

Assembly Language for x86 Processors

7th Edition

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Chapter 15: Disk Fundamentals

Slide show prepared by the author

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Chapter Overview

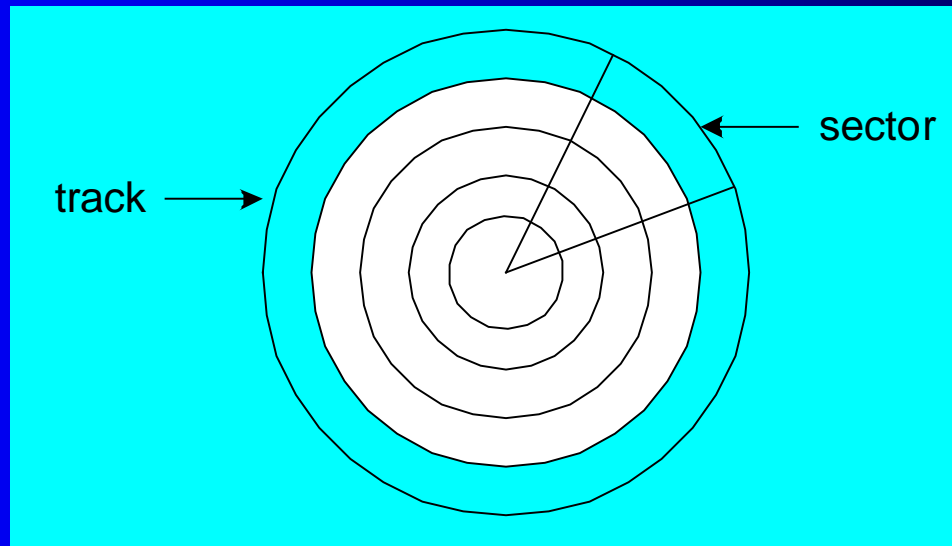
- **Disk Storage Systems**
- File Systems
- Disk Directory
- Reading and Writing Disk Sectors (7305h)
- System-Level File Functions

Disk Storage Systems

- Tracks, Cylinders, and Sectors
- Disk Partitions (Volumes)

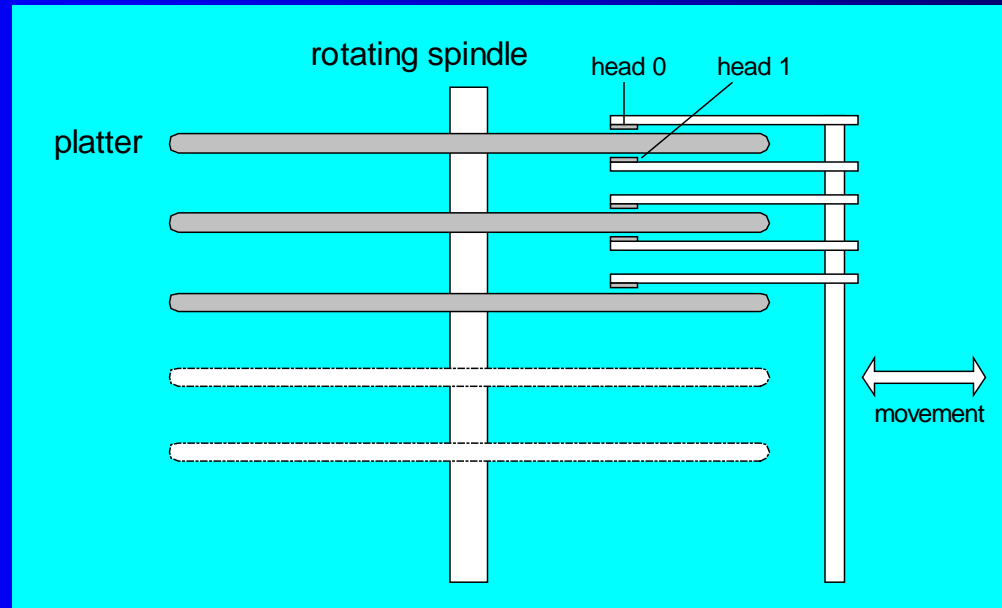
Tracks and Sectors

- **Physical disk geometry** - a way of describing the disk's structure to make it readable by the system BIOS
- **Track** - concentric circle containing data
- **Sector** - part of a track



