WHITE PAPER

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File Systems and Their Use on Compaq Armada Portable Products

This White Paper explains what a file system is, describes the differences between Microsoft file systems and helps the reader make a more informed choice as to what file system is best for them.

This document is intended for Compaq personnel and customers with a need for information about the files systems used on Compaq Armada Portable products.

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File System White Paper

First Edition (April 1998)
0122-0499-A

1 SUMMARY

This White Paper provides a brief overview of file systems. The advantages and disadvantages of several files systems in use today on Compaq Armada laptops are discussed. This lead to a discussion of which file system is best for a particular user scenario. Lastly, information and instructions are presented on how to switch from FAT16 to FAT32 and FAT16 to NTFS file systems.

2 WHAT IS A FILE SYSTEM?

Different operating systems have different files systems. The file system is that part of the operating system that handles all matters relating to disk drive type storage devices (i. e. floppy diskette drives and hard drives). . An example of functions that would be performed by a file system are opening and saving files from the disk drive.

Partitioning and formatting a disk drive prepares it for use by the operating system and installs the file system on it. Programs used to partition and format are operating system specific. A file system creates several different areas on the disk for the organization of the information stored on it. These are the master boot record, the partition table, the boot record, the file allocation table (from which the FAT file system takes its name and will be the basses of the remainder of this section), and the root directory.

At a low level, disks are organized into 512-byte groupings called sectors. The FAT system allocates space for files using a unit called a cluster, each of which is made up of a contiguous number of sectors. The number of sectors in a cluster must be a power of two. Microsoft calls these clusters 'allocation units'. The FAT is a database that associates clusters of disk space with files.

Each directory, the root directory and all subdirectories, is also a database. An MS-DOS 1.0 – 6.x directory has one main entry for each file. The FAT databases for files contain only one field which points to the contents of the file whereas the entries for a file in a directory or subdirectory have multiple fields. Some of the fields that can be displayed with the MS-DOS command DIR include name, extension, size, date, and time.

When a program requests retrieval of a file from the operating system, the operating system looks at the directory entry for the file to find the first cluster. It then looks at the FAT entry for that cluster to find the next cluster in the chain, repeating this process until it encounters the last cluster for the file.

For a brief history of various Microsoft file systems, see Appendix A.

3 FILE SYSTEM SUPPORT BY OPERATING SYSTEM FOR ARMADA LAPTOPS

The primary operating systems on Compaq Armada family of notebooks are MS-DOS/Windows 3.1x, Windows 95 (Retail/OSR1 and OSR2.x), Windows NT Workstation (NTW) 3.51 and 4.0. The file systems supported in each operating system are shown in the table below.[1]

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[1] Windows 95 and Windows NT have an Installable File System (IFS). The IFS adds support for files systems that did not ship with the operating system itself. Examples would be NFS (Network File System) favored by the Unix operating system and the Apple Macintosh's HFS Hierarchical File System.

	MS-DOS / Windows 3.1x	Windows 95 OSR1[2]	Windows 95 OSR2	Windows NTW 3.51	Windows NTW 4.0
FAT16	✔	✔	✔	✔	✔
FAT32			✔		
NTFS				✔	✔

4   WHAT IS A CLUSTER AND WHY DOES IT MATTER?

A cluster is the smallest amount of disk space that can be allocated to a file. In other words, a file will be at least one cluster in size and will more than likely be more than one.

To determine how many clusters a file will use, the file size is divided by the cluster size and rounded up. The difference between the file size and space allocated to the file is 'slack' or wasted space[3].

Smaller clusters are more efficient because they reduce the potential for wasted space. With FAT16, which can use large clusters, estimates of wasted space range from 2 to 40%. The amount of wasted space for a particular drive can be estimated with the following formula:

$$\text{(Cluster size} * \text{(\# of Directories} + \text{\# of Files}[4])/2)$$

Microsoft recently released a utility to determine how space could be gained by converting an existing system from FAT16 to FAT32[5]. This utility can be found at http://www.microsoft.com/windows98/info/fat32.htm.

When you use smaller cluster sizes, all files larger than the cluster size will be made up of more than one cluster. Thus they can become fragmented over time. If a file is fragmented, it means that its clusters are not physically located next to each other on the disk. This will cause delays when reading the file from the disk. Larger cluster sizes, relative to an operating system, in contrast will improve performance but potentially waste more space. It should be noted however, that Microsoft has made improvements to the FAT32 file system, which helps to overcome some of the performance degradation of using smaller clusters.

Microsoft supplies a utility for the Windows 95 operating system called 'Disk Defragmenter.' By running this program, the fragmented files will be rewritten to the hard drive so that their clusters are continuous. A similar program for NTW is not included with the operating system[6].

FAT16 gives the user no control of the cluster size. The size of the partition determines what cluster size will be used. The table below shows the partition and cluster sizes for FAT16 partitioned hard drives.

