Active@ File Recovery

User Guide

Version Number 2.0

Active@ File Recovery 2.0 END-USER LICENSE AGREEMENT

IMPORTANT-READ CAREFULLY

This End-User License Agreement ("EULA") is a legal agreement between you (either an individual or a single entity) and The

Active Data Recovery Services for the Active@ File Recovery later referred to as 'SOFTWARE'. By installing, copying, or otherwise using the SOFTWARE you agree to be bound by the terms of this EULA. If you do not agree to the terms of this EULA, do not install or use the SOFTWARE.

WE REQUIRE ALL OUR DEALERS TO PROVIDE EACH PURCHASER WITH FREE DEMO OF THE SOFTWARE TO GET A FULL UNDERSTANDING OF THE CAPABILITIES AND THE EASE OF USE OF THE SOFTWARE. OUR DEALERS HAD TO RECOMMEND YOU TO DOWNLOAD DEMO. WE WON'T ISSUE ANY REFUNDS AFTER PURCHASING FULL VERSION OF THE SOFTWARE.

Active Data Recovery Services may have patents, patent applications, trademarks, copyrights, or other intellectual property rights covering subject matter in this document. The furnishing of this document does not give you any license to these patents, trademarks, copyrights, or other intellectual property.

SOFTWARE LICENSE

1. The SOFTWARE is licensed, not sold. Copyright laws andinternational copyright treaties, as well as other intellectual property laws and treaties protect the SOFTWARE.

2. GRANT OF LICENSE.

(a) FREE DEMO COPY. You may use the full featured DEMO SOFTWARE without charge on an evaluation basis to recover any files having size less than 32Kb. You must pay the license fee and register your copy to recover files bigger than 32Kb in size.

(b) REDISTRIBUTION OF DEMO COPY. If you are using DEMO SOFTWARE on an evaluation basis you may make copies of the DEMO SOFTWARE as you wish; give exact copies of the original DEMO SOFTWARE to anyone; and distribute the DEMO SOFTWARE in its unmodified form via electronic means (Internet, BBS's, Shareware distribution libraries, CD-ROMs, etc.). You may not charge any fee for the copy or use of the evaluation DEMO SOFTWARE itself, but you may charge a distribution fee that is reasonably related to any cost you incur distributing the DEMO SOFTWARE (e.g. packaging). You must not represent in any way that you are selling the software itself. Your distribution of the DEMO SOFTWARE will not entitle you to any compensation from Active Data Recovery Software. You must distribute a copy of this EULA with any copy of the Software and anyone to whom you distribute the SOFTWARE is subject to this EULA.

(c) REGISTERED COPY. After you have purchased the license for SOFTWARE, and have received the registration key and the SOFTWARE distribution package, you are licensed to copy the SOFTWARE only into the memory of the number of computers corresponding to the number of licenses purchased. The primary user of the computer on which each licensed copy of the SOFTWARE is installed may make a second copy for his or her exclusive use on a portable computer. Under no other circumstances may the SOFTWARE be operated at the same time on more than the number of computers for which you have paid a separate license fee. You may not duplicate the SOFTWARE in whole or in part, except that you may make one copy of the SOFTWARE for backup or archival purposes. You may terminate this license at any time by destroying the original and all copies of the SOFTWARE in whatever form. You may permanently transfer all of your rights under this EULA provided you transfer all copies of the SOFTWARE (including copies of all prior versions if the SOFTWARE is an upgrade) and retain none, and the recipient agrees to the terms of this EULA.

3. RESTRICTIONS. You may not reverse engineer, decompile, or disassemble the SOFTWARE, except and only to the extent that such activity is expressly permitted by applicable law notwithstanding this limitation. You may not rent, lease, or lend the SOFTWARE. You may permanently transfer all of your rights under this EULA, provided the recipient agrees to the terms of this EULA. You may not use the SOFTWARE to perform any unauthorized transfer of information (e.g. transfer of files in violation of a copyright) or for any illegal purpose.

4. SUPPORT SERVICES. Active Data Recovery Services may provide you with support services related to the SOFTWARE. Use of Support Services is governed by the Active Data Recovery Services polices and programs described in the online documentation and web site, and/or other Active Data Recovery Services-provided materials, as they may be modified from time to time. Any supplemental software code provided to you as part of the Support Services shall be considered part of the SOFTWARE and subject to the terms and conditions of this EULA. With respect to technical information you provide to Active Data Recovery Services as part of the Support Services, Active Data Recovery Software may use such information for its business purposes, including for product support and development. Active Data Recovery Services will not utilize such technical information in a form that personally identifies you.

5. TERMINATION. Without prejudice to any other rights, Active Data Recovery Services may terminate this EULA if you fail to comply with the terms and conditions of this EULA. In such event, you must destroy all copies of the SOFTWARE.

6. COPYRIGHT. The SOFTWARE is protected by copyright law and international treaty provisions. You acknowledge that no title to the intellectual property in the SOFTWARE is transferred to you. You further acknowledge that title and full ownership rights to the SOFTWARE will remain the exclusive property of Active Data Recovery Services and you will not acquire any rights to the SOFTWARE except as expressly set forth in this license. You agree that any copies of the SOFTWARE will contain the same proprietary notices which appear on and in the SOFTWARE.

7. DISCLAIMER OF WARRANTY. Active Data Recovery Services expressly disclaims any warranty for the SOFTWARE. THE SOFTWARE AND ANY RELATED DOCUMENTATION IS PROVIDED "AS IS" WITHOUT WARRANTY OF ANY KIND, EITHER EXPRESS OR IMPLIED, INCLUDING, WITHOUT LIMITATION, THE IMPLIED WARRANTIES OR MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, OR NONINFRINGEMENT. THE ENTIRE RISK ARISING OUT OF USE OR PERFORMANCE OF THE SOFTWARE REMAINS WITH YOU.

8. LIMITATION OF LIABILITY. IN NO EVENT SHALL ACTIVE DATA RECOVERY SERVICES OR ITS SUPPLIERS BE LIABLE TO YOU FOR ANY CONSEQUENTIAL, SPECIAL, INCIDENTAL, OR INDIRECT DAMAGES OF ANY KIND ARISING OUT OF THE DELIVERY, PERFORMANCE, OR USE OF THE SOFTWARE, EVEN IF ACTIVE DATA RECOVERY SERVICES HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES. IN ANY EVENT, ACTIVE DATA RECOVERY SERVICES'S ENTIRE LIABILITY UNDER ANY PROVOSION OF THIS EULA SHALL BE LIMITED EXCLUSIVELY TO PRODUCT REPLACEMENT.

Active Data Recovery Services reserves all rights not expressly granted here.

Active Data Recovery Services is a registered name of LSoft Technologies Inc.

Contents

1 OVERVIEW

What Happened to my Data?

When a file is written to a hard drive, two separate systems come into play:

- Record of that file is kept in the Root Table or Master File Table (MFT)
- Physical hard drive addresses are labelled as 'occupied'. These addresses are physical locations called clusters.

When file is deleted from a hard drive, the same two systems are notified:

- The file record in the Root Table or MFT indicates the file has been deleted.
- Clusters are labeled as 'unoccupied'.

In the event of an accidental file deletion it is strongly recommended to perform the recovery operation as soon as possible. If any new files are written to the same drive, there is a chance that the file-writing process may have allocated these

Welcome to Active@ File Recovery

Active@ File Recovery is a powerful software utility, designed to restore accidentally deleted files and directories in local hard disk and removable storage devices, such as those associated with **CompactFlash** and **SmartMedia** digital cameras. It allows you to recover files that have been deleted from the Microsoft Windows Recycle Bin, as well as those deleted after avoiding the Recycle Bin (for example when using **Shift-Delete**).

Active@ File Recovery can be installed on and run from a floppy disk, so that the risk of overwriting your data is minimized.

Active@ File Recovery will help you to restore data residing on hard drives or floppy drives formatted in any of the following file systems:

- FAT12
- FAT16
- FAT32
- NTFS
- NTFS5

It works under all Windows family operating systems:

- Windows 95
- Windows 98
- Windows ME

- Windows NT
- Windows 2000
- Windows XP

Active@ File Recovery supports:

- Recovery from removable devices such as CompactFlash**,** SmartMedia, Secure Digital / MultiMediaCard, Sony MemorySticks, SunDisk, etc.
- IDE, ATA, SCSI hard drives and floppy disks
- Large sized drives (more than 8 GB)
- Long file names and local language (non-English) file names
- Recovery of compressed and fragmented files on NTFS
- Detection and recovery from deleted or damaged file partitions
- Exact file name or partial file name search
- Disk Image creation and restoring (restores from a backup file that represents a drive)

2 USING ACTIVE@ FILE RECOVERY

This chapter covers the main functions of Active@ File Recovery utility.

(!) *Important: For the safety reasons, the utility warns you if you are trying to write the restored file back into the same drive. A newly created file might overwrite the file under recovery (or a part of it), or the contents of the other deleted files. Always restore files to another logical removable, floppy or network drive.*

(i) *Note: Deleted files and folders differ from the non-deleted ones by icons:*

- Grey icon means that deleted file or folder has a good chance of recovery

- Black icon means that deleted file or folder has a poor chance of recovery because it has been overwritten (or may be partially overwritten) on the disk

Scanning a Drive for Deleted Files and Folders

Run Active@ File Recovery and do one of the following:

Click on the drive and then on the folder that you expect may contain deleted files or folders.

If you want to re-scan a drive or a folder, select it, then click the Scan toolbar button or select Scan from the context menu.

To stop (cancel) scanning process, click the Stop toolbar button.

See Also: Performing Extended Device Scan, Searching for Deleted Files and Folders

Performing Extended Device Scan

Extended device scan is useful when a partition or logical drive has been deleted or damaged. In other words, use it when you are unable to locate a proper drive in the list of drives under Local System Root. When you first click a PHYSICAL DRIVE node under Hardware Devices, a device scan is performed. You might see several Detected virtual drives; however this scan is a regular scan. After partition or drive is detected, the device scanner skips the space that is equal in size to that of the detected drive, and continues scanning. That is why the regular device scan is relatively fast.

Extended Device Scan scans the entire surface of the physical device to locate all possible logical drives and partitions, whether they are existing, damaged or deleted. Extended Device Scan does not skip any space on the HDD and it is relatively long process.

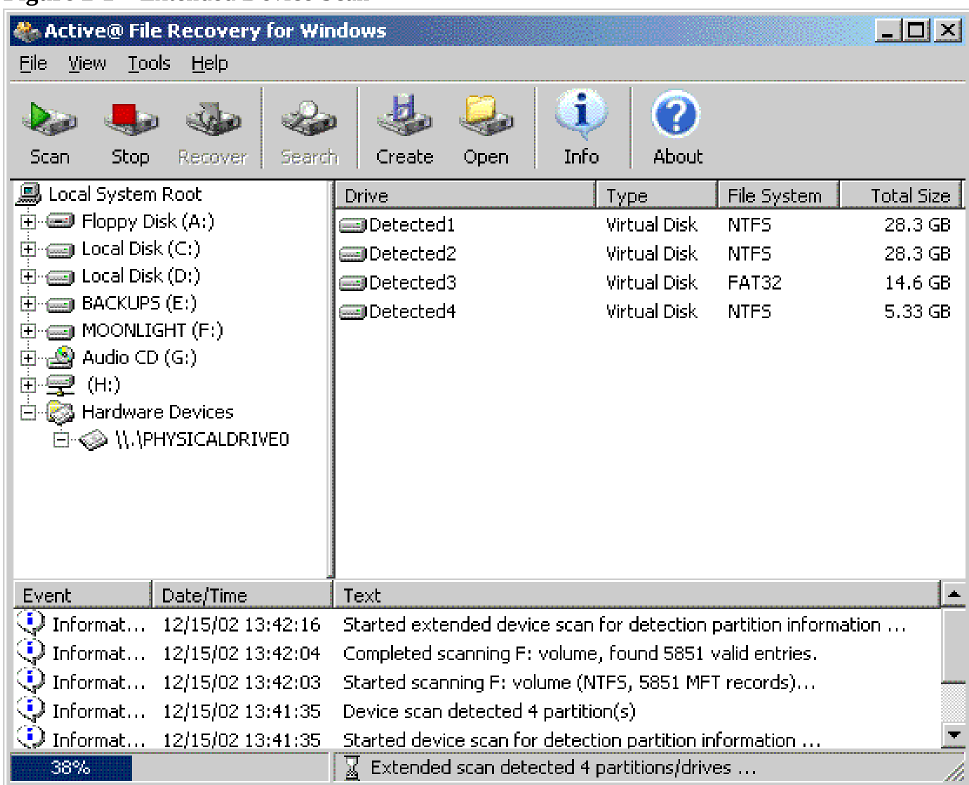
To perform Extended Device Scan do the following:

1 Click on the physical device that contains your data. Regular device scan is performed and you might see some Detected virtual drives.

2 When regular device scan is finished, click the **Scan** toolbar button or select **Scan Extended** from the context menu.

3 Wait until Extended Device Scan is finished. You can cancel operation anytime by clicking **Stop**.

Figure 2-1 Extended Device Scan



After Extended Device Scan is complete, inspect all Detected virtual disks to locate your data. Work with these drives the same way as with regular drives.

Searching for Deleted Files and Folders

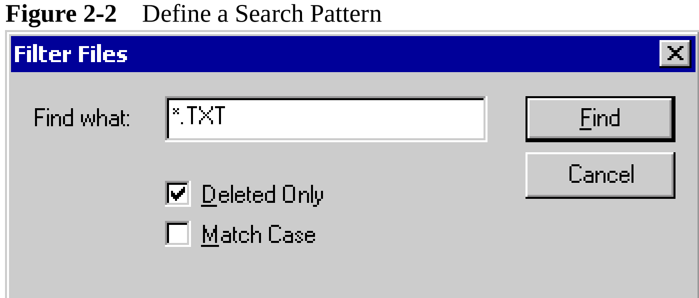
Use this method when you are not certain where the deleted file or folder was stored before it was accidentally deleted. If you know where the deleted file or folder should be, you can use **Device Scan** procedure as described above.

Follow the steps below:

1. Check the **Windows Recycle Bin** to see if the file or folder is there. If it is, use standard Windows **Restore** command to recover it from there. If not, continue with step 2.
2. If you are not certain where the deleted file or folder was before it was deleted, try to reduce the size of the search by not searching through those folders on the drive where you know it would not have been.
3. When you have chosen a folder where the deleted data might have been:

- Click the **Search** button on the toolbar, or right-click the drive or folder and click **Search** in the context menu.
- Define a search pattern in **Filter Files** dialog. For example, type *.TXT to find all files with “TXT” extension. Check **Deleted Only** to hide non-deleted files and folders.

Figure 2-2 Define a Search Pattern



- By default, the filter pattern is not case sensitive. If you want to make it case sensitive, enable the **Match Case** check box.
- Click **Find**. After the search is complete, examine folders on the left that contain matched files

The search pattern used here is the same pattern recognized when searching in Microsoft Windows.The asterisk symbol (*) in the pattern means that at this place can be zero or any number of any symbols. The question mark symbol (?) in the pattern means that at this place can be any single symbol.

Some examples are listed below:

*	All file on the drive or in the folder
*.TXT	All fields with “TXT” extension
My*.*	All files starting with “My”
MyFile.txt	Search for the file named “MyFile.txt”

See Also: Performing Extended Device Scan, Searching for Deleted Files and Folders

Restoring a Deleted File

Find and select the deleted file in the Active@ File Recovery.

To restore contents of the file run the **Recover** command by one of the following methods:

- Click **Recover** button on the toolbar.
- Right-click the file, and then click **Recover** from the context menu.
- Drag and drop the selected file to another logical drive.

Select a target drive and a folder to be used as a space for restoring the deleted file. To do this, use the standard Microsoft Windows **Browse for Folder** dialog.

If a file already exists in the target recovery folder with the same name as the file you are trying to recover, Active@ File Recovery adds the “**at**” character (**@**) to the filename in order to avoid filename duplication or overwriting the existing file.

For example, after recovering files you will see a listing that will include:

MyFile.doc **-** File existing in target recovery folder

MyFile@.doc **-** Recovered file whose original name was 'MyFile.doc'

After the recovery process is complete, make sure that the results are correct by verifying the contents of files and subfolders. In some cases, however, a file can not be reliably restored, because its contents or a part of it has already been overwritten.

See Also: Restoring a Deleted Folder, below.

Restoring a Deleted Folder

Find and select the deleted folder to be restored in the Active@ File Recovery

To recursively restore the contents of the folder with files and subfolders, the process is the same as described in the previous section about restoring files. Run the Recover command by one of the following methods:

- Click the Recover button on the toolbar.
- Right-click the file, and then click Recover from the context menu.
- Drag and drop the selected folder to another logical drive.

Select a drive and a folder for the deleted folder to be restored to using the standard Browse for Folder dialog

After the recovery process is complete, make sure that the results are correct by verifying the contents of the files and subfolders.

See Also: Restoring a Deleted File

Creating a Disk Image

A Disk Image is a mirror copy of your entire logical drive or physical device stored in one file. On a drive that contains deleted files that you want to recover, it may be a good idea to create a Disk Image, if you have enough space on another drive.

“Why,” you might ask, “should I create a Disk Image on a drive that holds my deleted files?”

Here is the answer: If you do something wrong while attempting to recover the files (for example, recovering them onto the same drive could destroy their contents), you will be able to recover these deleted files and folders from the Disk Image that you have wisely created.

The method for creating a Disk Image for a logical drive (DIM file) is slightly different from the method for creating a Disk Image for a physical device (HDD file). Both methods are listed below:

To create a Disk Image for a **logical drive**:

1 Start Active@ File Recovery and select the drive you want to create an image for under Local System Root.

2 Run the **Create Image** command by doing one of the following:

- Click the **Create Image** button on the toolbar.
- Right-click the selected drive, and click **Create Image** on the context menu.
- From the command bar, click **File** > **Save**. Navigate to the Disk Image location and click **Save**.

3 Watch the progress and wait while drive's contents are copied to the new location. You can cancel the process of image creation anytime by clicking **Stop.**

Disk Images for logical drives have .DIM extension by default.

To create a Disk Image for a **physical device** (HDD):

1 Start Active@ File Recovery and select the physical hardware device you want to create an image for under Hardware Devices folder

2 Run the **Create Image** command by doing one of the following:

- Click the **Create Image** button on the toolbar.
- Right-click the selected drive, and click **Create Image** on the context menu.
- From the command bar, click **File** > **Save**. Navigate to the Disk Image location and click **Save**.

3 Watch the progress and wait while drive's contents are copied to the new location. You can cancel the process of image creation anytime by clicking **Stop**.

Disk Images for physical drives have .HDD extension by default.

(!) *Important: The Target Location for the Create Image command must always be specified on other drive.*

FAT16 and FAT32 Restrictions

File systems FAT16 and FAT32 do not support file sizes larger than 2GB and 4GB respectively. In these file systems is not possible to create a disk image file for a drive as it is likely to grow larger than 2GB (or 4GB). The solution in this case is to use a target location formatted under the operating system Windows NT/2000/XP and NTFS.

See Also: Working with Disk Image, below.

Working with Disk Image

A Disk Image is a mirror copy of your entire logical drive or physical device stored in one file. On a drive that contains deleted files that you want to recover, it may be a good idea to create a Disk Image, if you have enough space on another drive.

To open a Disk Image for a **logical drive** (a file with .DIM extension):

1 Select the Local System Root node or any drive node

2 Run Open Image command by doing one of the following:

- Click the **Open Image** button on toolbar.
- Right-click the drive or the Local System Root node. Click **Open Image** in the context menu.
- From the command bar, click **File** > **Open**. Select an existing Disk Image (file with DIM extension) and click **Open**.