Cylinders and Seeking

- **Cylinder** - all tracks readable from one head position
- **Seek** - move read/write heads between tracks

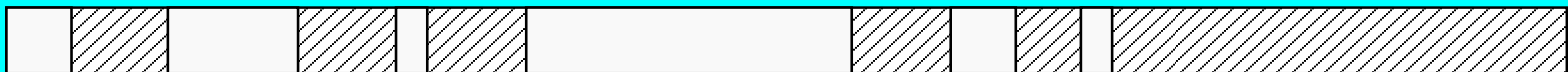


Disk Formatting

- Physical formatting
 - aka **low-level formatting**
 - Usually done at the factory.
 - Must be done before logical formatting
 - Defines the tracks, sectors, and cylinders
- Logical formatting
 - Permits disk to be accessed using sequentially numbered **logical sectors**
 - Installs a file system (ex: NTFS)
 - May install an operating system

Fragmentation

- A **fragmented** file is one whose sectors are no longer located in contiguous areas of the disk.
 - causes read/write heads to skip
 - slower file access
 - possible read/write errors



Translation

- Translation - conversion of physical disk geometry to a sequence of logical sector numbers
- Performed by a hard disk controller (firmware)
- **Logical sector numbers** are numbered sequentially, have no direct mapping to hardware

Disk Partitions

- Logical units that divide a physical hard disk
 - Also called **volumes**
- Primary partition
 - Up to four permitted
 - Each may boot a different OS
- Extended partition
 - Maximum of one permitted
 - May be divided into multiple **logical partitions**, each with a different drive letter
- Primary and Extended
 - Up to three primary and one extended

Logical Partitions

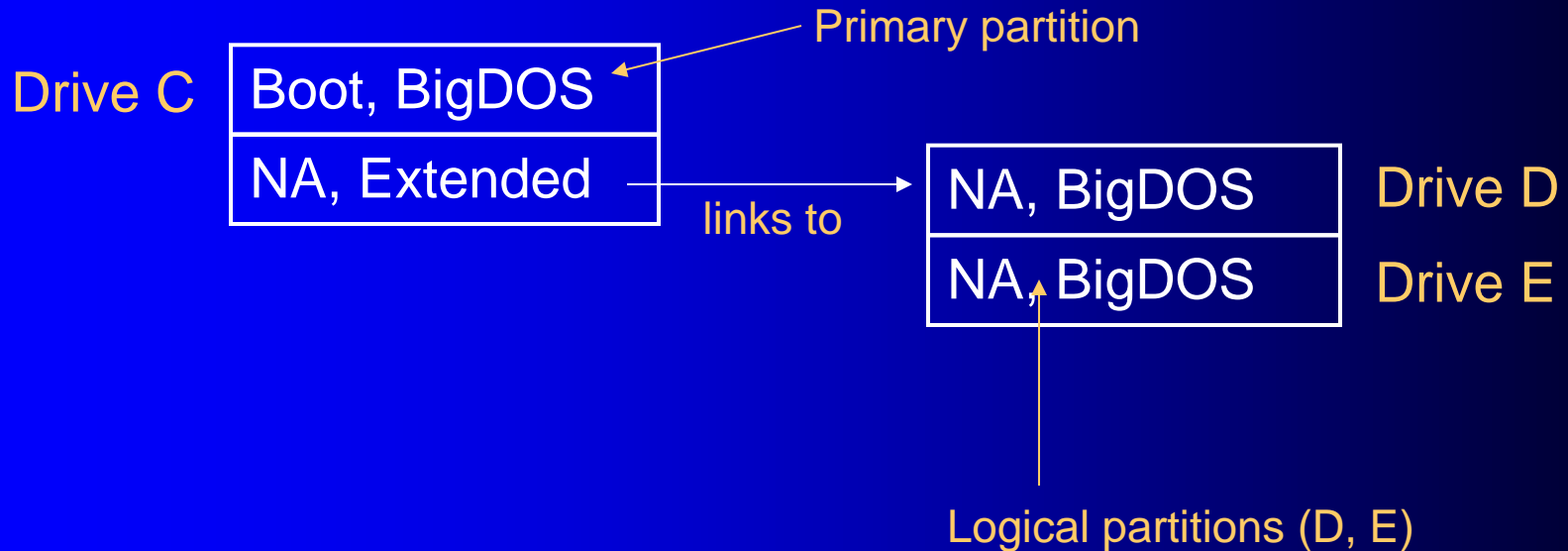
- Created from an extended partition
- No limit on the number
- Each has a separate drive letter
- Usually contain data
- Can be bootable (ex: Linux)