Partition Size	Cluster Size
0 MB - 15 MB	4K
16 MB - 127 MB	2K
128 MB - 255 MB	4K
256 MB - 511 MB	8K
512 MB - 1023 MB	16K
1024 MB - 2048 MB	32K

[2] Windows 95 OSR1 was installed on the Armada 1510, 1520, 1550, 4110, & 4120.
[3] Mathematically this would be Wasted Space = (Cluster Size* Number of Clusters) - File Size.
[4] Including hidden and system files
[5] Windows 98 will have a program called Drive Converter to convert between FAT16 and FAT32. Microsoft KB Article Q180134
[6] There are 3rd party software companies who supply these types of utilities. Compaq does not recommend any specific vendor and cautions the user to backup all data if choosing to use one.

FAT32 also uses a fixed cluster size, but it is the same for partitions of all sizes. FAT32 uses 4K clusters.

NTFS partitions can be formatted with varying cluster sizes controlled by the user. They range from 512 bytes to 4K. If the user does not specify what size cluster to use, a default cluster size will be used depending upon the partition size. The table below shows the default cluster size for NTFS formatted drives.

Partition Size	Cluster Size
0 MB - 511 MB	512 bytes
512 MB - 999 MB	1K
1 GB – 1.99 GB	2K
2 GB and grater	4K

5   FILE SYSTEMS CHARACTERISTICS

The following table outlines various characteristics of the different file systems supported on Compaq Armada notebooks.

	FAT16	FAT32	NTFS
Supported by Windows 95 OSR1	✔		
Supported by Windows 95 OSR2	✔	✔	
Supported by Windows NTW 4.0	✔		✔
Supports hot fixing			✔
Supports file level security			✔[7]
Ability to undelete a file	✔	✔	
Number of entries in root directory	256	Unlimited	Unlimited
Maximum number of files	65,535	Unlimited[8]	Unlimited[9]
Maximum partition size	2GB[10] [11]	2TB[12]	16EB[13]

6   CONVERTING BETWEEN FILE SYSTEMS

6.1 FAT16 to FAT32

There are no utilities from Microsoft for the Windows 95 operating system to convert a hard drive between the FAT16 and FAT32 file systems[14].

If the hard drive partition is over 512MB, you may convert it by enabling large disk support by repartitioning and reformatting the hard drive. In doing so, you will erase the operating system,

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[7] NTFS does not provide native encryption capability. Any low level disk editor would be to read the contents of the files.
[8] Only constrained by disk capacity
[9] Only constrained by disk capacity
[10] Gigabyte – 2 to the 30th power or 1,024 megabytes (2 to the 20th power or 1,048,576 bytes)
[11] 2GB in Windows 95/MS-DOS, 4GB in Windows NTW
[12] Terabyte – 2 to the 40th power or 1,024 gigabytes
[13] Exabyte – 2 to the 60th power or 1,024 petabytes (2 to the 50th power or 1,024 terabytes)
[14] Windows 98 will have a program called Drive Converter to convert between FAT16 and FAT32. Microsoft KB Article Q180134

programs, and all data on the hard drive. Therefore, **you should do a complete backup of the operating system, registry and all data before attempting any conversion**.

1. Backup your entire hard drive[15].
2. Boot the system with a Windows 95 OSR2 Boot Disk.
3. Type FDISK from the A:> prompt and press ENTER.
4. Press ENTER to enable large disk support
5. Choose option 3 and ENTER – Delete partition or Logical DOS Drive.
6. Choose option 1 and press ENTER – 1 - Delete Primary DOS Partition.
7. You will be prompted for the partition number. Verify which partition is to be deleted and supply that number and then press ENTER.
8. Enter the volume label if applicable and press ENTER.
9. You will be asked to confirm the deletion, answer Y and ENTER.
10. Press ESC(APE) to return to the main FDISK menu.
11. Press 1 and then ENTER – Create DOS partition or Logical DOS Drive.
12. Press 1 and then ENTER – Create Primary DOS Partition.
13. You will be asked if you wish to use the maximum available size partition, Press Y and then ENTER.
14. Press ESC(APE).
15. Restart the system with the boot disk inserted into the diskette drive. To restart the system, simultaneously press and hold the CTRL, ALT, and DEL keys.
16. Format the hard drive by typing FORMAT C:/s at the A:> prompt.
17. Restore your operating system and data files from the backup created in step 1.

There are third-party party software applications that convert hard disk partitions between the various file systems including FAT16, FAT32, and NTFS. Compaq does not recommend any specific vendor and cautions the customer to thoroughly investigate any of these utilities before using one.

6.2 FAT16 to NTFS

If you wish to convert your C: drive from the factory format of FAT16 to NTFS, follow the instructions outlined below. **Backup your entire system, including the system registry before the conversion**. Once you convert to NTFS, Microsoft does not support any tools to change the file system back to FAT16.