3 The opened disk image will appear underneath the Local System Root folder.

To open the Disk Image for a **physical device** (a file with .HDD extension):

1 Select the Hardware Devices folder or any device displayed

2 Run the **Open Image** command by doing one of the following:

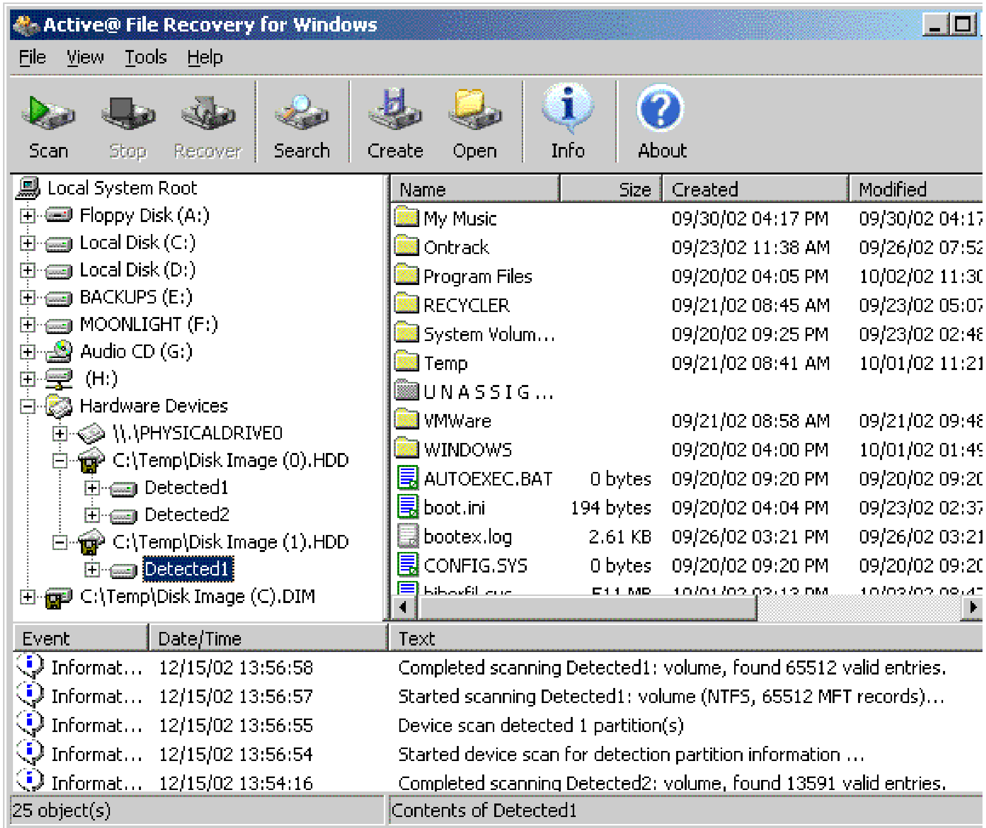
- Click the **Open Image** button on toolbar.
- Right-click the drive or the Hardware Devices node. Click **Open Image** on the context menu.
- From the command bar, click **File** > **Open**. Select an existing Disk Image (file with HDD extension) and click **Open**.

3 Opened disk image will appear underneath the Hardware Devices folder.

Another way to open a disk image file is to locate the file directly and execute the **Open Image** command from the right-click context menu.

Work with an opened Disk Image the same way as with any regular drive or device. Scan, find and restore files from it.

Figure 2-3 Sample Disk Image Screen



See Also: [Creating a Disk Image]()

3 FILE STORAGE HARDWARE AND DISK ORGANIZATION

This chapter covers information about Hard Disk Drives (HDD) and low-level disk organization.

Topics covered are:

- Hard Disk Drive Basics
- Master Boot Record (MBR)
- Partition Table

Hard Disk Drive Basics

A hard disk is a sealed unit containing a number of **platters** in a stack. Hard disks may be mounted in a horizontal or a vertical position. In this description, the hard drive is mounted horizontally.

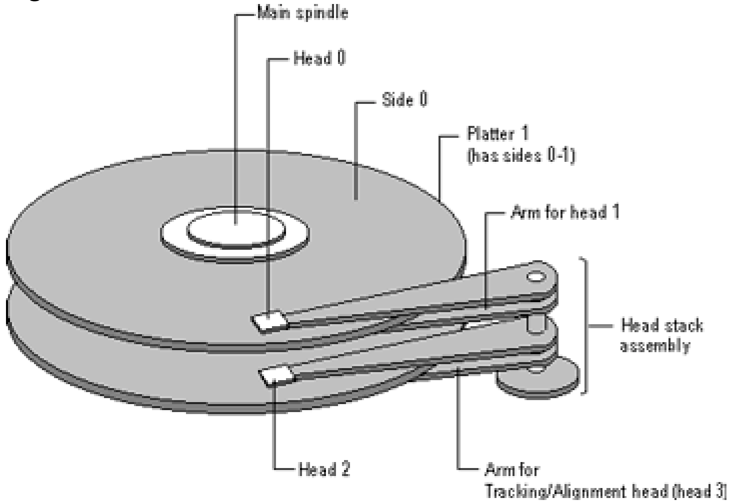
Electromagnetic read/write **heads** are positioned above and below each platter. As the platters spin, the drive heads move in toward the center surface and out toward the edge. In this way, the drive heads can reach the entire surface of each platter.

Making Tracks

On a hard disk, data is stored in thin, concentric bands. A drive head, while in one position can read or write a circular ring, or band called a **track**. There can be more than a thousand tracks on a 3.5-inch hard disk. Sections within each track are called **sectors**. A sector is the smallest physical storage unit on a disk, and is almost always 512 bytes (0.5 kB) in size.

The figure below shows a hard disk with two platters.

Figure 3-1 Parts of a Hard Drive



The structure of older hard drives (i.e. prior to Windows 95) will refer to a **cylinder/ head/ sector** notation. A cylinder is formed while all drive heads are in the same position on the disk. The tracks, stacked on top of each other form a cylinder. This scheme is slowly being eliminated with modern hard drives. All new disks use a translation factor to make their actual hardware layout appear continuous, as this is the way that operating systems from Windows 95 onward like to work.

To the operating system of a computer, tracks are logical rather than physical in structure, and are established when the disk is low-level formatted. Tracks are numbered, starting at 0 (the outermost edge of the disk), and going up to the highest numbered track, typically 1023, (close to the center). Similarly, there are 1,024 cylinders (numbered from 0 to 1023) on a hard disk.

The stack of platters rotate at a constant speed. The drive head, while positioned close to the center of the disk reads from a surface that is passing by more slowly than the surface at the outer edges of the disk. To compensate for this physical difference, tracks near the outside of the disk are less-densely populated with data than the tracks near the center of the disk. The result of the different data density is that the same amount of data can be read over the same period of time, from any drive head position.

The disk space is filled with data according to a standard plan. One side of one platter contains space reserved for hardware track-positioning information and is not available to the operating system. Thus, a disk assembly containing two platters has three sides available for data. Track-positioning data is written to the disk during assembly at the factory. The system **disk controller** reads this data to place the drive heads in the correct sector position.

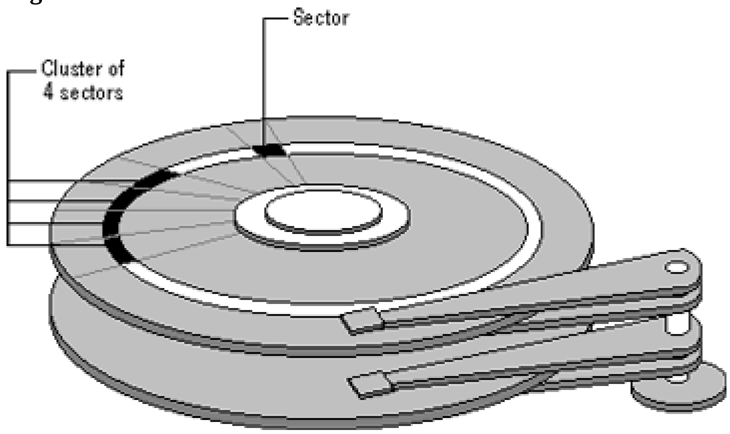
Sectors and Clusters

A sector, being the smallest physical storage unit on the disk, is almost always 512 bytes in size because 512 is a power of 2 (2 to the power of 9). The number 2 is used because there are two states in the most basic of computer languages **-** on and off.

Each disk sector is labelled using the factory track-positioning data. Sector identification data is written to the area immediately before the contents of the sector and identifies the starting address of the sector.

The optimal method of storing a file on a disk is in a **contiguous** series, i.e. all data in a stream stored end-to-end in a single line. As many files are larger than 512 bytes, it is up to the file system to allocate sectors to store the file's data. For example, if the file size is 800 bytes, two 512 k sectors are allocated for the file. A **cluster** is typically the same size as a sector. These two sectors with 800 bytes of data are called two clusters. They are called clusters because the space is reserved for the data contents. This process protects the stored data from being over-written. Later, if data is appended to the file and its size grows to 1600 bytes, another two clusters are allocated, storing the entire file within four clusters.

Figure 3-2 Sectors and Clusters



If contiguous clusters are not available (clusters that are adjacent to each other on the disk), the second two clusters may be written elsewhere on the same disk or within the same cylinder or on a different cylinder - wherever the file system finds two sectors available. A file stored in this non-contiguous manner is considered to be **fragmented**. Fragmentation can slow down system performance if the file system must direct the drive heads to several different addresses to find all the data in the file you want to read. The extra time for the heads to travel to a number of addresses causes a delay before the entire file is retrieved.

Cluster size can be changed to optimize file storage. A larger cluster size reduces the potential for fragmentation, but increases the likelihood that clusters will have unused space. Using clusters larger than one sector reduces fragmentation, and reduces the amount of disk space needed to store the information about the used and unused areas on the disk.

Most disks used in personal computers today rotate at a constant angular velocity. The tracks near the outside of the disk are less densely populated with data than the tracks near the center of the disk. Thus, a fixed amount of data can be read in a constant period of time, even though the speed of the disk surface is faster on the tracks located further away from the center of the disk.

Modern disks reserve one side of one platter for track positioning information, which is written to the disk at the factory during disk assembly. It is not available to the operating system. The disk controller uses this information to fine tune the head locations when the heads move to another location on the disk. When a side contains the track position information, that side cannot be used for data. Thus, a disk assembly containing two platters has three sides that are available for data.

Master Boot Record (MBR)

The Master Boot Record, created when you create the first partition on the hard disk, is probably the most important data structure on the disk. It is the first sector on every disk. The location is always track (cylinder) 0, side (head) 0, and sector 1.

The Master Boot Record contains the Partition Table for the disk and a small amount of executable code. On x86-based computers, the executable code examines the Partition Table, and identifies the system partition. The Master Boot Record then finds the system partition's starting location on the disk, and loads an copy of its Partition Boot Sector into memory. The Master Boot Record then transfers execution to executable code in the Partition Boot Sector.

(i) *Note: Although there is a Master Boot Record on every hard disk, the executable code in the sector is used only if the disk is connected to an x86-based computer and the disk contains the system partition.*

The example below shows a hex dump of the sector containing the Master Boot Record. The figure shows the sector in two parts:

- The first part is the Master Boot Record, which occupies the first 446 bytes of the sector. The disk signature (FD 4E F2 14) is at the end of the Master Boot Record code.
- The second part is the Partition Table.

```
Physical Sector: Cyl 0, Side 0, Sector 1
00000000: 00 33 C0 8E D0 BC 00 7C  - 8B F4 50 07 50 1F FB FC   .3.....|..P.P..
00000010: BF 00 06 B9 00 01 F2 A5  - EA 1D 06 00 00 BE BE 07   ................
00000020: B3 04 80 3C 80 74 0E 80  - 3C 00 75 1C 83 C6 10 FE   ...<.t..<.u.....
00000030: CB 75 EF CD 18 8B 14 8B  - 4C 02 8B EE 83 C6 10 FE   .u......L.......
00000040: CB 74 1A 80 3C 00 74 F4  - BE 8B 06 AC 3C 00 74 0B   .t..<.t.....<.t.
00000050: 56 BB 07 00 B4 0E CD 10  - 5E EB F0 EB FE BF 05 00   V.......^.......
00000060: BB 00 7C B8 01 02 57 CD  - 13 5F 73 0C 33 C0 CD 13   ..|...W.._s.3...
00000070: 4F 75 ED BE A3 06 EB D3  - BE C2 06 BF FE 7D 81 3D   Ou...........}.=
00000080: 55 AA 75 C7 8B F5 EA 00  - 7C 00 00 49 6E 76 61 6C   U.u.....|..Inval
00000090: 69 64 20 70 61 72 74 69  - 74 69 6F 6E 20 74 61 62   id partition tab
000000A0: 6C 65 00 45 72 72 6F 72  - 20 6C 6F 61 64 69 6E 67   le.Error loading
000000B0: 20 6F 70 65 72 61 74 69  - 6E 67 20 73 79 73 74 65    operating syste
000000C0: 6D 00 4D 69 73 73 69 6E  - 67 20 6F 70 65 72 61 74   m.Missing operat
000000D0: 69 6E 67 20 73 79 73 74  - 65 6D 00 00 80 45 14 15   ing system...E..
000000E0: 00 00 00 00 00 00 00 00  - 00 00 00 00 00 00 00 00   ................
000000F0: 00 00 00 00 00 00 00 00  - 00 00 00 00 00 00 00 00   ................
00000100: 00 00 00 00 00 00 00 00  - 00 00 00 00 00 00 00 00   ................
00000110: 00 00 00 00 00 00 00 00  - 00 00 00 00 00 00 00 00   ................
00000120: 00 00 00 00 00 00 00 00  - 00 00 00 00 00 00 00 00   ................
00000130: 00 00 00 00 00 00 00 00  - 00 00 00 00 00 00 00 00   ................
00000140: 00 00 00 00 00 00 00 00  - 00 00 00 00 00 00 00 00   ................
00000150: 00 00 00 00 00 00 00 00  - 00 00 00 00 00 00 00 00   ................
00000160: 00 00 00 00 00 00 00 00  - 00 00 00 00 00 00 00 00   ................
00000170: 00 00 00 00 00 00 00 00  - 00 00 00 00 00 00 00 00   ................
00000180: 00 00 00 00 00 00 00 00  - 00 00 00 00 00 00 00 00   ................
00000190: 00 00 00 00 00 00 00 00  - 00 00 00 00 00 00 00 00   ................
000001A0: 00 00 00 00 00 00 00 00  - 00 00 00 00 00 00 00 00   ................
000001B0: 00 00 00 00 00 00 00 00  - FD 4E F2 14 00 00         ..........N.....


                                                       80 01                 ..
000001C0: 01 00 06 0F 7F 96 3F 00  - 00 00 51 42 06 00 00 00   .....?...QB....
000001D0: 41 97 07 0F FF 2C 90 42  - 06 00 A0 3E 06 00 00 00   A....,.B...>....
000001E0: C1 2D 05 0F FF 92 30 81  - 0C 00 A0 91 01 00 00 00   .-....0.........
```

```
000001F0: C1 93 01 0F FF A6 D0 12  - 0E 00 C0 4E 00 00 55 AA   ..........N..U.
```

Viruses Can Infect the Master Boot Record

Many destructive viruses damage the Master Boot Record and make it impossible to start the computer from the hard disk. Because the code in the Master Boot Record executes before any operating system is started, no operating system can detect or recover from corruption of the Master Boot Record. You can use, for example, the DiskProbe program on Windows NT Workstation Resource Kit CD to display the Master Boot Record, and compare it to the Master Boot Record shown above. There are also utilities on the Microsoft Windows Resource Kits that enable you to save and restore the Master Boot Record.

For more detailed information see resource kits on Microsoft's web site http://www.microsoft.com/windows/reskits/webresources/default.asp or Microsoft Developers Network (MSDN) http://msdn.microsoft.com

Partition Table

The information about primary partitions and an extended partition is contained in the Partition Table, a 64-byte data structure located in the same sector as the Master Boot Record (cylinder 0, head 0, sector 1). The Partition Table conforms to a standard layout that is independent of the operating system. Each Partition Table entry is 16 bytes long, making a maximum of four entries available. Each entry starts at a predetermined offset from the beginning of the sector, as follows:

- Partition 1 0x01BE (446)
- Partition 2 0x01CE (462)
- Partition 3 0x01DE (478)
- Partition 4 0x01EE (494)

The last two bytes in the sector are a signature word for the sector and are always 0x55AA.

The next example is a printout of the Partition Table for the disk shown in an example earlier in this chapter. When there are fewer than four partitions, the remaining fields are all zeros.

```
                                                 80 01               ..
000001C0: 01 00 06 0F 7F 96 3F 00  - 00 00 51 42 06 00 00 00   .....?...QB....
000001D0: 41 97 07 0F FF 2C 90 42  - 06 00 A0 3E 06 00 00 00   A....,.B...>....
000001E0: C1 2D 05 0F FF 92 30 81  - 0C 00 A0 91 01 00 00 00   .-....0.........
000001F0: C1 93 01 0F FF A6 D0 12  - 0E 00 C0 4E 00 00 55 AA   ..........N..U.
```

The following table describes each entry in the Partition Table. The sample values correspond to the information for partition 1.

Partition Table Fields

Byte Offset	Field Length	Sample Value	Description
00	BYTE	0x80	Boot Indicator. Indicates whether the partition is the system partition. Legal values are: 00 = Do not use for booting. 80 = System partition.
01	BYTE	0x01	Starting Head.
02	6 bits	0x01	Starting Sector. Only bits 0-5 are used. Bits 6-7 are the upper two bits for the Starting Cylinder field.
03	10 bits	0x00	Starting Cylinder. This field contains the lower 8 bits of the cylinder value. Starting cylinder is thus a 10-bit number, with a maximum value of 1023.
04	BYTE	0x06	System ID. This byte defines the volume type. In Windows NT, it also indicates that a partition is part of a volume that requires the use of the HKEY_LOCAL_MACHINE\SYSTEM\DISK Registry subkey.
05	BYTE	0x0F	Ending Head.
06	6 bits	0x3F	Ending Sector. Only bits 0-5 are used. Bits 6-7 are the upper two bits for the Ending Cylinder field.
07	10 bits	0x196	Ending Cylinder. This field contains the lower 8 bits of the cylinder value. Ending cylinder is thus a 10-bit number, with a maximum value of 1023.
08	DWORD	3F 00 00 00	Relative Sector.
12	DWORD	51 42 06 00	Total Sectors.

The remainder of this section describes the uses of these fields. Definitions of the fields in the Partition Table is the same for primary partitions, extended partitions, and logical drives in extended partitions.

Boot Indicator Field

The Boot Indicator field indicates whether the volume is the system partition. On x-86-based computers, only one primary partition on the disk should have this field set. This field is used only on x86-based computers. On RISC-based computers, the NVRAM contains the information for finding the files to load.

On x86-based computers, it is possible to have different operating systems and different file systems on different volumes. For example, a computer could have MS-DOS on the first primary partition and Windows 95, UNIX, OS/2, or Windows NT on the second. You control which primary partition (active partition in FDISK) to use to start the computer by setting the Boot Indicator field for that partition in the Partition Table.

System ID Field

For primary partitions and logical drives, the System ID field describes the file system used to format the volume. Windows NT uses this field to determine what file system device drivers to load during startup. It also identifies the extended partition, if there is one defined.

These are the values for the System ID field:

Table 3-1 System ID Field Values

Value	Description
0x01	12-bit FAT primary partition or logical drive. The number of sectors in the volume is fewer than 32680.
0x04	16-bit FAT primary partition or logical drive. The number of sectors is between 32680 and 65535.
0x05	Extended partition. See section titled "Logical Drives and Extended Partitions," presented later in this chapter, for more information.
0x06	BIGDOS FAT primary partition or logical drive.
0x07	NTFS primary partition or logical drive.

Figure presented earlier in this section, has examples of a BIGDOS FAT partition, an NTFS partition, an extended partition, and a 12-bit FAT partition.

If you install Windows NT on a computer that has Windows 95 preinstalled, the FAT partitions might be shown as unknown. If you want to be able to use these partitions when running Windows NT, your only option is to delete the partitions.