Disk Partition Table

- Located in the disk's Master Boot Record (MBR), following a block of executable code
- Four entries, one for each possible partition
- Each entry contains the following fields:
 - state (*non-active*, *bootable*)
 - type of partition (*BigDOS*, *Extended*, . . .)
 - beginning head, cylinder, & sector numbers
 - ending head, cylinder, & sector numbers
 - offset of partition from MBR
 - number of sectors in the partition

See also: www.datarescue.com/laboratory/partition.htm

Cascading Partition Tables









Boot = bootable (system)

NA = non active

BigDOS = over 32 MB

Dual-Boot Example

| Volume | Layout | Type | File System | Status | Capacity | Free Space | % Free |
|--|-----------|-------|-------------|------------------|----------|------------|--------|
|  | Partition | Basic | | Healthy | 5.13 GB | 5.13 GB | 100 % |
|  | Partition | Basic | | Healthy | 2.01 GB | 2.01 GB | 100 % |
|  BACKUP (E:) | Partition | Basic | FAT32 | Healthy | 7.80 GB | 4.84 GB | 62 % |
|  DATA_1 (D:) | Partition | Basic | FAT32 | Healthy | 7.80 GB | 2.66 GB | 34 % |
|  SYSTEM 98 | Partition | Basic | FAT32 | Healthy | 1.85 GB | 1.12 GB | 57 % |
|  WIN2000-A (C:) | Partition | Basic | NTFS | Healthy (System) | 3.91 GB | 1.43 GB | 36 % |

- System 98 and Win2000-A are bootable partitions
 - One is called the system partition when active
- DATA_1 and BACKUP are logical partitions
 - Their data can be shared by both operating systems

Master Boot Record (MBR)

- The MBR contains the following elements:
 - Disk partition table
 - A program that jumps to the boot sector of the system partition

What's Next

- Disk Storage Systems
- **File Systems**
- Disk Directory
- Reading and Writing Disk Sectors (7305h)
- System-Level File Functions

