all the other factors previously discussed.

Backup and restore times can be greatly affected by backup application efficiency and how the data is broken up when reading and writing to the drive. Drag-and-drop as well as copy-and-paste performance is affected dramatically by the size and number of files copied. The Iomega REV drive has been optimized for writing addresses that start and stop on 64KB boundaries. Using Iomega REV System Software ensures that the system transfers at the maximum potential and optimal drive performance is achieved.

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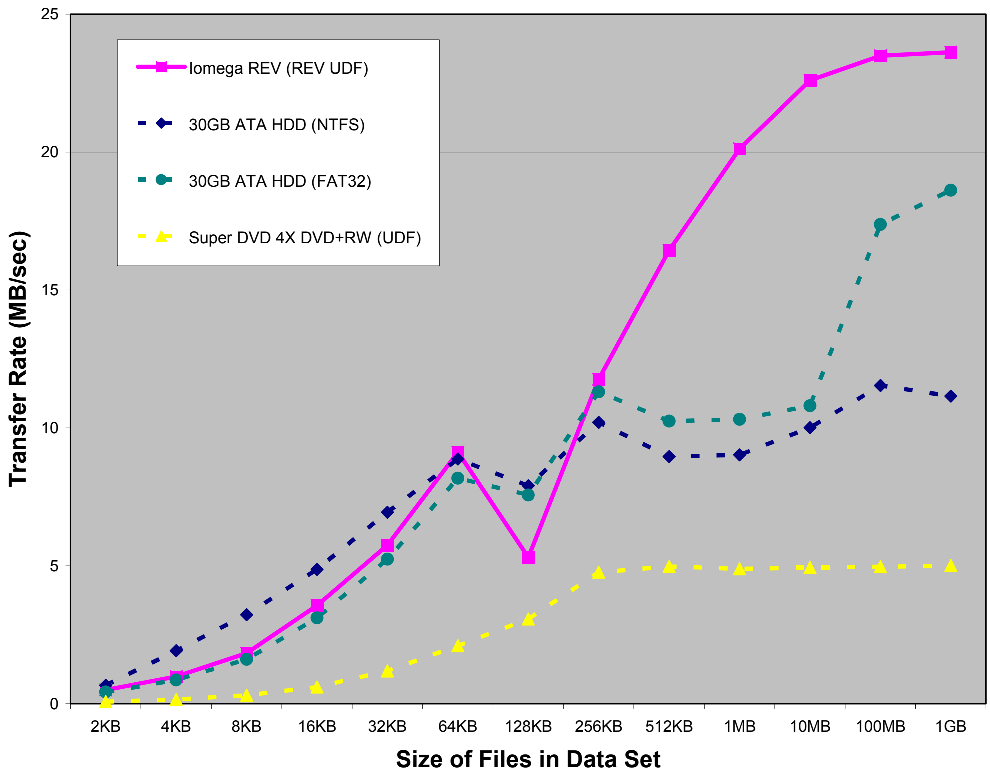
Appendix A

Drag and Drop File System Transfer Rate Performance by File Size Set for the Iomega REV and DVD+RW drives, and 2.5" 4200 RPM ATA HDDs



Appendix B

Backup Application Performance

System Configuration

Motherboard: Intel
CPU: Intel Pentium 4 3.06 GHz
Memory: 1.00 GBytes
File set: Calgary Corpus duplicated file set
4,788 files
1,075,335,124 bytes

NT Backup for Windows XP Professional

Backup Set Size (bytes)	Source Drive	Destination Drive	Elapsed Time	MB/s
1,075,335,124	Hitachi 160GB 7200 rpm	WD 10,000 rpm SATA	1 min. 43 sec.	10.44
1,075,335,124	Hitachi 160GB 7200 rpm	External USB HDD	1 min. 41 sec.	10.66
1,075,335,124	Hitachi 160GB 7200 rpm	Iomega USB REV	1 min. 47 sec.	10.05
1,075,335,124	Hitachi 160GB 7200 rpm	Iomega USB ATAPI	1 min. 48 sec.	9.96

Dantz Retrospect 9.0

Backup Set Size (bytes)	Source Drive	Destination Drive	Elapsed Time	MB/s
1,075,335,124	Hitachi 160GB 7200 rpm	WD 10,000 rpm SATA	0 min. 31 sec.	34.69
1,075,335,124	Hitachi 160GB 7200 rpm	External USB HDD	0 min. 59 sec.	18.23
1,075,335,124	Hitachi 160GB 7200 rpm	Iomega USB REV	1 min. 09 sec.	15.59
1,075,335,124	Hitachi 160GB 7200 rpm	Iomega ATAPI REV	0 min. 51 sec.	21.09