OEM versions of Windows 95 support the following four partition types for FAT file systems that Windows NT cannot recognize.

Table 3-2 Partition Types

Value	Description
0x0B	Primary Fat32 partition, using interrupt 13 (INT 13) extensions.
0x0C	Extended Fat32 partition, using INT 13 extensions.
0x0E	Extended Fat16 partition, using INT 13 extensions.
0x0F	Primary Fat16 partition, using INT 13 extensions.

When you create a volume set or a stripe set, Disk Administrator sets the high bit of the System ID field for each primary partition or logical drive that is a member of the volume. For example, a FAT primary partition or logical drive that is a member of a volume set or a stripe set has a System ID value of 0x86. An NTFS primary partition or logical drive has a System ID value of 0x87. This bit indicates that Windows NT needs to use the HKEY_LOCAL_MACHINE\SYSTEM\DISK Registry subkey to determine how the members of the volume set or stripe set relate to each other. Volumes that have the high bit set can only be accessed by Windows NT.

When a primary partition or logical drive that is a member of a volume set or a stripe set has failed due to write errors or cannot be accessed, the second most significant bit is set. The System ID byte is set to C6 in the case of a FAT volume, or C7 in the case of an NTFS volume.

(i) *Note: If you start up MS-DOS, it can only access primary partitions or logical drives that have a value of 0x01, 0x04, 0x05, or 0x06 for the System ID. However, you should be able to delete volumes that have the other values. If you use a MS-DOS-based* *low-level disk editor, you can read and write any sector, including ones that are in NTFS volumes.*

On Windows NT Server, mirror sets and stripe sets with parity also require the use of the Registry subkey HKEY_LOCAL_MACHINE\SYSTEM\DISK to determine how to access the disks.

Starting and Ending Head, Sector, and Cylinder Fields

On x86-based computers, the Starting and Ending Head, Cylinder, and Sector fields on the startup disk are very important for starting up the computer. The code in the Master Boot Record uses these fields to find and load the Partition Boot Sector.

The Ending Cylinder field in the Partition Table is ten bits long, which limits the maximum number of cylinders that can be described in the Partition Table to 1024. The Starting and Ending Head fields are one byte long, which limits this field to the range 0 – 255. The Starting and Ending Sector field is 6 bits long, limiting its range to 0 – 63. However, sectors start counting at 1 (versus 0 for the other fields), so the maximum number of sectors per track is 63.

Since current hard disks are low-level formatted with the industry standard 512-byte sector size, the maximum capacity disk that can be described by the Partition Table can be calculated as follows:

```
MaxCapacity = (sector size) x (sectors per track) x (cylinders)
x (heads)
```

Substituting the maximum possible values yields:

```
512 x 63 x 1024 x 256 = 8,455,716,864 bytes or 7.8 GB
```

The maximum formatted capacity is slightly less than 8 GB.

However, the maximum cluster size that you can use for FAT volumes when running Windows NT is 64K, when using a 512 byte sector size. Therefore, the maximum size for a FAT volume is 4 GB.

If you have a dual-boot configuration with Windows 95 or MS-DOS, FAT volumes that might be accessed when using either of those operating systems are limited to 2 GB. In addition, Macintosh computers that are viewing volumes on a computer running Windows NT cannot see more than 2 GB. If you try to use a FAT volume larger than 2 GB when running MS-DOS or Windows 95, or access it from a Macintosh computer, you might get a message that there are 0 bytes available. The same limit applies to OS/2 system and boot partitions.

The maximum size of a FAT volume on a specific computer depends on the disk geometry, and the maximum values that can fit in the fields described in this section. The next table shows the typical size of a FAT volume when translation is enabled, and when it is disabled. The number of cylinders in both situations is 1024.

Translation Mode	Number of Heads	Sectors Per Track	Maximum Size for System or Boot Partition
Disabled	64	32	1 GB
Enabled	255	63	4 GB

(i) *Note: RISC-based computers do not have a limit on the size of the system or boot partitions.*

If a primary partition or logical drive extends beyond cylinder 1023, all of these fields will contain the maximum values.

Relative Sectors and Number of Sectors Fields

For primary partitions, the Relative Sectors field represents the offset from the beginning of the disk to the beginning of the partition, counting by sectors. The Number of Sectors field represents the total number of sectors in the partition. For a description of these fields in extended partitions, see the section Logical Drives and Extended Partitions.

Windows NT uses these fields to access all partitions. When you format a partition when running Windows NT, it puts data into the Starting and Ending Cylinder, Head, and Sector fields only for backward compatibility with MS-DOS and Windows 95, and to maintain compatibility with the BIOS interrupt (INT) 13 for startup purposes.

Logical Drives and Extended Partitions

When more than four logical disks are required on a single physical disk, the first partition should be a primary partition. The second partition can be created as an extended partition, which can contain all the remaining unpartitioned space on the disk.

(i) *Note: A primary partition is one that can be used as the system partition. If the disk does not contain a system partition, you can configure the entire disk as a single, extended partition.*

Some computers create an EISA configuration partition as the first partition on the hard disk.

Windows NT detects an extended partition because the System ID byte in the Partition Table entry is set to 5. There can be only one extended partition on a hard disk.

Within the extended partition, you can create any number of logical drives. As a practical matter, the number of available drive letters is the limiting factor in the number of logical drives that you can define.

When you have an extended partition on the hard disk, the entry for that partition in the Partition Table (at the end of the Master Boot Record) points to the first disk sector in the extended partition. The first sector of each logical drive in an extended partition also has a Partition Table, which is the last 66 bytes of the sector. (The last two bytes of the sector are the end-of-sector marker.)

These are the entries in an extended Partition Table:

- The first entry is for the current logical drive.

- The second entry contains information about the next logical drive in the extended partition.
- Entries three and four are all zeroes.

This format repeats for every logical drive. The last logical drive has only its own partition entry listed. The entries for partitions 2-4 are all zeroes.

The Partition Table entry is the only information on the first side of the first cylinder of each logical drive in the extended partition. The entry for partition 1 in each Partition Table contains the starting address for data on the current logical drive. And the entry for partition 2 is the address of the sector that contains the Partition Table for the next logical drive.

The use of the Relative Sector and Total Sectors fields for logical drives in an extended partition is different than for primary partitions. For the partition 1 entry of each logical drive, the Relative Sectors field is the sector from the beginning of the logical drive that contains the Partition Boot Sector. The Total Sectors field is the number of sectors from the Partition Boot Sector to the end of the logical drive.

For the partition 2 entry, the Relative Sectors field is the offset from the beginning of the extended partition to the sector containing the Partition Table for the logical drive defined in the Partition 2 entry. The Total Sectors field is the total size of the logical drive defined in the Partition 2 entry.

(i) *Note: If a logical drive is part of a volume set, the Partition Boot Sector is at the beginning of the first member of the volume set. Other members of the volume set have data where the Partition Boot Sector would normally be located.*

For more detailed information see resource kits on Microsoft's web site http://www.microsoft.com/windows/reskits/webresources/default.asp or Microsoft Developers Network (MSDN) http://msdn.microsoft.com

4 THE FAT FILE SYSTEM

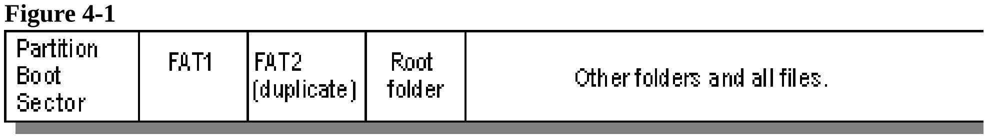
The File Allocation Table (FAT) file system is a simple file system originally designed for small disks and simple folder structures. The FAT file system is named for its method of organization, the file allocation table, which resides at the beginning of the volume. To protect the volume, two copies of the table are kept, in case one becomes damaged. In addition, the file allocation tables and the root folder must be stored in a fixed location so that the files needed to start the system can be correctly located.

A volume formatted with the FAT file system is allocated in clusters. The default cluster size is determined by the size of the volume. For the FAT file system, the cluster number must fit in 16 bits and must be a power of two.

Structure of a FAT Volume

The figure below illustrates how the FAT file system organizes a volume.

Figure 4-1



This section covers information about the FAT system. Topics covered are:

- FAT Partition Boot Sector
- FAT File System
- FAT Root Folder
- FAT Folder Structure
- FAT32 Features

Table 4-1 displays differences between the FAT systems:

Table 4-1 Differences Between FAT Systems

System	Bytes Per Cluster Within File Allocation Table	Cluster Limit
FAT12	1.5	Fewer than 4,087 clusters.
FAT16	2	Between 4,087 and 65,526 clusters, inclusive.
FAT32	4	Between 65,526 and 268,435,456 clusters, inclusive.

For more detailed information see resource kits on Microsoft's web site http://www.microsoft.com/windows/reskits/webresources/default.asp or Microsoft Developers Network (MSDN) http://msdn.microsoft.com.

FAT Partition Boot Sector

The Partition Boot Sector contains information that the file system uses to access the volume. On x86-based computers, the Master Boot Record use the Partition Boot Sector on the system partition to load the operating system kernel files.

Table 4-2 describes the fields in the Partition Boot Sector for a volume formatted with the FAT file system.

Table 4-2 Fields in Partition Boot Sector (FAT File System)

Byte Offset (in hex)	Field Length	Sample Value	Description
00	3 bytes	EB 3C 90	Jump instruction.
03	8 bytes	MSDOS5.0	OEM Name in text
0B	25 bytes		BIOS Parameter Block
24	26 bytes		Extended BIOS Parameter Block
3E	448 bytes		Bootstrap code
1FE	2 bytes	0x55AA	End of sector marker

Table 4-3 describes BIOS Parameter Block and Extended BIOS Parameter Block Fields.

Table 4-3 BIOS Parameter Block and Extended BIOS Parameter Block Fields

Byte Offset	Field Length	Sample Value	Description
0x0B	WORD	0x0002	Bytes per Sector. The size of a hardware sector. For most disks in use in the United States, the value of this field is 512.
0x0D	BYTE	0x08	Sectors Per Cluster. The number of sectors in a cluster. The default cluster size for a volume depends on the volume size and the file system.
0x0E	WORD	0x0100	Reserved Sectors. The number of sectors from the Partition Boot Sector to the start of the first file allocation table, including the Partition Boot Sector. The minimum value is 1. If the value is greater than 1, it means that the bootstrap code is too long to fit completely in the Partition Boot Sector.
0x10	BYTE	0x02	Number of file allocation tables (FATs). The number of copies of the file allocation table on the volume. Typically, the value of this field is 2.
0x11	WORD	0x0002	Root Entries. The total number of file name entries that can be stored in the root folder of the volume. One entry is always used as a Volume Label. Files with long filenames use up multiple entries per file. Therefore, the largest number of files in the root folder is typically 511, but you will run out of entries sooner if you use long filenames.
0x13	WORD	0x0000	Small Sectors. The number of sectors on the volume if the number fits in 16 bits (65535). For volumes larger than 65536 sectors, this field has a value of 0 and the Large Sectors field is used instead.
0x15	BYTE	0xF8	Media Type. Provides information about the media being used. A value of 0xF8 indicates a hard disk.
0x16	WORD	0xC900	Sectors per file allocation table (FAT). Number of sectors occupied by each of the file allocation tables on the volume. By using this information, together with the Number of FATs and Reserved Sectors, you can compute where the root folder begins. By using the number of entries in the root folder, you can also compute where the user data area of the volume begins.
0x18	WORD	0x3F00	Sectors per Track. The apparent disk geometry in use when the disk was low-level formatted.
0x1A	WORD	0x1000	Number of Heads. The apparent disk geometry in use when the disk was low-level formatted.
0x1C	DWORD	3F 00 00 00	Hidden Sectors. Same as the Relative Sector field in the Partition Table.
0x20	DWORD	51 42 06 00	Large Sectors. If the Small Sectors field is zero, this field contains the total number of sectors in the volume. If Small Sectors is nonzero, this field contains zero.

Byte Offset	Field Length	Sample Value	Description
0x24	BYTE	0x80	Physical Disk Number. This is related to the BIOS physical disk number. Floppy drives are numbered starting with 0x00 for the A disk. Physical hard disks are numbered starting with 0x80. The value is typically 0x80 for hard disks, regardless of how many physical disk drives exist, because the value is only relevant if the device is the startup disk.
0x25	BYTE	0x00	Current Head. Not used by the FAT file system.
0x26	BYTE	0x29	Signature. Must be either 0x28 or 0x29 in order to be recognized by Windows NT.
0x27	4 bytes	CE 13 46 30	Volume Serial Number. A unique number that is created when you format the volume.
0x2B	11 bytes	NO NAME	Volume Label. This field was used to store the volume label, but the volume label is now stored as special file in the root directory.
0x36	8 bytes	FAT16	System ID. Either FAT12 or FAT16, depending on the format of the disk.

For more detailed information see resource kits on Microsoft's web site http://www.microsoft.com/windows/reskits/webresources/default.asp or Microsoft Developers Network (MSDN) http://msdn.microsoft.com

File Allocation Sytstem

The FAT file allocation system is named for its method of organization, the file allocation table, which resides at the beginning of the volume. To protect the volume, two copies of the table are kept, in case one becomes damaged. In addition, the file allocation tables must be stored in a fixed location so that the files needed to start the system can be correctly located.

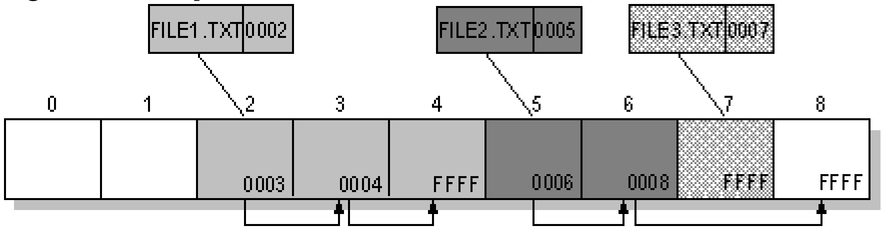
The file allocation table contains the following types of information about each cluster on the volume (see example below for FAT16):

- Unused (0x0000)
- Cluster in use by a file
- Bad cluster (0xFFF7)
- Last cluster in a file (0xFFF8-0xFFFF)

There is no organization to the FAT folder structure, and files are given the first available location on the volume. The starting cluster number is the address of the first cluster used by the file. Each cluster contains a pointer to the next cluster in the file, or an indication (0xFFFF) that this cluster is the end of the file. These links and end of file indicators are shown below.

Example of File Allocation Table

Figure 4-2 Example of File Allocation Table



This illustration shows three files. The file File1.txt is a file that is large enough to use three clusters. The second file, File2.txt, is a fragmented file that also requires three clusters. A small file, File3.txt, fits completely in one cluster. In each case, the folder structure points to the first cluster of the file.

For more detailed information see resource kits on Microsoft's web site http://www.microsoft.com/windows/reskits/webresources/default.asp or Microsoft Developers Network (MSDN) http://msdn.microsoft.com

FAT Root Folder

The root folder contains an entry for each file and folder on the root. The only difference between the root folder and other folders is that the root folder is on a specified location on the disk and has a fixed size (512 entries for a hard disk, number of entries on a floppy disk depends on the size of the disk).

See Folder Structure topic for details about folder organization.

For more detailed information see resource kits on Microsoft's web site http://www.microsoft.com/windows/reskits/webresources/default.asp or Microsoft Developers Network (MSDN) http://msdn.microsoft.com

FAT Folder Structure

Folders have set of 32-byte **Folder Entries** for each file and subfolder contained in the folder (see example figure below).

The **Folder Entry** includes the following information:

- Name (eight-plus-three characters)
- Attribute byte (8 bits worth of information, described later in this section)
- Create time (24 bits)
- Create date (16 bits)
- Last access date (16 bits)
- Last modified time (16 bits)
- Last modified date (16 bits.)
- Starting cluster number in the file allocation table (16 bits)
- File size (32 bits)

There is no organization to the FAT folder structure, and files are given the first available location on the volume. The starting cluster number is the address of the first cluster used by the file. Each cluster contains a pointer to the next cluster in the file, or an indication (0xFFFF) that this cluster is the end of the file. See File Allocation System for details.

The information in the folder is used by all operating systems that support the FAT file system. In addition, Windows NT can store additional time stamps in a FAT folder entry. These time stamps show when the file was created or last accessed and are used principally by POSIX applications.

Because all entries in a folder are the same size, the attribute byte for each entry in a folder describes what kind of entry it is. One bit indicates that the entry is for a subfolder, while another bit marks the entry as a volume label. Normally, only the operating system controls the settings of these bits.

A FAT file has four attributes bits that can be turned on or off by the user — archive file, system file, hidden file, and read-only file.

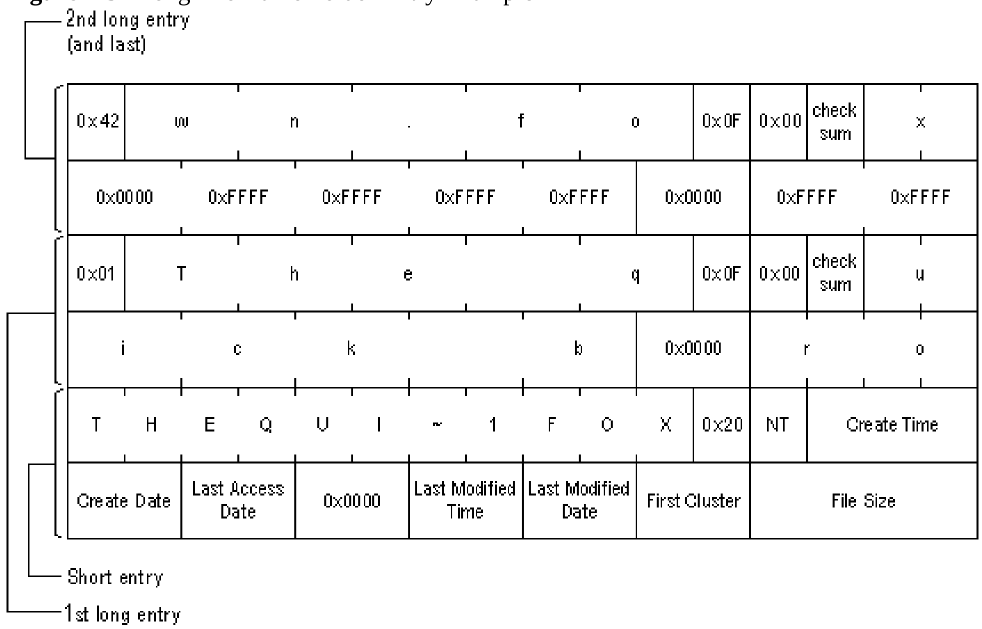
Filenames on FAT Volumes

Beginning with Windows NT 3.5, files created or renamed on FAT volumes use the attribute bits to support long filenames in a way that does not interfere with how MS-DOS or OS/2 accesses the volume. Whenever a user creates a file with a long filename, Windows creates an eight-plus-three name for the file. In addition to this conventional entry, Windows creates one or more secondary folder entries for the file, one for each 13 characters in the long filename. Each of these secondary folder entries stores a corresponding part of the long filename in Unicode. Windows sets the volume, read-only, system, and hidden file attribute bits of the secondary folder entry to mark it as part of a long filename. MS-DOS and OS/2 generally ignore folder entries with all four of these attribute bits set, so these entries are effectively invisible to these operating systems. Instead, MS-DOS and OS/2 access the file by using the conventional eight-plus-three filename contained in the folder entry for the file.

Example of Folder Entries for the long filename

Figure 4-3 below shows all of the folder entries for the file Thequi~1.fox, which has a long name of The quick brown.fox. The long name is in Unicode, so each character in the name uses two bytes in the folder entry. The attribute field for the long name entries has the value 0x0F. The attribute field for the short name is 0x20.