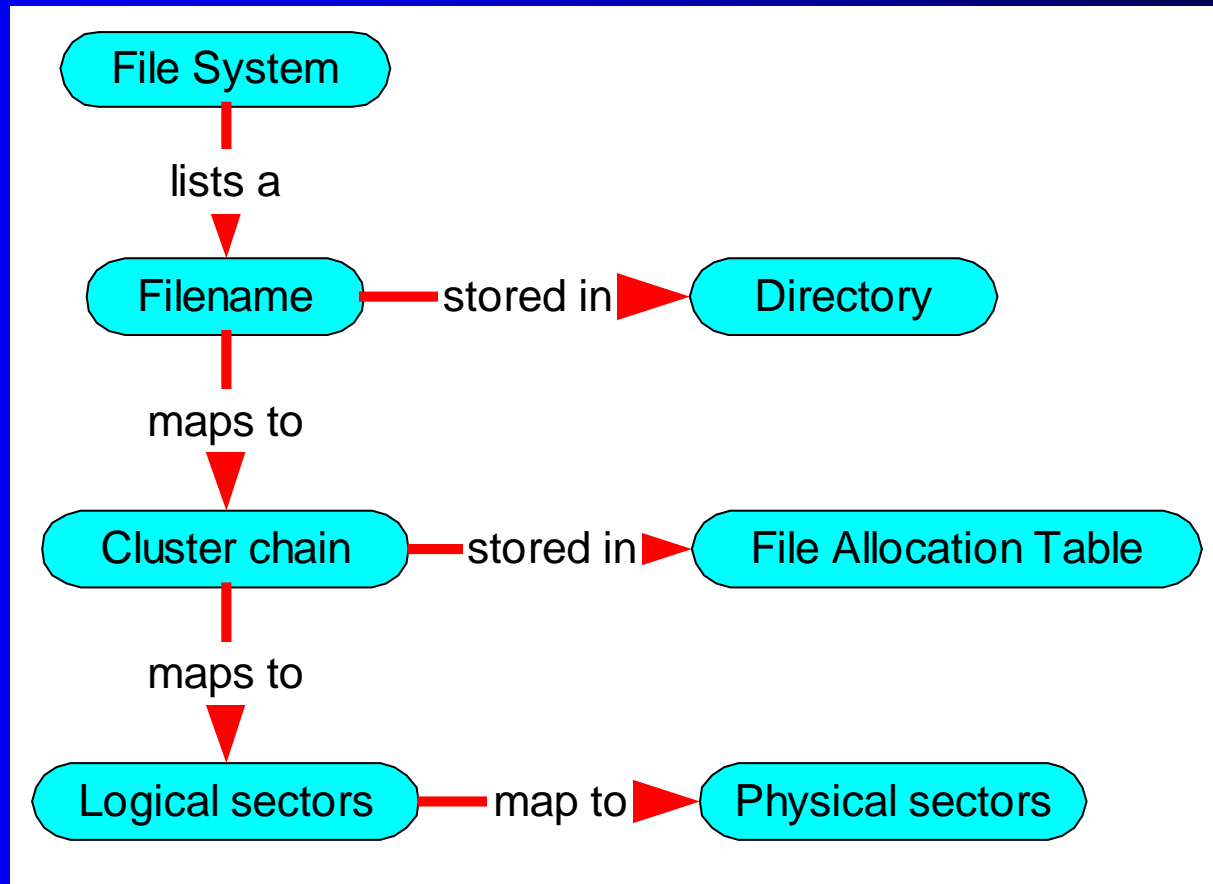
File Systems

- Directory, File, Cluster Relationships
- Clusters
- FAT12
- FAT16
- FAT32
- NTFS
- Primary Disk Areas

File System

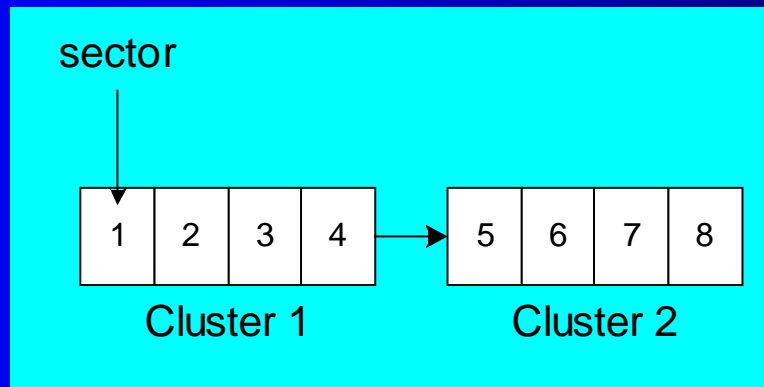
- This is what it does for you:
 - Keeps track of allocated and free space
 - Maintains directories and filenames
 - Tracks the sector location of each file and directory