- From a 'Compand Prompt' window, type CONVERT C: /FS:NTFS. The message '*The type of the file system is FAT. Convert cannot gain exclusive access to the C: drive, so it cannot convert it now. Would you like to schedule it to be converted the next time the system restarts (Y/N)?'* Type Y and press enter.
- Restart the system.
- During the conversion, the operating system will display a status.
- The system will reboot again to finish the conversion process.

Your file system has now been converted to NTFS.

7 WHICH FILE SYSTEM IS RIGHT FOR YOU?

Unfortunately, there is no simple answer to this question. Every operating system installation is different as the needs of users differ widely. There are many things to consider when making the decision on which file system to use. Among them are:

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[15] There are many different software packages and media available to perform a backup. Consult your IS department for help in selecting the appropriate software and media.

- The advantages and disadvantages of each file system characteristic and operating system support for the file system (see Section 5 on page 5).
- Plans for upgrading the operating system installed on the PC.
- Any legacy or vertical software applications that may have special requirements.[16]
- Capacity of the hard drive.[17]
- Ease or ability of converting the file system in the future.

If the user is unsure which file system is best for them, Compaq makes the following recommendations for its Armada portables:

For all hard drives under 4GB, the file system should be FAT16. The reasons include:
- FAT16 is supported by all releases of Windows 95, Windows 98 and Windows NTW.
- The computer can be upgraded from Windows 95 to Windows NTW without the need of repartitioning or reformatting the hard drive.
- It is the most widely supported file system by legacy applications.

For hard drives over 4GB, FAT32 is generally the best choice for Windows 95 OSR2[18] and NTFS is generally the best choice for Windows NTW. These choices will allow all space on the hard drive to be usable and can be partitioned as a single logical drive.

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[16] Some applications may not be able to understand what size hard drive the computer has depending upon when the application was written and what assumptions the programmer made. As an example, programs often ask the operating system how much free space is available on the hard drive. If the program was expecting a number no larger than 32MB and it is given the value 4GB, anomalies may occur because the program's mathematical formulas will return numbers different than expected (i.e. negative numbers).
[17] FAT32 does not support hard drives less than 512MB.
[18] Customers using Windows 95 OSR1 on hard drives larger than 4GB will not be able to use all of the space since OSR1 does not support FAT32 or NTFS as noted in section 5.

A. APPENDIX A - A BRIEF HISTORY OF PERSONAL COMPUTER FILE SYSTEMS

A.1 FAT

In 1981, Microsoft's MS-DOS 1.0 was released, on diskette, for the IBM personal computer. The MS-DOS file system, FAT (named for its file allocation table) provided more than enough power to format these small diskettes and to manage the hierarchical directory structures and files. It supported 11 character names (8.3 – 8 characters for the name and 3 for the extension i.e. FILEFOUR.TXT). It became known as FAT12.

Version 2.0 added support for hard drives of up to 15MB. The FAT12 file system continued to meet the needs of personal computer users that now added the hard drives to their computers. However, file searches and data retrieval took significantly longer on hard drives than on the original low-density floppy diskettes because of their size. The user could have two hard drives with a total storage capacity of 30MB.

By the mid-1980s MS-DOS had reached version 3.0 which changed the file system from FAT12 to FAT16. FAT16 supported hard drives of up to 32MB in size. It wasn't until MS-DOS 3.3 that support for more than one hard-drive partition was available. Users could now have up to two partitions per hard drive giving them access to 128MB of storage (two drives with two 32MB partitions each).

With MS-DOS version 4.0, released in 1988, support for up to a 2GB partition on a hard drive was added. This meant that the maximum theoretical storage space available was 8GB (two drives with two 2GB partitions each). However, hard drives were still relatively very expensive, and the most common large hard drive was 200MB.[19]

A.2 HPFS

HPFS (high-performance file system) was designed by Microsoft to address some of the limitations of the FAT file system. It is not supported by any currently shipping Microsoft operating system[20] and is included here only for continuity purposes. HPFS supported hard disks and partitions up to 2048 GB, improved performance versus MS-DOS' FAT16, and allowed for the hot fixing the file system if a bad spot was detected on the hard drive. Support for file names longer than 11 characters was added but did not included the ability to use spaces or preserve case sensitivity.

A.3 NTFS

NTFS is the native file system for Windows NT. It built upon the improvements of HPFS. It added a transaction log that allowed file system operations to be rolled back to recover from errors, multiple data streams, POSIX support and support for files and volumes of up to 16 exabytes.[21]

A.4 FAT32

FAT32 was introduced with Windows 95 OSR2. OSR2 is only available preinstalled by OEM computer system vendors like Compaq. FAT32 was based upon FAT16 but added support for long filenames and hard drive partitions over 2 GB (up to 2 TB). Additional improvements are more efficient storage through the use of smaller clusters and reliability enhancements.[22]

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[19] Microsoft KB Article Q69912
[20] Windows NT supports booting from a HPFS partition but the operating system itself can not be installed on a HPFS partition.
[21] Microsoft KB Article Q100108
[22] Microsoft KB Article Q154997