Figure 4-3 Long File Name Folder Entry Example



(i) *Note: Windows NT/2000/XP and Windows 95/98/ME use the same algorithm to create long and short filenames. On computers that dual-boot these two operating systems, files that you create when running one of the operating systems can be accessed when running the other.*

FAT32 Features

The following topics describe the FAT32 file system.

- File System Specifications
- Boot Sector and Bootstrap Modifications
- FAT Mirroring
- Partition Types

File System Specifications

FAT32 is a derivative of the File Allocation Table (FAT) file system that supports drives with over 2GB of storage. Because FAT32 drives can contain more than 65,526 clusters, smaller clusters are used than on large FAT16 drives. This method results in more efficient space allocation on the FAT32 drive.

The largest possible file for a FAT32 drive is 4GB minus 2 bytes.

The FAT32 file system includes four bytes per cluster within the file allocation table. Note that the high 4 bits of the 32-bit values in the FAT32 file allocation table are reserved and are not part of the cluster number.

Boot Sector and Bootstrap Modifications

Table 4-4 Modifications to Boot Sector

Modifications	**Description**
Reserved Sectors	FAT32 drives contain more reserved sectors than FAT16 or FAT12 drives. The number of reserved sectors is usually 32, but can vary.
Boot Sector Modifications	Because a FAT32 BIOS Parameter Block (BPB), represented by the BPB structure, is larger than a standard BPB, the boot record on FAT32 drives is greater than 1 sector. In addition, there is a sector in the reserved area on FAT32 drives that contains values for the count of free clusters and the cluster number of the most recently allocated cluster. These values are members of the BIGFATBOOTFSINFO structure which is contained within this sector. These additional fields allow the system to initialize the values without having to read the entire file allocation table.
Root Directory	The root directory on a FAT32 drive is not stored in a fixed location as it is on FAT16 and FAT12 drives. On FAT32 drives, the root directory is an ordinary cluster chain. The **A_BF_BPB_RootDirStrtClus** member in the BPB structure contains the number of the first cluster in the root directory. This allows the root directory to grow as needed. In addition, the **BPB_RootEntries** member of BPB is ignored on a FAT32 drive.
Sectors Per FAT	The **A_BF_BPB_SectorsPerFAT** member of BPB is *always zero* on a FAT32 drive. Additionally, the **A_BF_BPB_BigSectorsPerFat** and **A_BF_BPB_BigSectorsPerFatHi** members of the updated BPB provide equivalent information for FAT32 media.

BPB (FAT32)

The BPB for FAT32 drives is an extended version of the FAT16/FAT12 BPB. It contains identical information to a standard BPB, but also includes several extra fields for FAT32 specific information.

This structure is implemented in Windows OEM Service Release 2 and later.

```
A_BF_BPB    STRUC
    A_BF_BPB_BytesPerSector       DW    ?
    A_BF_BPB_SectorsPerCluster    DB    ?
    A_BF_BPB_ReservedSectors      DW    ?
    A_BF_BPB_NumberOfFATs         DB    ?
    A_BF_BPB_RootEntries          DW    ?
    A_BF_BPB_TotalSectors         DW    ?
    A_BF_BPB_MediaDescriptor      DB    ?
    A_BF_BPB_SectorsPerFAT        DW    ?
    A_BF_BPB_SectorsPerTrack      DW    ?
    A_BF_BPB_Heads                DW    ?
    A_BF_BPB_HiddenSectors        DW    ?
    A_BF_BPB_HiddenSectorsHigh    DW    ?
```

```
    A_BF_BPB_BigTotalSectors      DW    ?
    A_BF_BPB_BigTotalSectorsHigh  DW    ?
    A_BF_BPB_BigSectorsPerFat     DW    ?
    A_BF_BPB_BigSectorsPerFatHi   DW    ?
    A_BF_BPB_ExtFlags             DW    ?
    A_BF_BPB_FS_Version           DW    ?
    A_BF_BPB_RootDirStrtClus      DW    ?
    A_BF_BPB_RootDirStrtClusHi    DW    ?
    A_BF_BPB_FSInfoSec            DW    ?
    A_BF_BPB_BkUpBootSec          DW    ?
    A_BF_BPB_Reserved             DW    6 DUP (?)
A_BF_BPB    ENDS
```

Table 4-5 BPB Members

Member Name	Description
A_BF_BPB_BytesPerSector	The number of bytes per sector.
A_BF_BPB_SectorsPerCluster	The number of sectors per cluster.
A_BF_BPB_ReservedSectors	The number of reserved sectors, beginning with sector 0.
A_BF_BPB_NumberOfFATs	The number of File Allocation Tables.
A_BF_BPB_RootEntries	This member is ignored on FAT32 drives.
A_BF_BPB_TotalSectors	The size of the partition, in sectors.
A_BF_BPB_MediaDescriptor	The media descriptor. Values in this member are identical to standard BPB.
A_BF_BPB_SectorsPerFAT	The number of sectors per FAT.
(i) *Note: This member will always be zero in a FAT32 BPB. Use the values from A_BF_BPB_BigSectorsPerFat and A_BF_BPB_BigSectorsPerFatHi for FAT32 media.*	
A_BF_BPB_SectorsPerTrack	The number of sectors per track.
A_BF_BPB_Heads	The number of read/write heads on the drive.
A_BF_BPB_HiddenSectors	The number of hidden sectors on the drive.
A_BF_BPB_HiddenSectorsHigh	The high word of the hidden sectors value.
A_BF_BPB_BigTotalSectors	The total number of sectors on the FAT32 drive.
A_BF_BPB_BigTotalSectorsHigh	The high word of the FAT32 total sectors value.
A_BF_BPB_BigSectorsPerFat	The number of sectors per FAT on the FAT32 drive.
A_BF_BPB_BigSectorsPerFatHi	The high word of the FAT32 sectors per FAT value.
A_BF_BPBExtFlags	Flags describing the drive. Bit 8 of this value indicates whether or not information written to the active FAT will be written to all copies of the FAT. The low 4 bits of this value contain the 0-based FAT number of the Active FAT, but are only meaningful if bit 8 is set. This member can contain a combination of the following values.
Value	Description
BGBPB_F_ActiveFATMsk	Mask for low four bits. (000Fh)
BGBPB_F_NoFATMirror	Mask indicating FAT (0080h) mirroring state. If set, FAT mirroring is disabled. If clear, FAT mirroring is enabled.
	Bits 4-6 and 8-15 are reserved.
A_BF_BPB_FS_Version	The file system version number of the FAT32 drive. The high byte represents the major version, and the low byte represents the minor version.
A_BF_BPB_RootDirStrtClus	The cluster number of the first cluster in the FAT32 drive's root directory.
A_BF_BPB_RootDirStrtClusHi	The high word of the FAT32 starting cluster number.
A_BF_BPB_FSInfoSec	The sector number of the file system information sector. The file system info sector contains a BIGFATBOOTFSINFO structure. This member is set to 0FFFFh if there is no FSINFO sector. Otherwise, this value must be non-zero and less than the reserved sector count.
A_BF_BPB_BkUpBootSec	The sector number of the backup boot sector. This member is set to 0FFFFh if there is no backup boot sector. Otherwise, this value must be non-zero and less than the reserved sector count.

Member Name	Description
A_BF_BPB_Reserved	Reserved member.

BIGFATBOOTFSINFO (FAT32)

Contains information about the file system on a FAT32 volume. This structure is implemented in Windows OEM Service Release 2 and later.

```
BIGFATBOOTFSINFO STRUC
    bfFSInf_Sig             DD    ?
    bfFSInf_free_clus_cnt   DD    ?
    bfFSInf_next_free_clus  DD    ?
    bfFSInf_resvd           DD    3 DUP (?)
BIGFATBOOTFSINFO ENDS
```

Table 4-6 BIGFATBOOTFSINFO Members

Member Name	Description
bfFSInf_Sig	The signature of the file system information sector. The value in this member is FSINFOSIG (0x61417272L).
bfFSInf_free_clus_cnt	The count of free clusters on the drive. Set to -1 when the count is unknown.
bfFSInf_next_free_clus	The cluster number of the cluster that was most recently allocated.
bfFSInf_resvd	Reserved member.

FAT Mirroring

On all FAT drives, there may be multiple copies of the FAT. If an error occurs reading the primary copy, the file system will attempt to read from the backup copies. On FAT16 and FAT12 drives, the first FAT is always the primary copy and any modifications will automatically be written to all copies. However, on FAT32 drives, FAT mirroring can be disabled and a FAT other than the first one can be the primary (or "active") copy of the FAT.

Mirroring is enabled by clearing bit 0x0080 in the extdpb_flags member of a FAT32 Drive Parameter Block (DPB) structure.

Table 4-7 FAT Mirroring

Mirroring	**Description**
When Enabled (bit 0x0080 clear)	With mirroring enabled, whenever a FAT sector is written, it will also be written to every other FAT. Also, a mirrored FAT sector can be read from any FAT. A FAT32 drive with multiple FATs will behave the same as FAT16 and FAT12 drives with multiple FATs. That is, the multiple FATs are backups of each other.
When Disabled (bit 0x0080 set)	With mirroring disabled, only one of the FATs is active. The active FAT is the one specified by bits 0 through 3 of the **extdpb_flags** member of DPB. The other FATs are ignored. Disabling mirroring allows better handling of a drive with a bad sector in one of the FATs. If a bad sector exists, access to the damaged FAT can be completely disabled. Then, a new FAT can be built in one of the inactive FATs and then made accessible by changing the active FAT value in **extdpb_flags**.

Drive Parameter Block (FAT32)

The DPB was extended to include FAT32 information. Changes are effective for Windows 95 OEM Service Release 2 and later.

```
DPB STRUC
    dpb_drive            DB    ?
    dpb_unit             DB    ?
    dpb_sector_size      DW    ?
    dpb_cluster_mask     DB    ?
    dpb_cluster_shift    DB    ?
    dpb_first_fat        DW    ?
    dpb_fat_count        DB    ?
    dpb_root_entries     DW    ?
    dpb_first_sector     DW    ?
    dpb_max_cluster      DW    ?
    dpb_fat_size         DW    ?
    dpb_dir_sector       DW    ?
    dpb_reserved2        DD    ?
    dpb_media            DB    ?
ifdef NOTFAT32
    dpb_first_access     DB    ?
else
    dpb_reserved         DB    ?
endif
    dpb_reserved3        DD    ?
    dpb_next_free        DW    ?
    dpb_free_cnt         DW    ?
ifndef NOTFAT32
    extdpb_free_cnt_hi   DW    ?
    extdpb_flags         DW    ?
    extdpb_FSInfoSec     DW    ?
    extdpb_BkUpBootSec   DW    ?
    extdpb_first_sector  DD    ?
    extdpb_max_cluster   DD    ?
    extdpb_fat_size      DD    ?
    extdpb_root_clus     DD    ?
    extdpb_next_free     DD    ?
endif
DPB ENDS
```

Table 4-8 DBP Members

Member Name	Description
dpb_drive	The drive number (0 = A, 1 = B, and so on).
dpb_unit	Specifies the unit number. The device driver uses the unit number to distinguish the specified drive from the other drives it supports.
dpb_sector_size	The size of each sector, in bytes.
dpb_cluster_mask	The number of sectors per cluster minus 1.
dpb_cluster_shift	The number of sectors per cluster, expressed as a power of 2.
dpb_first_fat	The sector number of the first sector containing the file allocation table (FAT).
dpb_fat_count	The number of FATs on the drive.
dpb_root_entries	The number of entries in the root directory.
dpb_first_sector	The sector number of the first sector in the first cluster.
dpb_max_cluster	The number of clusters on the drive plus 1. This member is undefined for FAT32 drives.
dpb_fat_size	The number of sectors occupied by each FAT. The value of zero indicates a FAT32 drive. Use the value in extdpb_fat_size instead.
dpb_dir_sector	The sector number of the first sector containing the root directory. This member is undefined for FAT32 drives.
dpb_reserved2	Reserved member. Do not use.
dpb_media	Specifies the media descriptor for the medium in the specified drive.
reserved	Reserved member. Do not use.
dpb_first_access	Indicates whether the medium in the drive has been accessed. This member is initialized to -1 to force a media check the first time this DPB is used.
dpb_reserved3	Reserved member. Do not use.
dpb_next_free	The cluster number of the most recently allocated cluster.
dpb_free_cnt	The number of free clusters on the medium. This member is 0FFFFh if the number is unknown.
extdpb_free_cnt_hi	The high word of free count.
extdpb_flags	Flags describing the drive. The low 4 bits of this value contain the 0-based FAT number of the Active FAT. This member can contain a combination of the following values.
Value	Description
BGBPB_F_ActiveFATMsk (000Fh)	Mask for low four bits.
BGBPB_F_NoFATMirror (0080h)	Do not mirror active FAT to inactive FATs.
	Bits 4-6 and 8-15 are reserved.
extdpb_FSInfoSec	The sector number of the file system information sector. This member is set to 0FFFFh if there is no FSINFO sector. Otherwise, this value must be non-zero and less than the reserved sector count.
extdpb_BkUpBootSec	The sector number of the backup boot sector. This member is set to 0FFFFh if there is no backup boot sector. Otherwise, this value must be non-zero and less than the reserved sector count.
extdpb_first_sector	The first sector of the first cluster.
extdpb_max_cluster	The number of clusters on the drive plus 1.
extdpb_fat_size	The number of sectors occupied by the FAT.

Member Name	Description
extdpb_root_clus	The cluster number of the first cluster in the root directory.
extdpb_next_free	The number of the cluster that was most recently allocated.

FAT32 Partition Types

The following table displays all valid partition types and their corresponding values for use in the **Part_FileSystem** member of the s_partition structure.

Table 4-9 Partition Type Values

Value	Description
PART_UNKNOWN (00h)	Unknown
PART_DOS2_FAT (01h)	12-bit FAT
PART_DOS3_FAT (04h)	16-bit FAT. Partitions smaller than 32MB.
PART_EXTENDED (05h)	Extended MS-DOS Partition
PART_DOS4_FAT (06h)	16-bit FAT. Partitions larger than or equal to 32MB.
PART_DOS32 (0Bh)	32-bit FAT. Partitions up to 2047GB.
PART_DOS32X (0Ch)	Same as PART_DOS32 (0Bh), but uses Logical Block Address Int 13h extensions.
PART_DOSX13 (0Eh)	Same as PART_DOS4_FAT (06h), but uses Logical Block Address Int 13h extensions.
PART_DOSX13X (0Fh)	Same as PART_EXTENDED (05h), but uses Logical Block Address Int 13h extensions.

s_partition (FAT32)

(i) *Note: Values for head and track are 0-based. Sector values are 1-based. This structure is implemented in Windows OEM Service Release 2 and later.*

```
s_partition    STRUC
    Part_BootInd        DB    ?
    Part_FirstHead      DB    ?
    Part_FirstSector    DB    ?
    Part_FirstTrack     DB    ?
    Part_FileSystem     DB    ?
    Part_LastHead       DB    ?
    Part_LastSector     DB    ?
    Part_LastTrack      DB    ?
    Part_StartSector    DD    ?
    Part_NumSectors     DD    ?
s_partition    ENDS
```

Table 4-10 s_partition Members

Member Name	Description
Part_BootInd	Specifies whether the partition is bootable or not. This value could be set to PART_BOOTABLE (80h), or PART_NON_BOOTABLE(00h). The first partition designated as PART_BOOTABLE is the boot partition. All others are not. Setting multiple partitions to PART_BOOTABLE will result in boot errors.

Member Name	Description
Part_FirstHead	The first head of this partition. This is a 0-based number representing the offset from the beginning of the disk. The partition includes this head.
Part_FirstSector	The first sector of this partition. This is a 1-based, 6-bit number representing the offset from the beginning of the disk. The partition includes this sector. Bits 0 through 5 specify the 6-bit value; bits 6 and 7 are used with the Part_FirstTrack member.
Part_FirstTrack	The first track of this partition. This is an inclusive 0-based, 10-bit number that represents the offset from the beginning of the disk. The high 2 bits of this value are specified by bits 6 and 7 of the Part_FirstSector member.
PartFileSystem	Specifies the file system for the partition. The following are acceptable values:
Value	Description
PART_UNKNOWN(00h)	Unknown.
PART_DOS2_FAT(01h)	12-bit FAT.
PART_DOS3_FAT(04h)	16-bit FAT. Partition smaller than 32MB.
PART_EXTENDED(05h)	Extended MS-DOS Partition.
PART_DOS4_FAT(06h)	16-bit FAT. Partition larger than or equal to 32MB.
PART_DOS32(0Bh)	32-bit FAT. Partition up to 2047GB.
PART_DOS32X(0Ch)	Same as PART_DOS32(0Bh), but uses Logical Block Address **Int 13h** extensions.
PART_DOSX13(0Eh)	Same as PART_DOS4_FAT(06h), but uses Logical Block Address **Int 13h** extensions.
PART_DOSX13X(0Fh)	Same as PART_EXTENDED(05h), but uses Logical Block Address **Int 13h** extensions.
Part_LastHead	The last head of the partition. This is a 0-based number that represents the offset from the beginning of the disk. The partition includes the head specified by this member.
Part_LastSector	The last sector of this partition. This is a 1-based, 6-bit number representing offset from the beginning of the disk. The partition includes the sector specified by this member. Bits 0 through 5 specify the 6-bit value; bits 6 and 7 are used with the **Part_LastTrack** member.
Part_LastTrack	The last track of this partition. This is a 0-based, 10-bit number that represents offset from the beginning of the disk. The partition includes this track. The high 2 bits of this value are specified by bits 6 and 7 of the **Part_LastSector** member.
Part_StartSector	Specifies the 1-based number of the first sector on the disk. This value may not be accurate for extended partitions. Use the **Part_FirstSector** value for extended partitions.
Part_NumSectors	The 1-based number of sectors in the partition.

5 The NTFS File System

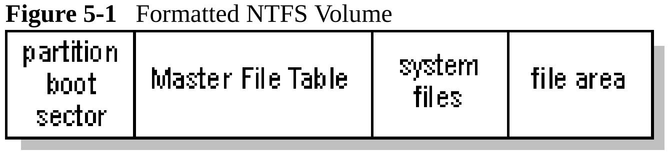
The Windows NT file system (NTFS) provides a combination of performance, reliability, and compatibility not found in the FAT file system. It is designed to quickly perform standard file operations such as read, write, and search — and even advanced operations such as file-system recovery — on very large hard disks.

Formatting a volume with the NTFS file system results in the creation of several system files and the Master File Table (MFT), which contains information about all the files and folders on the NTFS volume.

The first information on an NTFS volume is the Partition Boot Sector, which starts at sector 0 and can be up to 16 sectors long. The first file on an NTFS volume is the Master File Table (MFT).

The following figure illustrates the layout of an NTFS volume when formatting has finished.

Figure 5-1 Formatted NTFS Volume



This chapter covers information about NTFS. Topics covered are listed below:

- NTFS Partition Boot Sector
- NTFS Master File Table (MFT)
- NTFS File Types
- NTFS Data Integrity and Recoverability

The NTFS file system includes security features required for file servers and high-end personal computers in a corporate environment. The NTFS file system also supports data access control and ownership privileges that are important for the integrity of critical data. While folders shared on a Windows NT computer are assigned particular permissions, NTFS files and folders can have permissions assigned whether they are shared or not. NTFS is the only file system on Windows NT that allows you to assign permissions to individual files.

The NTFS file system has a simple, yet very powerful design. Basically, everything on the volume is a file and everything in a file is an attribute, from the data attribute, to the security attribute, to the file name attribute. Every sector on an NTFS volume that is allocated belongs to some file. Even the file system metadata (information that describes the file system itself) is part of a file.

What's New in NTFS5 (Windows 2000)

Encryption The Encrypting File System (EFS) provides the core file encryption technology used to store encrypted files on NTFS volumes. EFS keeps files safe from intruders who might gain unauthorized physical access to sensitive, stored data (for example, by stealing a portable computer or external disk drive).

Disk Quotas Windows 2000 supports disk quotas for NTFS volumes. You can use disk quotas to monitor and limit disk-space use.

Reparse Points Reparse points are new file system objects in NTFS that can be applied to NTFS files or folders. A file or folder that contains a reparse point acquires additional behavior not present in the underlying file system. Reparse points are used by many of the new storage features in Windows 2000, including volume mount points.

Volume Mount Points Volume mount points are new to NTFS. Based on reparse points, volume mount points allow administrators to graft access to the root of one local volume onto the folder structure of another local volume.

Sparse Files Sparse files allow programs to create very large files but consume disk space only as needed.

Distributed Link Tracking NTFS provides a link-tracking service that maintains the integrity of shortcuts to files as well as OLE links within compound documents.

For more detailed information see resource kits on Microsoft's web site http://www.microsoft.com/windows/reskits/webresources/default.asp or Microsoft Developers Network (MSDN) http://msdn.microsoft.com

NTFS Partition Boot Sector

Table 5-1 describes the boot sector of a volume formatted with NTFS. When you format an NTFS volume, the format program allocates the first 16 sectors for the boot sector and the bootstrap code.

Table 5-1 NTFS Boot Sector

Byte Offset	Field Length	Field Name
0x00	3 bytes	Jump Instruction
0x03	LONGLONG	OEM ID
0x0B	25 bytes	BPB
0x24	48 bytes	Extended BPB
0x54	426 bytes	Bootstrap Code
0x01FE	WORD	End of Sector Marker

On NTFS volumes, the data fields that follow the BPB form an extended BPB. The data in these fields enables Ntldr (NT loader program) to find the master file table (MFT) during startup. On NTFS volumes, the MFT is not located in a predefined sector, as on FAT16 and FAT32 volumes. For this reason, the MFT can be moved if there is a bad sector in its normal location. However, if the data is corrupted, the MFT cannot be located, and Windows NT/2000 assumes that the volume has not been formatted.

The following example illustrates the boot sector of an NTFS volume formatted while running Windows 2000. The printout is formatted in three sections:

- Bytes 0x00– 0x0A are the jump instruction and the OEM ID (shown in bold print).
- Bytes 0x0B–0x53 are the BPB and the extended BPB.
- The remaining code is the bootstrap code and the end of sector marker (shown in bold print).

```
Physical Sector: Cyl 0, Side 1, Sector 1
00000000: EB 52 90 4E 54 46 53 20 - 20 20 20 00 02 08 00 00 .R.NTFS ........
00000010: 00 00 00 00 00 F8 00 00 - 3F 00 FF 00 3F 00 00 00 ........?...?...
00000020: 00 00 00 00 80 00 80 00 - 4A F5 7F 00 00 00 00 00 ........J.......
00000030: 04 00 00 00 00 00 00 00 - 54 FF 07 00 00 00 00 00 ........T.......
00000040: F6 00 00 00 01 00 00 00 - 14 A5 1B 74 C9 1B 74 1C ...........t..t.
00000050: 00 00 00 00 FA 33 C0 8E - D0 BC 00 7C FB B8 C0 07 .....3.....|....
00000060: 8E D8 E8 16 00 B8 00 0D - 8E C0 33 DB C6 06 0E 00 ..........3.....
00000070: 10 E8 53 00 68 00 0D 68 - 6A 02 CB 8A 16 24 00 B4 ..S.h..hj....$..
00000080: 08 CD 13 73 05 B9 FF FF - 8A F1 66 0F B6 C6 40 66 ...s......f...@f
00000090: 0F B6 D1 80 E2 3F F7 E2 - 86 CD C0 ED 06 41 66 0F .....?.......Af.
000000A0: B7 C9 66 F7 E1 66 A3 20 - 00 C3 B4 41 BB AA 55 8A ..f..f. ...A..U.
000000B0: 16 24 00 CD 13 72 0F 81 - FB 55 AA 75 09 F6 C1 01 .$...r...U.u....
000000C0: 74 04 FE 06 14 00 C3 66 - 60 1E 06 66 A1 10 00 66 t......f`..f...f
000000D0: 03 06 1C 00 66 3B 06 20 - 00 0F 82 3A 00 1E 66 6A ....f;. ...:..fj
000000E0: 00 66 50 06 53 66 68 10 - 00 01 00 80 3E 14 00 00 .fP.Sfh.....>...
000000F0: 0F 85 0C 00 E8 B3 FF 80 - 3E 14 00 00 0F 84 61 00 ........>.....a.
00000100: B4 42 8A 16 24 00 16 1F - 8B F4 CD 13 66 58 5B 07 .B..$......fX[..
00000110: 66 58 66 58 1F EB 2D 66 - 33 D2 66 0F B7 0E 18 00 fXfX.-f3.f......
00000120: 66 F7 F1 FE C2 8A CA 66 - 8B D0 66 C1 EA 10 F7 36 f......f..f....6
00000130: 1A 00 86 D6 8A 16 24 00 - 8A E8 C0 E4 06 0A CC B8 ......$.........
00000140: 01 02 CD 13 0F 82 19 00 - 8C C0 05 20 00 8E C0 66 ........... ...f
00000150: FF 06 10 00 FF 0E 0E 00 - 0F 85 6F FF 07 1F 66 61 ..........o...fa
00000160: C3 A0 F8 01 E8 09 00 A0 - FB 01 E8 03 00 FB EB FE ................
00000170: B4 01 8B F0 AC 3C 00 74 - 09 B4 0E BB 07 00 CD 10 .....<.t........
00000180: EB F2 C3 0D 0A 41 20 64 - 69 73 6B 20 72 65 61 64 .....A disk read
00000190: 20 65 72 72 6F 72 20 6F - 63 63 75 72 72 65 64 00  error occurred.
000001A0: 0D 0A 4E 54 4C 44 52 20 - 69 73 20 6D 69 73 73 69 ..NTLDR is missi
000001B0: 6E 67 00 0D 0A 4E 54 4C - 44 52 20 69 73 20 63 6F ng...NTLDR is co
000001C0: 6D 70 72 65 73 73 65 64 - 00 0D 0A 50 72 65 73 73 mpressed...Press
000001D0: 20 43 74 72 6C 2B 41 6C - 74 2B 44 65 6C 20 74 6F  Ctrl+Alt+Del to
000001E0: 20 72 65 73 74 61 72 74 - 0D 0A 00 00 00 00 00 00  restart........
000001F0: 00 00 00 00 00 00 00 00 - 83 A0 B3 C9 00 00 55 AA ..............U.
```

The following table describes the fields in the BPB and the extended BPB on NTFS volumes. The fields starting at 0x0B, 0x0D, 0x15, 0x18, 0x1A, and 0x1C match those on FAT16 and FAT32 volumes. The sample values correspond to the data in this example.

Table 5-2 BPB Fields on NTFS

Byte Offset	Field Length	Sample Value	Field Name
0x0B	WORD	0x0002	Bytes Per Sector
0x0D	BYTE	0x08	Sectors Per Cluster
0x0E	WORD	0x0000	Reserved Sectors
0x10	3 BYTES	0x000000	always 0
0x13	WORD	0x0000	not used by NTFS
0x15	BYTE	0xF8	Media Descriptor
0x16	WORD	0x0000	always 0
0x18	WORD	0x3F00	Sectors Per Track
0x1A	WORD	0xFF00	Number Of Heads
0x1C	DWORD	0x3F000000	Hidden Sectors
0x20	DWORD	0x00000000	not used by NTFS
0x24	DWORD	0x80008000	not used by NTFS
0x28	LONGLONG	0x4AF57F0000000000	Total Sectors
0x30	LONGLONG	0x0400000000000000	Logical Cluster Number for the file $MFT
0x38	LONGLONG	0x54FF070000000000	Logical Cluster Number for the file $MFTMirr
0x40	DWORD	0xF6000000	Clusters Per File Record Segment
0x44	DWORD	0x01000000	Clusters Per Index Block
0x48	LONGLONG	0x14A51B74C91B741C	Volume Serial Number
0x50	DWORD	0x00000000	Checksum

Protecting the Boot Sector

Because a normally functioning system relies on the boot sector to access a volume, it is highly recommended that you run disk scanning tools such as Chkdsk regularly, as well as back up all of your data files to protect against data loss if you lose access to a volume.

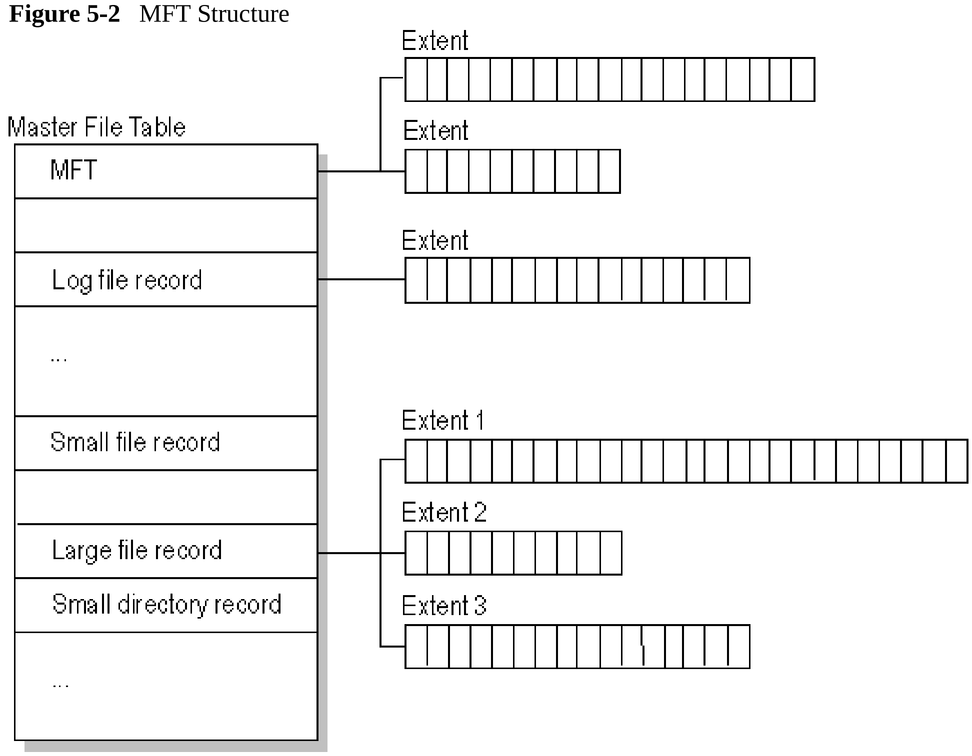
NTFS Master File Table (MFT)

Each file on an NTFS volume is represented by a record in a special file called the master file table (MFT). NTFS reserves the first 16 records of the table for special information. The first record of this table describes the master file table itself, followed by a MFT mirror record. If the first MFT record is corrupted, NTFS reads the second record to find the MFT mirror file, whose first record is identical to the first record of the MFT. The locations of the data segments for both the MFT and MFT mirror file are recorded in the boot sector. A duplicate of the boot sector is located at the logical center of the disk.

The third record of the MFT is the log file, used for file recovery. The log file is discussed in detail later in this chapter. The seventeenth and following records of the master file table are for each file and directory (also viewed as a file by NTFS) on the volume.

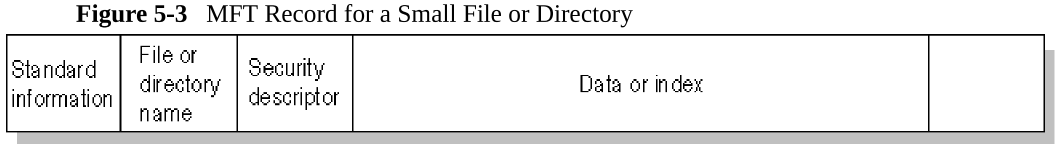
Figure provides a simplified illustration of the MFT structure:

Figure 5-2 MFT Structure



The master file table allocates a certain amount of space for each file record. The attributes of a file are written to the allocated space in the MFT. Small files and directories (typically 1500 bytes or smaller), such as the file illustrated in next figure, can entirely be contained within the master file table record.

Figure 5-3 MFT Record for a Small File or Directory



This design makes file access very fast. Consider, for example, the FAT file system, which uses a file allocation table to list the names and addresses of each file. FAT directory entries contain an index into the file allocation table. When you want to view a file, FAT first reads the file allocation table and assures that it exists. Then FAT retrieves the file by searching the chain of allocation units assigned to the file. With NTFS, as soon as you look up the file, it's there for you to use.

Directory records are housed within the master file table just like file records. Instead of data, directories contain index information. Small directory records reside entirely within the MFT structure. Large directories are organized into B-trees, having records with pointers to external clusters containing directory entries that could not be contained within the MFT structure.

NTFS File Types

This section covers the following topics:

- NTFS File Attributes
- NTFS System Files
- NTFS Multiple Data Streams
- NTFS Compressed Files
- NTFS Encrypted Files
- NTFS Sparse Files

NTFS File Attributes

The NTFS file system views each file (or folder) as a set of file attributes. Elements such as the file's name, its security information, and even its data, are all file attributes. Each attribute is identified by an attribute type code and, optionally, an attribute name.

When a file's attributes can fit within the MFT file record, they are called resident attributes. For example, information such as filename and time stamp are always included in the MFT file record. When all of the information for a file is too large to fit in the MFT file record, some of its attributes are nonresident. The nonresident attributes are allocated one or more clusters of disk space elsewhere in the volume. NTFS creates the Attribute List attribute to describe the location of all of the attribute records.

Table 5-3 lists all of the file attributes currently defined by the NTFS file system. This list is extensible, meaning that other file attributes can be defined in the future.

Table 5-3 File Attributes Defined by NTFS

Attribute Type	Description
Standard Information	Includes information such as timestamp and link count.
Attribute List	Lists the location of all attribute records that do not fit in the MFT record.
File Name	A repeatable attribute for both long and short file names. The long name of the file can be up to 255 Unicode characters. The short name is the 8.3, case-insensitive name for the file. Additional names, or hard links, required by POSIX can be included as additional file name attributes.
Security Descriptor	Describes who owns the file and who can access it.
Data	Contains file data. NTFS allows multiple data attributes per file. Each file typically has one unnamed data attribute. A file can also have one or more named data attributes, each using a particular syntax.
Object ID	A volume-unique file identifier. Used by the distributed link tracking service. Not all files have object identifiers.
Logged Tool Stream	Similar to a data stream, but operations are logged to the NTFS log file just like NTFS metadata changes. This is used by EFS.
Reparse Point	Used for volume mount points. They are also used by Installable File System (IFS) filter drivers to mark certain files as special to that driver.
Index Root	Used to implement folders and other indexes.
Index Allocation	Used to implement folders and other indexes.
Bitmap	Used to implement folders and other indexes.
Volume Information	Used only in the $Volume system file. Contains the volume version.
Volume Name	Used only in the $Volume system file. Contains the volume label.

NTFS System Files

NTFS includes several system files, all of which are hidden from view on the NTFS volume. A system file is one used by the file system to store its metadata and to implement the file system. System files are placed on the volume by the Format utility.

Table 5-4 Metadata Stored in the Master File Table

System File	File Name	MFT Record	Purpose of the File
Master file table	$Mft	0	Contains one base file record for each file and folder on an NTFS volume. If the allocation information for a file or folder is too large to fit within a single record, other file records are allocated as well.
Master file table 2	$MftMirr	1	A duplicate image of the first four records of the MFT. This file guarantees access to the MFT in case of a single-sector failure.

System File	File Name	MFT Record	Purpose of the File
Log file	$Log file	2	Contains a list of transaction steps used for NTFS recoverability. Log file size depends on the volume size and can be as large as 4 MB. It is used by Windows NT/2000 to restore consistency to NTFS after a system failure.
Volume	$Volume	3	Contains information about the volume, such as the volume label and the volume version.
Attribute definitions	$AttrDef	4	A table of attribute names, numbers, and descriptions.
Root file name index	$	5	The root folder.
Cluster bitmap	$Bitmap	6	A representation of the volume showing which clusters are in use.
Boot sector	$Boot	7	Includes the BPB used to mount the volume and additional bootstrap loader code used if the volume is bootable.
Bad cluster file	$BadClus	8	Contains bad clusters for the volume.
Security file	$Secure	9	Contains unique security descriptors for all files within a volume.
Upcase table	$Upcase	10	Converts lowercase characters to matching Unicode uppercase characters.
NTFS extension file	$Extend	11	Used for various optional extensions such as quotas, reparse point data, and object identifiers.
		12–15	Reserved for future use.

NTFS Multiple Data Streams

NTFS supports multiple data streams, where the stream name identifies a new data attribute on the file. A handle can be opened to each data stream. A data stream, then, is a unique set of file attributes. Streams have separate opportunistic locks, file locks, and sizes, but common permissions.

This feature enables you to manage data as a single unit. The following is an example of an alternate stream:

```
myfile.dat:stream2
```

A library of files might exist where the files are defined as alternate streams, as in the following example:

```
library:file1
       :file2
       :file3
```

A file can be associated with more than one application at a time, such as Microsoft® Word and Microsoft® WordPad. For instance, a file structure like the following illustrates file association, but not multiple files:

```
program:source_file
       :doc_file
       :object_file
       :executable_file
```

To create an alternate data stream, at the command prompt, you can type commands such as:

```
echo text>program:source_file
more <program:source_file
```

(!) *Important: When you copy an NTFS file to a FAT volume, such as a floppy disk, data streams and other attributes not supported by FAT are lost.*

NTFS Compressed Files

Windows NT/2000 supports compression on individual files, folders, and entire NTFS volumes. Files compressed on an NTFS volume can be read and written by any Windows-based application without first being decompressed by another program. Decompression occurs automatically when the file is read. The file is compressed again when it is closed or saved. Compressed files and folders have an attribute of C when viewed in Windows Explorer.

Only NTFS can read the compressed form of the data. When an application such as Microsoft® Word or an operating system command such as **copy** requests access to the file, the compression filter driver decompresses the file before making it available. For example, if you copy a compressed file from another Windows NT/2000–based computer to a compressed folder on your hard disk, the file is decompressed when read, copied, and then recompressed when saved.

This compression algorithm is similar to that used by the Windows 98 application DriveSpace 3, with one important difference — the limited functionality compresses the entire primary volume or logical volume. NTFS allows for the compression of an entire volume, of one or more folders within a volume, or even one or more files within a folder of an NTFS volume.

The compression algorithms in NTFS are designed to support cluster sizes of up to 4 KB. When the cluster size is greater than 4 KB on an NTFS volume, none of the NTFS compression functions are available.

Each NTFS data stream contains information that indicates whether any part of the stream is compressed. Individual compressed buffers are identified by “holes” following them in the information stored for that stream. If there is a hole, NTFS automatically decompresses the preceding buffer to fill the hole.

NTFS provides real-time access to a compressed file, decompressing the file when it is opened and compressing it when it is closed. When writing a compressed file, the system reserves disk space for the uncompressed size. The system gets back unused space as each individual compression buffer is compressed.

NTFS Encrypted Files (Windows 2000 only)

The Encrypting File System (EFS) provides the core file encryption technology used to store encrypted files on NTFS volumes. EFS keeps files safe from intruders who might gain unauthorized physical access to sensitive, stored data (for example, by stealing a portable computer or external disk drive).

EFS uses symmetric key encryption in conjunction with public key technology to protect files and ensure that only the owner of a file can access it. Users of EFS are issued a digital certificate with a public key and a private key pair. EFS uses the key set for the user who is logged on to the local computer where the private key is stored.

Users work with encrypted files and folders just as they do with any other files and folders. Encryption is transparent to the user who encrypted the file; the system automatically decrypts the file or folder when the user accesses. When the file is saved, encryption is reapplied. However, intruders who try to access the encrypted files or folders receive an “Access denied” message if they try to open, copy, move, or rename the encrypted file or folder.

To encrypt or decrypt a folder or file, set the encryption attribute for folders and files just as you set any other attribute. If you encrypt a folder, all files and subfolders created in the encrypted folder are automatically encrypted. It is recommended that you encrypt at the folder level.

NTFS Sparse Files (Windows 2000 only)

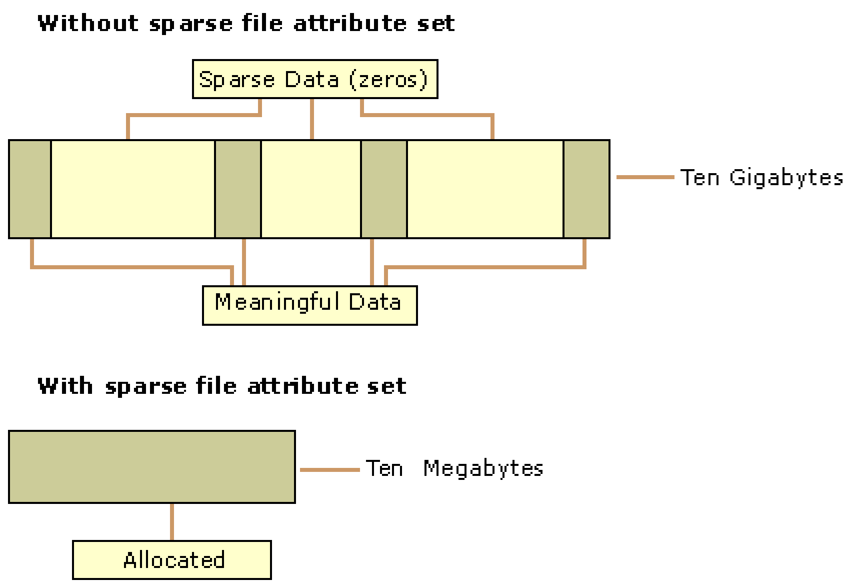
A sparse file has an attribute that causes the I/O subsystem to allocate only meaningful (nonzero) data. Nonzero data is allocated on disk, and non-meaningful data (large strings of data composed of zeros) is not. When a sparse file is read, allocated data is returned as it was stored; non-allocated data is returned, by default, as zeros.

NTFS deallocates sparse data streams and only maintains other data as allocated. When a program accesses a sparse file, the file system yields allocated data as actual data and deallocated data as zeros.

NTFS includes full sparse file support for both compressed and uncompressed files. NTFS handles read operations on sparse files by returning allocated data and sparse data. It is possible to read a sparse file as allocated data and a range of data without retrieving the entire data set, although NTFS returns the entire data set by default.

With the sparse file attribute set, the file system can deallocate data from anywhere in the file and, when an application calls, yield the zero data by range instead of storing and returning the actual data. File system application programming interfaces (APIs) allow for the file to be copied or backed as actual bits and sparse stream ranges. The net result is efficient file system storage and access. Next figure shows how data is stored with and without the sparse file attribute set.

Figure 5-4 Windows 2000 Data Storage



(!) *Important: If you copy or move a sparse file to a FAT or a non-Windows 2000 NTFS volume, the file is built to its originally specified size. If the required space is not available, the operation does not complete.*

Data Integrity and Recoverability with NTFS

NTFS is a recoverable file system that guarantees the consistency of the volume by using standard transaction logging and recovery techniques. In the event of a disk failure, NTFS restores consistency by running a recovery procedure that accesses information stored in a log file. The NTFS recovery procedure is exact, guaranteeing that the volume is restored to a consistent state. Transaction logging requires a very small amount of overhead.

NTFS ensures the integrity of all NTFS volumes by automatically performing disk recovery operations the first time a program accesses an NTFS volume after the computer is restarted following a failure.

NTFS also uses a technique called cluster remapping to minimize the effects of a bad sector on an NTFS volume.

(!) *Important: If either the master boot record (MBR) or boot sector is corrupted, you might not be able to access data on the volume.*

Recovering Data with NTFS

NTFS views each I/O operation that modifies a system file on the NTFS volume as a transaction, and manages each one as an integral unit. Once started, the transaction is either completed or, in the event of a disk failure, rolled back (such as when the NTFS volume is returned to the state it was in before the transaction was initiated).

To ensure that a transaction can be completed or rolled back, NTFS records the suboperations of a transaction in a log file before they are written to the disk. When a complete transaction is recorded in the log file, NTFS performs the suboperations of the transaction on the volume cache. After NTFS updates the cache, it commits the transaction by recording in the log file that the entire transaction is complete.

Once a transaction is committed, NTFS ensures that the entire transaction appears on the volume, even if the disk fails. During recovery operations, NTFS redoes each committed transaction found in the log file. Then NTFS locates the transactions in the log file that were not committed at the time of the system failure and undoes each transaction suboperation recorded in the log file. Incomplete modifications to the volume are prohibited.

NTFS uses the Log File service to log all redo and undo information for a transaction. NTFS uses the redo information to repeat the transaction. The undo information enables NTFS to undo transactions that are not complete or that have an error.

(!) *Important: NTFS uses transaction logging and recovery to guarantee that the volume structure is not corrupted. For this reason, all system files remain accessible after a system failure. However, user data can be lost because of a system failure or a bad sector.*

Cluster Remapping

In the event of a bad-sector error, NTFS implements a recovery technique called cluster remapping. When Windows 2000 detects a bad-sector, NTFS dynamically remaps the cluster containing the bad sector and allocates a new cluster for the data. If the error occurred during a read, NTFS returns a read error to the calling program, and the data is lost. If the error occurs during a write, NTFS writes the data to the new cluster, and no data is lost.

NTFS puts the address of the cluster containing the bad sector in its bad cluster file so the bad sector is not reused.

(!) *Important: Cluster remapping is not a backup alternative. Once errors are detected, the disk should be monitored closely and replaced if the defect list grows. This type of error is displayed in the Event Log.*

6 THE FILE RECOVERY PROCESS

File recovery process can be briefly described as drive or folder scanning to find deleted entries in Root Folder (FAT) or Master File Table (NTFS) then for the particular deleted entry, defining clusters chain to be recovered and then copying contents of these clusters to the newly created file.

Different file systems maintain their own specific logical data structures, however basically each file system:

- Has a list or catalog of file entries, so we can iterate through this list and entries, marked as deleted
- Keeps for each entry a list of data clusters, so we can try to find out set of clusters composing the file

After finding out the proper file entry and assembling set of clusters, composing the file, read and copy these clusters to another location.

Step by Step with examples:

- Disk Scanning
- Defining the Chain of Clusters
- Recovering the Chain of Clusters

Not every deleted file can be recovered, however there are some assumptions that are common to all deleted files:

- First, we assume that the file entry still exists (it has not been overwritten with other data). The fewer files that have been created on the drive where the deleted file was resided, increases the chances that space for the deleted file entry has not been used for other entries.
- Second, we assume that the file entry is more-or-less safe to point to the proper place where file clusters are located. In some cases (it has been noticed in Windows XP, on large FAT32 volumes) the operating system damages file entries right after deletion so that the first data cluster becomes invalid and further entry restoration is not possible.
- Third, we assume that the file data clusters are safe (not overwritten with other data). The fewer write operations events on the drive where deleted file resided, the more chances that the space occupied by data clusters of the deleted file has not been used for other data storage.

General Advice After Data Loss

1 DO NOT WRITE ANYTHING ONTO THE DRIVE CONTAINING YOUR IMPORTANT DATA THAT YOU HAVE JUST DELETED ACCIDENTALLY!

Even data recovery software installation can spoil your sensitive data. If the data is really important to you and you do not have another logical drive to install software to, take the whole hard drive out of the computer and plug it into another computer where data recovery software has been already installed or use recovery software that does not require installation, for example recovery software which is capable to run from bootable floppy.

2 DO NOT TRY TO SAVE ONTO THE SAME DRIVE DATA THAT YOU FOUND AND TRYING TO RECOVER!

When saving recovered data onto the same drive where sensitive data is located, you can intrude in process of recovering by overwriting FAT/MFT records for this and other deleted entries. It is better to save data onto another logical, removable, network or floppy drive.

Disk Scanning for Deleted Entries

Disk Scanning is a process of low-level enumeration of all entries in the Root Folders on FAT12, FAT16, FAT32 or in Master File Table (MFT) on NTFS, NTFS5. The goal is to find and display deleted entries.

In spite of different file/folder entry structure for the different file systems, all of them contain basic file attributes like name, size, creation and modification date/time, file attributes, existing/deleted status, etc....

Given that a drive contains root file table and any file table (MFT, root folder of the drive, regular folder, or even deleted folder) has location, size and predefined structure, we can scan it from the beginning to the end checking each entry, if it's deleted or not and then display information for all found deleted entries.

(i) *Note: Deleted entries are marked differently depending on the file system. For example, in FAT any deleted entry, file or folder has been marked with ASCII symbol 229 (OxE5) that becomes first symbol of the structure entry. On NTFS deleted entry has a special attribute in file header that points whether the file has been deleted or not.*

Example of scanning a folder on FAT16:

1 Existing folder MyFolder entry (long entry and short entry)

```
0003EE20   41 4D 00 79 00 46 00 6F   00 6C 00 0F 00 09 64 00   AM.y.F.o.l....d.
0003EE30   65 00 72 00 00 00 FF FF   FF FF 00 00 FF FF FF FF   e.r...yyyy..yyyy
0003EE40   4D 59 46 4F 4C 44 45 52   20 20 20 10 00 4A C4 93   MYFOLDER   ..JA“
0003EE50   56 2B 56 2B 00 00 C5 93   56 2B 02 00 00 00 00 00   V+V+..A“V+......
```

2 Deleted file MyFile.txt entry (long entry and short entry)

```
0003EE60   E5 4D 00 79 00 46 00 69   00 6C 00 0F 00 BA 65 00   aM.y.F.i.l...?e.
0003EE70   2E 00 74 00 78 00 74 00   00 00 00 00 FF FF FF FF   ..t.x.t.....yyyy
0003EE80   E5 59 46 49 4C 45 20 20   54 58 54 20 00 C3 D6 93   aYFILE  TXT .AO“
0003EE90   56 2B 56 2B 00 00 EE 93   56 2B 03 00 33 B7 01 00   V+V+..i“V+..3·..
```

3 Existing file Setuplog.txt entry (the only short entry)

```
0003EEA0   53 45 54 55 50 4C 4F 47   54 58 54 20 18 8C F7 93   SETUPLOGTXT .??“
```

```
0003EEB0   56 2B 56 2B 00 00 03 14  47 2B 07 00 8D 33 03 00   V+V+....G+..?3..
0003EEC0   00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ................
0003EED0   00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ................

Offset      0  1  2  3  4  5  6  7   8  9  A  B  C  D  E  F
```

This folder contains 3 entries, one of them is deleted. First entry is an existing folder MyFolder. Second one is a deleted file MyFile.txt Third one is an existing file Setuplog.txt.

First symbol of the deleted file entry is marked with E5 symbol, so Disk Scanner can assume that this entry has been deleted.

Example of scanning folder on NTFS5 (Windows 2000):

For our drive we have input parameters:

- Total Sectors 610406
- Cluster size 512 bytes
- One Sector per Cluster
- MFT starts from offset 0x4000, non-fragmented
- MFT record size 1024 bytes
- MFT Size 1968 records

Thus we can iterate through all 1968 MFT records, starting from the absolute offset 0x4000 on the volume looking for the deleted entries. We are interested in MFT entry 57 having offset 0x4000 + 57 * 1024 = 74752 = 0x12400 because it contains our recently deleted file “My Presentation.ppt”

Below MFT record number 57 is displayed:

```
Offset      0  1  2  3  4  5  6  7   8  9  A  B  C  D  E  F

00012400   46 49 4C 45 2A 00 03 00  9C 74 21 03 00 00 00 00   FILE*...?t!.....
00012410   47 00 02 00 30 00 00 00  D8 01 00 00 00 04 00 00   G...0...O.......
00012420   00 00 00 00 00 00 00 00  05 00 03 00 00 00 00 00   ................
00012430   10 00 00 00 60 00 00 00  00 00 00 00 00 00 00 00   ....`...........
00012440   48 00 00 00 18 00 00 00  20 53 DD A3 18 F1 C1 01   H....... SY?.nA.
00012450   00 30 2B D8 48 E9 C0 01  C0 BF 20 A0 18 F1 C1 01   .0+OHeA.A?  .nA.
00012460   20 53 DD A3 18 F1 C1 01  20 00 00 00 00 00 00 00    SY?.nA. .......
00012470   00 00 00 00 00 00 00 00  00 00 00 00 02 01 00 00   ................
00012480   00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ................
00012490   30 00 00 00 78 00 00 00  00 00 00 00 00 00 03 00   0...x...........
000124A0   5A 00 00 00 18 00 01 00  05 00 00 00 00 00 05 00   Z...............
000124B0   20 53 DD A3 18 F1 C1 01  20 53 DD A3 18 F1 C1 01    SY?.nA. SY?.nA.
000124C0   20 53 DD A3 18 F1 C1 01  20 53 DD A3 18 F1 C1 01    SY?.nA. SY?.nA.
000124D0   00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ................
000124E0   20 00 00 00 00 00 00 00  0C 02 4D 00 59 00 50 00    .........M.Y.P.
000124F0   52 00 45 00 53 00 7E 00  31 00 2E 00 50 00 50 00   R.E.S.~.1...P.P.
00012500   54 00 69 00 6F 00 6E 00  30 00 00 00 80 00 00 00   T.i.o.n.0...ˆ...
00012510   00 00 00 00 00 00 02 00  68 00 00 00 18 00 01 00   ........h.......
00012520   05 00 00 00 00 00 05 00  20 53 DD A3 18 F1 C1 01   ........ SY?.nA.
00012530   20 53 DD A3 18 F1 C1 01  20 53 DD A3 18 F1 C1 01    SY?.nA. SY?.nA.
00012540   20 53 DD A3 18 F1 C1 01  00 00 00 00 00 00 00 00    SY?.nA.........
00012550   00 00 00 00 00 00 00 00  20 00 00 00 00 00 00 00   ........ .......
00012560   13 01 4D 00 79 00 20 00  50 00 72 00 65 00 73 00   ..M.y. .P.r.e.s.
00012570   65 00 6E 00 74 00 61 00  74 00 69 00 6F 00 6E 00   e.n.t.a.t.i.o.n.
00012580   2E 00 70 00 70 00 74 00  80 00 00 00 48 00 00 00   ..p.p.t.ˆ...H...
00012590   01 00 00 00 00 00 04 00  00 00 00 00 00 00 00 00   ................
000125A0   6D 00 00 00 00 00 00 00  40 00 00 00 00 00 00 00   m.......@.......
000125B0   00 DC 00 00 00 00 00 00  00 DC 00 00 00 00 00 00   .U.......U......
000125C0   00 DC 00 00 00 00 00 00  31 6E EB C4 04 00 00 00   .U......1neA....
000125D0   FF FF FF FF 82 79 47 11  00 00 00 00 00 00 00 00   yyyy,yG.........
000125E0   00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ................
```

```
000125F0   00 00 00 00 00 00 00 00  00 00 00 00 00 00 03 00   ................
................
00012600   00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ................
```

MFT Record has pre-defined structure. It has a set of attributes defining any file of folder parameters.

MFT Record begins with standard File Record Header (first bold section, offset 0x00):

- "FILE" identifier (4 bytes)
- Offset to update sequence (2 bytes)
- Size of update sequence (2 bytes)
- $LogFile Sequence Number (LSN) (8 bytes)
- Sequence Number (2 bytes)
- Reference Count (2 bytes)
- Offset to Update Sequence Array (2 bytes)
- Flags (2 bytes)
- Real size of the FILE record (4 bytes)
- Allocated size of the FILE record (4 bytes)
- File reference to the base FILE record (8 bytes)
- Next Attribute Id (2 bytes)

The most important information for us in this block is a file state: deleted or in-use. If Flags (in red color) field has bit 1 set, it means that file is in-use. In our example it is zero, i.e. file is deleted.

Starting from 0x48, we have **Standard Information Attribute** (second bold section):

- File Creation Time (8 bytes)
- File Last Modification Time (8 bytes)
- File Last Modification Time for File Record (8 bytes)
- File Access Time for File Record (8 bytes)
- DOS File Permissions (4 bytes) 0x20 in our case Archive Attribute

Following standard attribute header, we have **File Name Attribute** belonging to DOS name space, short file names, (third bold section, offset 0xA8) and again following standard attribute header, we have **File Name Attribute** belonging to Win32 name space, long file names, (third bold section, offset 0x120):

- File Reference to the Parent Directory (8 bytes)
- File Modification Times (32 bytes)
- Allocated Size of the File (8 bytes)
- Real Size of the File (8 bytes)
- Flags (8 bytes)
- Length of File Name (1 byte)
- File Name Space (1 byte)

- File Name (Length of File Name * 2 bytes)

In our case from this section we can extract file name, "My Presentation.ppt", File Creation and Modification times, and Parent Directory Record number.

Starting from offset 0x188, there is a non-resident Data attribute (green section).

- Attribute Type (4 bytes) (e.g. 0x80)
- Length including header (4 bytes)
- Non-resident flag (1 byte)
- Name length (1 byte)
- Offset to the Name (2 bytes)
- Flags (2 bytes)
- Attribute Id (2 bytes)
- Starting VCN (8 bytes)
- Last VCN (8 bytes)
- Offset to the Data Runs (2 bytes)
- Compression Unit Size (2 bytes)
- Padding (4 bytes)
- Allocated size of the attribute (8 bytes)
- Real size of the attribute (8 bytes)
- Initialized data size of the stream (8 bytes)
- Data Runs ...

In this section we are interested in Compression Unit size (zero in our case means non-compressed), Allocated and Real size of attribute that is equal to our file size (0xDC00 = 56320 bytes), and Data Runs (see the next topic).

Defining the Chain of Clusters

To reconstruct a file from a set of clusters, we need to define a chain of clusters. Here are the steps:

1. Scan the drive to locate and identify data.
2. One-by-one, go through each file cluster (NTFS) or each free cluster (FAT) that we presume belongs to the file
3. Continue chaining the clusters until the size of the cumulative total of clusters approximately equals the total size of the deleted file. If the file is fragmented, the chain of clusters will be composed of several extents (NTFS), or select probable contiguous clusters and bypass occupied clusters that appear to have random data (FAT).

   The location of these clusters can vary depending on file system. For example, a file deleted in a FAT volume has its first cluster in the Root entry; the other clusters can be found in the File Allocation Table. In NTFS each file has a **_DATA_** attribute that describes "data runs". Disassembling data runs reveals **extents**. For each extent there is a **start cluster offset** and a **number of clusters in extent**. By enumerating the extents, the file's cluster chain can be assembled.

The clusters chain can be assembled manually, using low-level disk editors, however it is much simpler using a data recovery utility, like **Active@ UNERASER**.

Defining a Cluster Chain in FAT16

In the previous topic, we were examining a sample set of data with a deleted file named **MyFile.txt**. This example will continue with the same theme.

The folder we scanned before contains a record for this file:

```
0003EE60 E5 4D 00 79 00 46 00 69   00 6C 00 0F 00 BA 65 00   aM.y.F.i.l...?e.
0003EE70 2E 00 74 00 78 00 74 00   00 00 00 00 FF FF FF FF   ..t.x.t.....yyyy
0003EE80 E5 59 46 49 4C 45 20 20   54 58 54 20 00 C3 D6 93   aYFILE TXT .AO"
0003EE90 56 2B 56 2B 00 00 EE 93   56 2B 03 00 33 B7 01 00   V+V+..i"V+..3..
```

We can calculate size of the deleted file based on root entry structure. Last four bytes are 33 B7 01 00 and converting them to decimal value (changing bytes order), we get 112435 bytes. Previous 2 bytes (03 00) are the number of the first cluster of the deleted file. Repeating for them the conversion operation, we get number 03 **-** this is the start cluster of the file.

What we can see in the File Allocation Table at this moment?

```
Offset    0  1  2  3  4  5  6  7    8  9  A  B  C  D  E  F
00000200 F8 FF FF FF FF FF 00 00   00 00 00 00 00 00 08 00   oyyyyy..........
00000210 09 00 0A 00 0B 00 0C 00   0D 00 FF FF 00 00 00 00   ..........yy....
00000220 00 00 00 00 00 00 00 00   00 00 00 00 00 00 00 00   ................
```

Zeros! And it is good in our case **-** it means that these clusters are free, i.e. most likely our file was not overwritten by another file's data. Now we have chain of clusters 3, 4, 5, 6 and we are ready to recover it.

Some explanations:

- We started looking from offset 6 because each cluster entry in FAT16 takes 2 bytes, our file starts from 3rd cluster, i.e. 3*2=6.
- We considered 4 clusters because cluster size on our drive is 32 Kb, our file size is 112, 435 bytes, i.e. 3clusters*32Kb = 96Kb plus a little bit more.
- We assumed that this file was not fragmented, i.e. all clusters were located consecutively. We need 4 clusters, we found 4 free consecutive clusters, so this assumption sounds reasonable, although in real life it may be not true.

(i) *Note: In many cases data cannot be successfully recovered, because the cluster chain cannot be defined. This will occur when another file or folder is written on the same drive as the one where the deleted file is located. Warning messages about this fact will be displayed while recovering data using Active@ UNDELETE.*

Defining a Cluster Chain in NTFS

When recovering in NTFS, a part of DATA attributes called **Data Runs** provides the location of file clusters. In most cases, DATA attributes are stored in the Master File Table (MFT) record. Finding the MFT record for a deleted file will most likely lead to the location of the cluster's chain.

In example below the DATA attribute is marked with a green color. Data Runs inside the DATA attribute are marked as Bold.

```
Offset    0  1  2  3  4  5  6  7     8  9  A  B  C  D  E  F
00012580 2E 00 70 00 70 00 74 00   80 00 00 00 48 00 00 00   ..p.p.t._...H...
00012590 01 00 00 00 00 00 04 00   00 00 00 00 00 00 00 00   ................
000125A0 6D 00 00 00 00 00 00 00   40 00 00 00 00 00 00 00   m.......@.......
000125B0 00 DC 00 00 00 00 00 00   00 DC 00 00 00 00 00 00   .U.......U......
000125C0 00 DC 00 00 00 00 00 00   31 6E EB C4 04 00 00 00   .U......1neA....
000125D0 FF FF FF FF 82 79 47 11   00 00 00 00 00 00 00 00   yyyy,yG.........
```

Decrypting Data Runs

Decrypting data runs can be accomplished using the following steps:

1. First byte (0x31) shows how many bytes are allocated for the length of the run (0x1 in the example case) and for the first cluster offset (0x3 in our case).
2. Take one byte (0x6E) that points to the length of the run.
3. Pick up 3 bytes pointing to the start cluster offset (0xEBC404).
4. Changing bytes order we get first cluster of the file 312555 (equals 0x04C4EB).
5. Starting from this cluster we need to pick up 110 clusters (equals 0x6E).
6. Next byte (0x00) tells us that no more data runs exist.
7. Our file is not fragmented, so we have the only one data run.
8. Lastly, check to see if there is enough information (size of the file). Cluster size is 512 bytes. There are 110 clusters, 110*512 = 56,320 bytes. Our file size was defined as 56,320 bytes, so we have enough information now to recover the file clusters.

Recovering the Chain of Clusters

After the cluster chain is defined, the final task is to read and save the contents of the defined clusters to another place, verifying their contents. With a chain of clusters and standard formulae, it is possible to calculate each **cluster offset** from the beginning of the drive. Formulae for calculating cluster offset vary, depending on file system. Starting from the calculated offset, copy a volume of data equal to the size of the chain of clusters into a newly-created file.

To calculate the cluster offset in a FAT drive, we need to know:

- Boot sector size
- Number of FAT-supported copies
- Size of one copy of FAT
- Size of main root folder
- Number of sectors per cluster
- Number of bytes per sector

NTFS format defines a linear space and calculating the cluster offset is simply a matter of multiplying the cluster number by the cluster size.

Recovering Cluster Chain in FAT16

This section continues the examination of the deleted file **MyFile.txt** from previous topics. By now we have chain of clusters numbered 3, 4, 5 and 6 identified for recovering. Our cluster consists of 64 sectors, sector size is 512 bytes, so cluster size is: 64*512 = 32,768 bytes = 32 Kb.

The first data sector is 535 (we have 1 boot sector, plus 2 copies of FAT times 251 sectors each, plus root folder 32 sectors, total 534 occupied by system data sectors).

Clusters 0 and 1 do not exist, so the first data cluster is 2.

Cluster number 3 is next to cluster 2, i.e. it is located 64 sectors behind the first data sector (535 + 64 = 599).

Equal offset of 306,668 byte from the beginning of the drive (0x4AE00).

With a help of low-level disk editor on the disk we can see our data starting with offset 0x4AE00, or cluster 3, or sector 599:

```
Offset    0  1  2  3  4  5  6  7      8  9  A  B  C  D  E  F
0004AE00 47 55 49 20 6D 6F 64 65    20 53 65 74 75 70 20 68   GUI mode Setup h
0004AE10 61 73 20 73 74 61 72 74    65 64 2E 0D 0A 43 3A 5C   as started...C:\
0004AE20 57 49 4E 4E 54 5C 44 72    69 76 65 72 20 43 61 63   WINNT\Driver Cac
```

Because the cluster chain is consecutive, all we need to do is copy 112,435 bytes starting from this place. If the cluster chain was not consecutive, we would need to re-calculate the offset for each cluster and copy 3 times the value of 64*512 = 32768 bytes starting from each cluster offset. The last cluster copy remainder, 14,131 bytes is calculated as 112,435 bytes - (3 * 32,768 bytes).

Recovering Cluster Chain in NTFS

In our example we just need to pick up 110 clusters starting from the cluster 312555.

Cluster size is 512 byte, so the offset of the first cluster would be 512 * 312555 = 160028160 = 0x0989D600

```
Offset    0  1  2  3  4  5  6  7      8  9  A  B  C  D  E  F

0989D600 D0 CF 11 E0 A1 B1 1A E1    00 00 00 00 00 00 00 00   ÐÏ.à¡±.á........
0989D610 00 00 00 00 00 00 00 00    3E 00 03 00 FE FF 09 00   ........>...þÿ..
0989D620 06 00 00 00 00 00 00 00    00 00 00 00 01 00 00 00   ................
0989D630 69 00 00 00 00 00 00 00    00 10 00 00 6B 00 00 00   i...........k...
0989D640 01 00 00 00 FE FF FF FF    00 00 00 00 6A 00 00 00   ....þÿÿÿ....j...
0989D650 FF FF FF FF FF FF FF FF    FF FF FF FF FF FF FF FF   ÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿÿ
```

In the above data, data recovery is complete when data has been read from this point through 110 clusters (56320 bytes). This data is copied to another location.

7 THE PARTITION RECOVERY PROCESS

System Boot Process

In some cases, the first indication of a problem with hard drive data is a refusal of the machine to perform a bootstrap startup. For the machine to be able to start properly, the following conditions must apply:

- Master Boot Record (MBR) exists and is safe
- Partition Table exists and contains at least one active partition

If the above is in place, executable code in the MBR selects an active partition and passes control there, so it can start loading the standard files (COMMAND.COM, NTLDR,...) depending on the file system type on that partition.

If these files are missing or corrupted it will be impossible for the operating system to boot - if you have ever seen the famous “NTLDR is missing...” error, you understand the situation.

When using Active@ File Recovery, the recovery software accesses the damaged drive at a low level, bypassing the standard system boot process (this is the same as if you instructed the computer to boot from another hard drive). Once the computer is running in this recovery environment, it will help you to see all other files and directories on the drive and allow you to copy data to a safe place on another drive.

Partition Visibility

A more serious situation exists if your computer will start and cannot see a drive partition or physical drive (see Note below). For the partition or physical drive to be visible to the Operating System the following conditions must apply:

- Partition/Drive can be found via Partition Table
- Partition/Drive boot sector is safe

If the above conditions are true, the OS can read the partition or physical drive parameters and display the drive in the list of the available drives.

If the file system is damaged (Root, FAT area on FAT12/FAT16/FAT32, or system MFT records on NTFS) the drive's content might not be displayed and we might see errors like “MFT is corrupted”, or “Drive is invalid”... If this is the case it is less likely that you will be able to restore your data. Do not despair, as there may be some tricks or tips to display some of the residual entries that are still safe, allowing you to recover your data to another location.

Partition recovery describes two things:

Physical partition recovery. The goal is to identify the problem and write information to the proper place on the hard drive so that the partition becomes visible to the OS again. This can be done using manual Disk Editors along with proper guidelines or using recovery software, designed specifically for this purpose.

Active@ Partition Recovery software implements this approach.

Virtual partition recovery. The goal is to determine the critical parameters of the deleted/damaged/overwritten partition and render it open to scanning in order to display its content. This approach can be applied in some cases when physical partition recovery is not possible (for example, partition boot sector is dead) and is commonly used by recovery software. This process is almost impossible to implement it manually.

Active@ File Recovery, Active@ UNERASER for DOS software both implement this approach.

(i) *Note: If your computer has two operating systems and you choose to start in Windows 95/98 or ME, these operating systems cannot see partitions that are formatted for NTFS. This is normal operation for these operating systems. To view NTFS partitions, you must be in a Windows NT/2000/XP environment.*

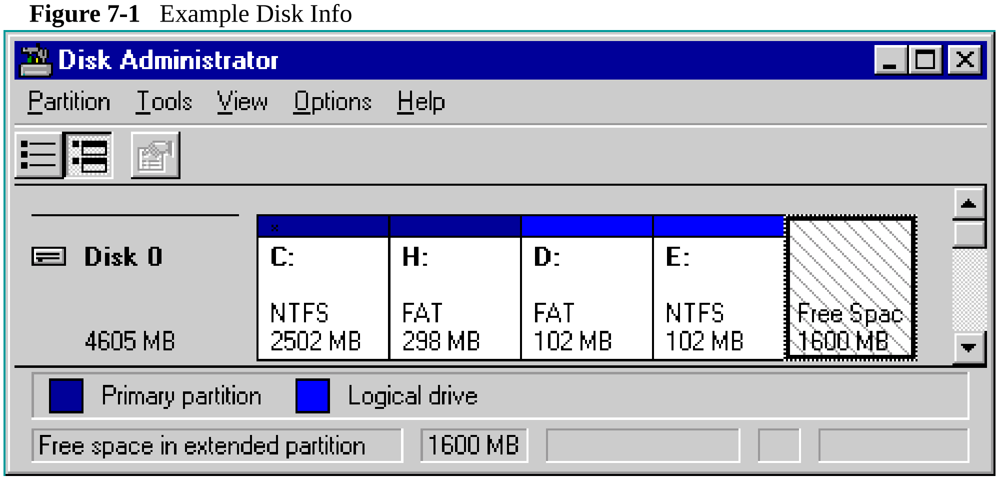
Other Partition Recovery Topics

These topics related to the recovery of partitions apply to any file system:

- MBR is Damaged
- Partition is Deleted or Partition Table is Damaged
- Partition Boot Sector is Damaged
- Missing or Corrupted System Files

For these topics the following disk layout will be used:

Figure 7-1 Example Disk Info



The figure shows a system with two primary partitions (C:(NTFS) and H:(FAT)) and one extended partition having two logical drives (D: (FAT) and E:(NTFS))

MBR is Damaged

The Master Boot Record (MBR) will be created when you create the first partition on the hard disk. It is very important data structure on the disk. The Master Boot Record contains the Partition Table for the disk and a small amount of executable code for the boot start. The location is always the first sector on the disk.

The first 446 (0x1BE) bytes are MBR itself, the next 64 bytes are the Partition Table, the last two bytes in the sector are a signature word for the sector and are always 0x55AA.

Blank Screen on Startup

For our disk layout we have MBR:

```
Physical Sector: Cyl 0, Side 0, Sector 1
000000000   33 C0 8E D0 BC 00 7C FB  50 07 50 1F FC BE 1B 7C   3AZ??.|uP.P.u?.|
000000010   BF 1B 06 50 57 B9 E5 01  F3 A4 CB BE BE 07 B1 04   ?..PW?a.o¤E??.±.
000000020   38 2C 7C 09 75 15 83 C6  10 E2 F5 CD 18 8B 14 8B   8,|.u.??.aoI.‹.‹
000000030   EE 83 C6 10 49 74 16 38  2C 74 F6 BE 10 07 4E AC   i??.It.8,to?..N¬
000000040   3C 00 74 FA BB 07 00 B4  0E CD 10 EB F2 89 46 25   <.tu»..?.I.eo‰F%
000000050   96 8A 46 04 B4 06 3C 0E  74 11 B4 0B 3C 0C 74 05   –SF.?.<.t.?.<.t.
000000060   3A C4 75 2B 40 C6 46 25  06 75 24 BB AA 55 50 B4   :Au+@?F%.u$»?UP?
000000070   41 CD 13 58 72 16 81 FB  55 AA 75 10 F6 C1 01 74   AI.Xr.?uU?u.oA.t
000000080   0B 8A E0 88 56 24 C7 06  A1 06 EB 1E 88 66 04 BF   .Sa?V$C.?.e.?f.?
000000090   0A 00 B8 01 02 8B DC 33  C9 83 FF 05 7F 03 8B 4E   ..?..‹U3E?y..‹N
0000000A0   25 03 4E 02 CD 13 72 29  BE 46 07 81 3E FE 7D 55   %.N.I.r)?F.?>?}U
0000000B0   AA 74 5A 83 EF 05 7F DA  85 F6 75 83 BE 27 07 EB   ?tZ?i.U…ou??'.e
0000000C0   8A 98 91 52 99 03 46 08  13 56 0A E8 12 00 5A EB   S?‘R™.F..V.e..Ze
0000000D0   D5 4F 74 E4 33 C0 CD 13  EB B8 00 00 00 00 00 00   OOta3AI.e?......
0000000E0   56 33 F6 56 56 52 50 06  53 51 BE 10 00 56 8B F4   V3oVVRP.SQ?..V‹o
0000000F0   50 52 B8 00 42 8A 56 24  CD 13 5A 58 8D 64 10 72   PR?.BSV$I.ZX?d.r
000000100   0A 40 75 01 42 80 C7 02  E2 F7 F8 5E C3 EB 74 49   .@u.BˆC.a?o^AetI
000000110   6E 76 61 6C 69 64 20 70  61 72 74 69 74 69 6F 6E   nvalid partition
000000120   20 74 61 62 6C 65 00 45  72 72 6F 72 20 6C 6F 61    table.Error loa
000000130   64 69 6E 67 20 6F 70 65  72 61 74 69 6E 67 20 73   ding operating s
000000140   79 73 74 65 6D 00 4D 69  73 73 69 6E 67 20 6F 70   ystem.Missing op
000000150   65 72 61 74 69 6E 67 20  73 79 73 74 65 6D 00 00   erating system..
000000160   00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ................
000000170   00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ................
000000180   00 00 00 8B FC 1E 57 8B  F5 CB 00 00 00 00 00 00   ...‹u.W‹oE......
000000190   00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ................
0000001A0   00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ................
0000001B0   00 00 00 00 00 00 00 00  A6 34 1F BA 00 00 80 01   ........¦4.?..ˆ.
0000001C0   01 00 07 FE 7F 3E 3F 00  00 00 40 32 4E 00 00 00   ...?>?...@2N...
0000001D0   41 3F 06 FE 7F 64 7F 32  4E 00 A6 50 09 00 00 00   A?.?d2N.¦P....
0000001E0   41 65 0F FE BF 4A 25 83  57 00 66 61 38 00 00 00   Ae.??J%?W.fa8...
0000001F0   00 00 00 00 00 00 00 00  00 00 00 00 00 00 55 AA   ..............U?
```

To simulate what will happen if the first sector has been damaged (by a virus, for example), we will overwrite the first 16 bytes with zeros, as shown below:

```
000000000   00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ................
000000010   BF 1B 06 50 57 B9 E5 01  F3 A4 CB BE BE 07 B1 04   ?..PW?a.o¤E??.±.
```

We have effectively destroyed the MBR at this point. When we try to restart the computer, we see the hardware testing procedures, and then a blank screen without any messages. This blank screen confirms that the piece of code at the beginning of the MBR could not be executed properly. Error messages cannot be displayed because the MBR cannot be run.

If we boot from a system floppy, however, we can see a hard drive FAT partition and the files on it. We are able to perform standard operations like file copy, program execution and so on. This is possible because only the first part of the MBR has been damaged. The partition table is safe and we can access our drives when we boot from the operating system installed on the other drive.

Operating System Not Found

In this next scenario, we explore what will happen if the **sector signature** (last word 0x55AA) has been removed or damaged?

To explore this scenario, we write zeros to the location of sector signature, as shown below:

```
Physical Sector: Cyl 0, Side 0, Sector 1
0000001E0   41 65 0F FE BF 4A 25 83  57 00 66 61 38 00 00 00   Ae.??J%?W.fa8...
0000001F0   00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ................
```

When we try to boot now, we see the “Operating System not found” error message.

When encountering this message on system boot, run **Disk Viewer** and check the first physical sector on the hard drive to see whether it looks like a valid MBR or not. Here are things to check:

- See if it is filled up with zeros or any other single character.
- Check whether error messages (like you can see above “Invalid partition table”...) are present or not.
- Check whether the disk signature (0x55AA) is present.

The simplest way to repair or re-create the MBR is to run Microsoft's standard utility called **FDISK** with a parameter **/MBR**. The command looks like the sample below:

```
A:\> FDISK.EXE  /MBR
```

FDISK is a standard utility included in MS-DOS, Windows 95, 98, ME.

If you have Windows NT / 2000 / XP, you can boot from startup floppy disks or CD-ROM, choose **Repair** option during setup, and run **Recovery Console**. When you are logged on, you can run **FIXMBR** command to repair the MBR.

Another alternative is to use a third party MBR recovery utility or if you've created an MBR backup, repair the damaged MBR by restoring the backup (Active@ Partition Recovery has such capabilities).

Recovering Data if the First Sector is Bad or Unreadable

In the **Blank Screen** simulation, above, we simulated the destroyed first sector scenario. When you try to read the first sector using Disk Viewer/Editor you should get an error message saying that the sector is unreadable. In this case recovery software is unable to help you to bring the hard drive back to the working condition, i.e. physical partition recovery is not possible.

The only thing that can be done is to scan and search for partitions (i.e. perform virtual partition recovery). When something is found - display the data save it to another location. Software, like Active@ File Recovery, Active@ UNERASER for DOS will help you here.

Partition is Deleted or Partition Table is Damaged

The information about primary partitions and extended partition is contained in the Partition Table, a 64-byte data structure, located in the same sector as the Master Boot Record (cylinder 0, head 0, sector 1). The Partition Table conforms to a standard layout, which is independent of the operating system. The last two bytes in the sector are a signature word for the sector and are always 0x55AA.

For our disk layout we have Partition Table:

```
 Physical Sector: Cyl 0, Side 0, Sector 1
0000001B0                                             80 01   ..............€.
0000001C0   01 00 07 FE 7F 3E 3F  00 00 00 40 32 4E 00 00 00   ...?>?...@2N...
0000001D0   41 3F 06 FE 7F 64 7F 32  4E 00 A6 50 09 00 00 00   A?.?d2N.¦P....
0000001E0   41 65 0F FE BF 4A 25 83  57 00 66 61 38 00 00 00   Ae.??J%?W.fa8...
0000001F0   00 00 00 00 00 00 00 00  00 00 00 00 00 00 55 AA   ..............U?
```

We can see three existing entries and one empty entry:

- Partition 1, offset 0x01BE (446)
- Partition 2, offset 0x01CE (462)
- Partition 3, offset 0x01DE (478)
- Partition 4 - empty, offset 0x01EE (494)

Each Partition Table entry is 16 bytes long, making a maximum of four entries available. Each partition entry has fields for Boot Indicator (BYTE), Starting Head (BYTE), Starting Sector (6 bits), Starting Cylinder (10 bits), System ID (BYTE), Ending Head (BYTE), Ending Sector (6 bits), Ending Cylinder (10 bits), Relative Sector (DWORD), Total Sectors (DWORD).

Thus the MBR loader can assume the location and size of partitions. MBR loader looks for the “active” partition, i.e. partition that has Boot Indicator equals 0x80 (the first one in our case) and passes control to the partition boot sector for further loading.

Below, a number of situations are simulated demonstrating events which cause a computer to hang while booting or in a data loss scenario:

1 No disk partition has been set to the Active state (Boot Indicator=0x80).

To simulate this scenario, remove the Boot Indicator from the first partition as below:

```
0000001B0                                            00 01  ................
0000001C0 01 00 07 FE 7F 3E 3F  00 00 00 40 32 4E 00 00 00  ...?>?...@2N...
```

When we try to boot now, we see an error message like “Operating System not found”. This demonstrates a situation where the loader wants to pass control to the active system, and cannot determine which partition is active and contains the system.

2 A partition has been set to the Active state (Boot Indicator=0x80) but there are no system files on that partition.

(This situation is possible if we had used FDISK and not selected the correct active partition).

The Loader tries to pass control to the partition, fails, tries to boot again from other devices like the floppy. If it fails to boot again, an error message like “Non-System Disk or Disk Error” appears.

3 Partition entry has been deleted.

If the partition entry has been deleted, the next two partitions will move one line up in the partition table, as below:

```
Physical Sector: Cyl 0, Side 0, Sector 1
0000001B0                                               80 00   ..............€.
0000001C0   41 3F 06 FE 7F 64 7F 32  4E 00 A6 50 09 00 00 00   A?.?d2N.¦P....
0000001D0   41 65 0F FE BF 4A 25 83  57 00 66 61 38 00 00 00   Ae.??J%?W.fa8...
0000001E0   00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ................
0000001F0   00 00 00 00 00 00 00 00  00 00 00 00 00 00 55 AA   ..............U?
```

If we try to boot now, the partition previous identified as “second” (FAT) partition becomes the “first” and the loader will try to boot from it. If the operating system does not exist within the partition, the same error messages appear.

4 Partition entry has been damaged.

To simulate this situation, write zeros to the location of the first partition entry.

```
Physical Sector: Cyl 0, Side 0, Sector 1
0000001B0                                               80 00   ..............€.
0000001C0   00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ................
0000001D0   41 3F 06 FE 7F 64 7F 32  4E 00 A6 50 09 00 00 00   A?.?d2N.¦P....
0000001E0   41 65 0F FE BF 4A 25 83  57 00 66 61 38 00 00 00   Ae.??J%?W.fa8...
0000001F0   00 00 00 00 00 00 00 00  00 00 00 00 00 00 55 AA   ..............U?
```

If we try to boot now, the MBR loader will try to read and interpret zeros (or other garbage) as partition parameters. The error message will read “Missing Operating System”.

Thus, the second step in partition recovery is to run Disk Viewer and to make sure that the proper partition exists in the partition table and has been set as active.

Can Recovery Software Help in the Above Scenarios?

Recovery Software can help in the following ways:

1. Discover and suggest you to choose the partition to be active (even FDISK does so).
2. Discover and suggest you to choose the partition to be active.
3. Perform a free disk space scan to look for partition boot sector or remaining of the deleted partition information in order to try to reconstruct Partition Table entry for the deleted partition.
4. Perform all disk space scan to look for partition boot sector or remaining of the damaged partition information in order to try to reconstruct Partition Table entry for the damaged partition entry.

Why is the Partition Boot Sector so Important?

If recovery software finds it, all necessary parameters to reconstruct partition entry in the Partition Table are there. (see Partition Boot Sector topic for details).

What if a Partition Entry was Deleted Then Recreated and Re-formatted?

In this case, instead of the original partition entry we would have a new one and everything would work fine except that later on we could recall that we had some important data on the original partition. If you've created MBR, Partition Table, Volume Sectors backup before the problem (for example, Active@ Partition Recovery and Active@ UNERASER can do this), you can virtually restore it back and look for your data (in case if it has not been overwritten with new data yet). Some advanced recovery tools also have an ability to scan the disk surface and try to reconstruct previously deleted partition information from the remnants of information (i.e. perform virtual partition recovery). However there is no guarantee that you can recover anything.

Partition Boot Sector is Damaged

The Partition Boot Sector contains information, which the file system uses to access the volume. On personal computers, the Master Boot Record uses the Partition Boot Sector on the system partition to load the operating system kernel files. Partition Boot Sector is the first sector of the Partition.

For our first NTFS partition we have boot sector:

```
Physical Sector: Cyl 0, Side 1, Sector 1
000000000   EB 5B 90 4E 54 46 53 20  20 20 20 00 02 01 00 00   e[?NTFS    .....
000000010   00 00 00 00 00 F8 00 00  3F 00 FF 00 3F 00 00 00   .....o..?.y.?...
000000020   00 00 00 00 80 00 80 00  3F 32 4E 00 00 00 00 00   ....€.€.?2N.....
000000030   5B 43 01 00 00 00 00 00  1F 19 27 00 00 00 00 00   [C.......'.....
000000040   02 00 00 00 08 00 00 00  10 EC 46 C4 00 47 C4 0C   .........iFA.GA.
000000050   00 00 00 00 00 00 00 00  00 00 00 00 00 FA 33 C0   .............u3A
000000060   8E D0 BC 00 7C FB B8 C0  07 8E D8 C7 06 54 00 00   Z??.|u?A.ZOC.T..
000000070   00 C7 06 56 00 00 00 C7  06 5B 00 10 00 B8 00 0D   .C.V...C.[...?..
000000080   8E C0 2B DB E8 07 00 68  00 0D 68 66 02 CB 50 53   ZA+Ue..h..hf.EPS
000000090   51 52 06 66 A1 54 00 66  03 06 1C 00 66 33 D2 66   QR.f?T.f....f3Of
0000000A0   0F B7 0E 18 00 66 F7 F1  FE C2 88 16 5A 00 66 8B   .·...f?n?A?.Z.f‹
0000000B0   D0 66 C1 EA 10 F7 36 1A  00 88 16 25 00 A3 58 00   ?fAe.?6..?.%.?X.
0000000C0   A1 18 00 2A 06 5A 00 40  3B 06 5B 00 76 03 A1 5B   ?..*.Z.@;.[.v.?[
0000000D0   00 50 B4 02 8B 16 58 00  B1 06 D2 E6 0A 36 5A 00   .P?.‹.X.±.O?.6Z.
0000000E0   8B CA 86 E9 8A 36 25 00  B2 80 CD 13 58 72 2A 01   ‹E†eS6%.?€I.Xr*.
0000000F0   06 54 00 83 16 56 00 00  29 06 5B 00 76 0B C1 E0   .T.?.V..).[.v.Aa
000000100   05 8C C2 03 D0 8E C2 EB  8A 07 5A 59 5B 58 C3 BE   .?A.?ZAeS.ZY[XA?
000000110   59 01 EB 08 BE E3 01 EB  03 BE 39 01 E8 09 00 BE   Y.e.?a.e.?9.e..?
000000120   AD 01 E8 03 00 FB EB FE  AC 3C 00 74 09 B4 0E BB   -.e..ue?¬<.t.?.»
000000130   07 00 CD 10 EB F2 C3 1D  00 41 20 64 69 73 6B 20   ..I.eoA..A disk
000000140   72 65 61 64 20 65 72 72  6F 72 20 6F 63 63 75 72   read error occur
000000150   72 65 64 2E 0D 0A 00 29  00 41 20 6B 65 72 6E 65   red....).A kerne
000000160   6C 20 66 69 6C 65 20 69  73 20 6D 69 73 73 69 6E   l file is missin
000000170   67 20 66 72 6F 6D 20 74  68 65 20 64 69 73 6B 2E   g from the disk.
000000180   0D 0A 00 25 00 41 20 6B  65 72 6E 65 6C 20 66 69   ...%.A kernel fi
000000190   6C 65 20 69 73 20 74 6F  6F 20 64 69 73 63 6F 6E   le is too discon
0000001A0   74 69 67 75 6F 75 73 2E  0D 0A 00 33 00 49 6E 73   tiguous....3.Ins
0000001B0   65 72 74 20 61 20 73 79  73 74 65 6D 20 64 69 73   ert a system dis
0000001C0   6B 65 74 74 65 20 61 6E  64 20 72 65 73 74 61 72   kette and restar
0000001D0   74 0D 0A 74 68 65 20 73  79 73 74 65 6D 2E 0D 0A   t..the system...
0000001E0   00 17 00 5C 4E 54 4C 44  52 20 69 73 20 63 6F 6D   ...\NTLDR is com
0000001F0   70 72 65 73 73 65 64 2E  0D 0A 00 00 00 00 55 AA   pressed.......U?

Offset       0  1  2  3  4  5  6  7   8  9  A  B  C  D  E  F
```

The printout is formatted in three sections:

- Bytes 0x00– 0x0A are the jump instruction and the OEM ID (shown in bold print).
- Bytes 0x0B–0x53 are the BIOS Parameter Block (BPB) and the extended BPB.

  This block contains such essential parameters as:
  - Bytes Per Sector (WORD, offset 0x0B),
  - Sectors Per Cluster (BYTE, offset 0x0D),
  - Media Descriptor (BYTE, offset 0x15),
  - Sectors Per Track (WORD, offset 0x18),
  - Number of Heads (WORD, offset 0x1A),
  - Hidden Sectors (DWORD, offset 0x1C),
  - Total Sectors (LONGLONG, offset 0x28), etc....

- The remaining code is the bootstrap code (that is necessary for the proper system boot) and the end of sector marker (shown in bold print).

This sector is so important on NTFS, for example, that a duplicate of the boot sector is located on the disk.

Boot Sector for FAT looks different, however its BPB contains parameters similar to the above mentioned. There is no extra copy of this sector stored anywhere, so recovery on FAT is not as convenient as it is on NTFS.

What Will Happen if Partition Boot Sector is Damaged or Bad/Unreadable?

To simulate this scenario, we fill up several lines of the Partition Boot Sector with zeros:

```
000000000   00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ................
000000010   00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ................
000000020   00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ................
000000030   00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ................
000000040   00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ................
000000050   00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ................
000000060   8E D0 BC 00 7C FB B8 C0  07 8E D8 C7 06 54 00 00   Z??.|u?A.ZOC.T..
```

If we try to boot, we'll see “Non System Disk” or “Disk Error”. After we fail to load from it and from floppy, partition becomes unbootable.

Because a normally functioning system relies on the boot sector to access a volume, it is highly recommended that you run disk-scanning tools such as **Chkdsk** regularly, as well as back up all of your data files to protect against data loss in case you lose access to the volume.

Tools like Active@ Partition Recovery and Active@ UNERASER allow you to create a backup of the MBR, Partition Table and Volume Boot Sectors so that if for some reason the system fails to boot, you can restore your partition information and have access to files and folders on that partition.

What if This Sector is Damaged?

- If we do have backup of the whole disk or MBR/Boot Sectors we can try to restore it from there.
- If we do not have backup, in case of NTFS we could try to locate a duplicate of Partition Boot Sector and get information from there.
- If duplicate boot sector is not found, only virtual partition recovery might be possible if we can determine critical partition parameters such as Sectors per Cluster, etc.

Can I Fix NTFS Boot Sector Using Standard Windows NT/2000/XP Tools?

On NTFS a copy of the boot sector is stored in the middle or at the end of the Volume.

You can boot from startup floppy disks or CD-ROM, choose the **Repair** option during setup, and run **Recovery Console**. When you are logged on, you can run the **FIXBOOT** command to try to fix boot sector.

Can Recovery Software Help in This Situation?

It can backup MBR, Partition Table and Boot Sectors and restore them in case of damage.

It can try to find out duplicate boot sector on the drive and re-create the original one or perform virtual data recovery based on found partition parameters

Some advanced techniques allow assuming drive parameters even if duplicate boot sector is not found (i.e. perform virtual partition recovery) and give the user virtual access to the data on the drive to be able to copy them to the safer location.

Missing or Corrupted System Files

For the operating system to boot properly, system files are required to be safe.

In case of Windows 95 / 98 / ME, these files are **msdos.sys, config.sys, autoexec.bat, system.ini, system.dat, user.dat,** etc.

In case of Windows NT / 2000 / XP these files are: **NTLDR, ntdetect.com, boot.ini,** located at the root folder of the bootable volume, **Registry files** (i.e., SAM, SECURITY, SYSTEM and SOFTWARE), etc.

If these files have been deleted, corrupted or damaged by a virus, Windows will be unable to boot. You'll see error messages like “NTLDR is missing ...“.

The next step in the recovery process is to check the existence and safety of system files (you won't able to check them all, but you must check at least **NTLDR**, **ntdetect.com**, **boot.ini** which cause most problems).

To do it in Windows 95 / 98 / ME, boot in **Command Prompt** mode, or from a bootable floppy and check the system files in the command line or with a help of third party recovery software.

To do it in Windows NT / 2000 / XP, use the **Emergency Repair Process**, **Recovery Console** or third party recovery software.

Emergency Repair Process

To proceed with Emergency Repair Process, you need an **Emergency Repair Disk** (ERD). It is recommended to create an ERD after you install and customize Windows. To create it, use the **Backup** utility from System Tools. You can use the ERD to repair a damaged boot sector, damaged MBR, repair or replace missing or damaged NT Loader (NTLDR) and ntdetect.com files.

If you do not have an ERD, the emergency repair process can attempt to locate your Windows installation and start repairing your system, but it may not be able to do so.

To run the process, boot from a Windows bootable disk or CD, and choose the **Repair** option when system suggests you to proceed with installation or repairing. Then press **R** to run Emergency Repair Process and choose **Fast** or **Manual Repair** option. Fast Repair is recommended for most users, Manual Repair **-** for Administrators and advanced users only.

If the emergency repair process is successful, your computer will automatically restart and you should have a working system

Recovery Console

Recovery Console is a command line utility similar to MS-DOS command line. You can list and display folder content, copy, delete, replace files, format drives and perform many other administrative tasks.

To run Recovery Console, boot from Windows bootable disks or CD and choose the **Repair** option. When the system suggests you to proceed with installation or repairing and then press **C** to run Recovery Console. You will be asked which system you want to log on to and then for the Administrator's password. After you logged on, you can display the drive's contents, check the existence and safety of critical files and, for example, copy them back to restore them if they have been accidentally deleted.

Recovery Software

Third party recovery software in most cases does not allow you to deal with system files due to the risk of further damage to the system, however you can use it to check for the existence and safety of these files, or to perform virtual partition recovery.

8 TROUBLESHOOTING

The scenarios in this chapter originate from actual help service offered to customers.

"UNREGISTERED VERSION" Message

I have purchased and copied software onto the floppy. When starting Active@ File Recovery, I get a message that reads "UNREGISTERED VERSION".

Possible Cause

You forgot to copy **SETTINGS.INI**. This file contains your registration key.

Solution 1 Look for SETTINGS.INI at the installation folder and copy it to the same place where you start Active@ File Recovery from.

Solution 2 Install software directly to the floppy disk. All necessary files will be copied there.

Maximizing Chances of Recovering Files

I deleted a file. How long do I have before data recovery is no longer possible?

Discussion

It is not possible to predict a time like this in hours or days. Microsoft Windows can overwrite a deleted file immediately if it selects the same data clusters.

Solution To maximize chances of recovery try not to write anything onto the drive where a deleted file is located before you start using recovery software.

Getting the Trial Version

How can I download the trial version of Active@ File Recovery utility?

Solution You can do it from the www.file-recovery.net Web site. The trial version is a utility with full functionality of the final program. The only limitation is the maximum size of the file being restored.

Restoring Files

I have deleted a very important document. It was deleted before Active@ File Recovery was installed on my computer. Is it possible to restore it?

Solution If the file has not already been over written (by some other files) then chances are good for recovery.

When you discover that an important file has been deleted, download and install Active@ File Recovery and search for this file. It may be a good idea to avoid disk activity on this particular hard drive as follows:

- Do not delete other files
- Avoid restarting the computer
- Do not open a large number of programs concurrently (increased OS paging and swapping activity takes place on the hard drive)

All of these activities are disk storage intensive. A new temporary file might overwrite or partially overwrite the deleted document. More drive storage events will make finding a particular file more complicated.

The more free hard drive space you have on your computer, the greater the chances for a successful retrieval of deleted file contents. It is always a good idea to extract and install Active@ File Recovery to a different physical hard drive - one that does not contain important deleted file(s).

Windows 2000, Windows XP

Does Active@ File Recovery work under Windows 2000 / XP?

Answer Yes, it does.

Windows 3.x

Does Active@ File Recovery work under Windows 3.x

Answer No. Support of 16-bit operation systems like Windows 3.1 is not implemented.

Browser Support

I have Netscape Navigator 4.6 as my default browser. Will I be able to install and use Active@ File Recovery?

Answer Yes. To download and install software you need to have Internet Explorer or Netscape Navigator, or any other browser that supports file download. The browser is required only to retrieve the file. After software installation the browser is not needed to run the utility.

Non-English File Names

Does Active@ File Recovery support localized (e.g. French, Spanish) file names?

Answer Yes. Provided the operating system and file system support localized file names, the utility will support special characters.

Long File Names

Will Active@ File Recovery recover long file names?

Answer Yes. Provided the operating system and file system support long file names the utility supports them.

Disk Image

What is a Disk Image? Why is it needed?

Answer Disk Image is a mirror of your logical drive that is stored in one file. A Disk Image file can be useful when you want to back up the contents of the whole drive, and restore it or work with it later.

Before you start recovering deleted files, it may be a good idea to create a Disk Image for this drive, if you have enough space on another drive. If something goes wrong while recovering the files (for example, recovering them onto the same drive could destroy their contents), you will be able to recover these deleted files and folders from the Disk Image that you have wisely created.

Recovery Tips

DO NOT WRITE ANYTHING ONTO THE DRIVE CONTAINING YOUR IMPORTANT DATA THAT YOU HAVE JUST DELETED ACCIDENTALLY!

Even data recovery software installation could spoil your sensitive data. If the data is really important to you, and you do not have another logical drive to install software to, take whole hard drive out of the computer and plug into another computer where data recovery software has been already installed.

DO NOT SAVE ONTO THE SAME DRIVE DATA THAT YOU FOUND AND TRYING TO RECOVER!

While saving recovered data onto the same drive where sensitive data was located, you can intrude in the process of recovering by overwriting table records for this and other deleted entries. It is better to save data onto another logical, removable, network or floppy drive.

CREATE DISK IMAGE IF YOU HAVE EXTRA HARD DRIVE, OR OTHER LOGICAL DRIVES ARE BIG ENOUGH!

Disk Image is a mirror of your logical drive that is stored in one file. This can be useful when you want to backup the contents of the whole drive, and restore it or work with it later. Before you start recovering the deleted files, it may be a good idea to create a Disk Image for this drive, if you have enough space at another drive. If you do something wrong while recovering the files (for example, recovering them onto the same drive could destroy their contents), you will be able to recover these deleted files and folders from the Disk Image that you have wisely created.

Active Data Recovery Services

Active Data Recovery Services is a division of LSoft Technologies Inc, software development company designing disk utilities related to the recovery of lost data.

Our mission is to create a software framework for the data security of our clients. New powerful and unique security technologies have been created to serve this goal. As the latest technologies expand the power and reach of the Personal Computer for its users, our ambition is to remain committed to supporting these advances.

Contact Information

Postal Address
LSoft Technologies Inc.
2550 Argentia Road, Suite 218
Mississauga, Ontario, Canada
L5N5R1

Fax: 1 (416) 352-7561
Customer Service: sales@file-recovery.net
Technical Support: support@file-recovery.net