Directory, File, Cluster, Sector Relationships



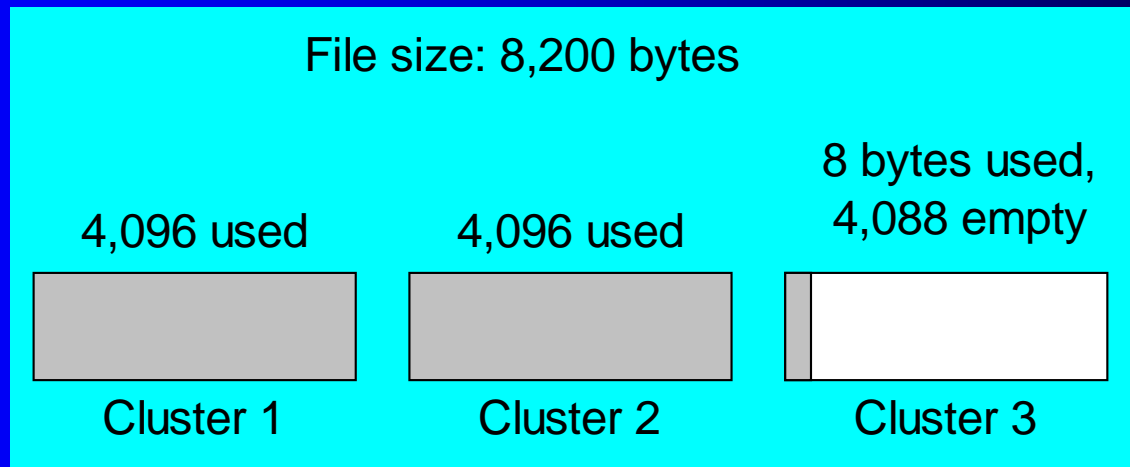
Cluster (1 of 2)

- Smallest unit of space used by a file
- Consists of one or more adjacent sectors
- Size depends on both the type of file system in use and the disk partition size
- A **file** is a linked sequence of clusters. Example:



Cluster (2 of 2)

- A file always uses at least one cluster
- A high percentage of space may be wasted
- Example: 8,200-byte file requires three 4K clusters:



FAT12

- Designed for diskettes
- Each FAT entry is 12 bits
- Very little fault tolerance
 - two copies of the FAT (cluster table)
- Optimal storage for small files
 - 512-byte clusters

FAT16

- MS-DOS format for hard disks
- 16-bit FAT entries
- Large cluster size when disk > 1 GB
 - inefficient for small files
- Max 2 GB size under MS-DOS
- Little or no recovery from read/write errors

FAT32

- Supports long filenames
- Supported by all version of MS-Windows from Windows 95 onward
 - (except Windows NT)
- 32-bit FAT entries
- 32 GB maximum volume size
- Improved recovery from read/write errors

NTFS

- Supported by Windows NT, 2000, and XP
- Handles large volumes
 - can span multiple hard drives
- Efficient cluster size (4K) on large volumes
- Unicode filenames
- Permissions on files & folders
- Share folders across network
- Built-in compression and encryption
- Track changes in a *change journal*
- Disk quotas for individuals or groups
- Robust error recovery
- Disk mirroring

Primary Disk Areas

- A disk or volume is divided into predefined areas and assigned specific logical sectors.
- Example: 1.44 MB diskette
 - Boot record (sector 0)
 - File allocation table (sectors 1 – 18)
 - Root directory (sectors 19 – 32)
 - Data area (sectors 33 – 2,879)

Your turn . . .

1. A 1.44 MB diskette has 512 bytes per cluster.
Suppose a certain file begins in cluster number 5.
Which logical disk sector contains the beginning of the file? (*Hint: see page 503*).
2. Suppose a certain hard drive has 4 KB per cluster,
and we know that the data area begins in sector 100.
If a particular file begins in cluster 10, which logical
sectors are used by the cluster?

(answers on next panel . . .)

Answers

1. The data area begins in Sector 33. Each cluster = 1 sector, so the file begins in sector $33 + 5 =$ sector 38.
2. The hard drive has 8 sectors per cluster. The starting cluster number of the file is $100 + (8 * 10) = 180$. Therefore, sectors 180 – 187 are used by the file's first cluster.

Boot Record (1 of 2)

- Fields in a typical MS-DOS boot record:
 - Jump to boot code (JMP instruction)
 - Manufacturer name, version number
 - Bytes per sector
 - Sectors per cluster
 - Number of reserved sectors (preceding FAT #1)
 - Number of copies of FAT
 - Maximum number of root directory entries
 - Number of disk sectors for drives under 32 MB
 - Media descriptor byte
 - Size of FAT, in sectors
 - Sectors per track

Boot Record (2 of 2)

(continued)

- Number of drive heads
- Number of hidden sectors
- Number of disk sectors for drives over 32 MB
- Drive number (modified by MS-DOS)
- Reserved
- Extended boot signature (always 29h)
- Volume ID number (binary)
- Volume label
- File-system type (ASCII)
- Start of boot program and data

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Keeping Track of Files

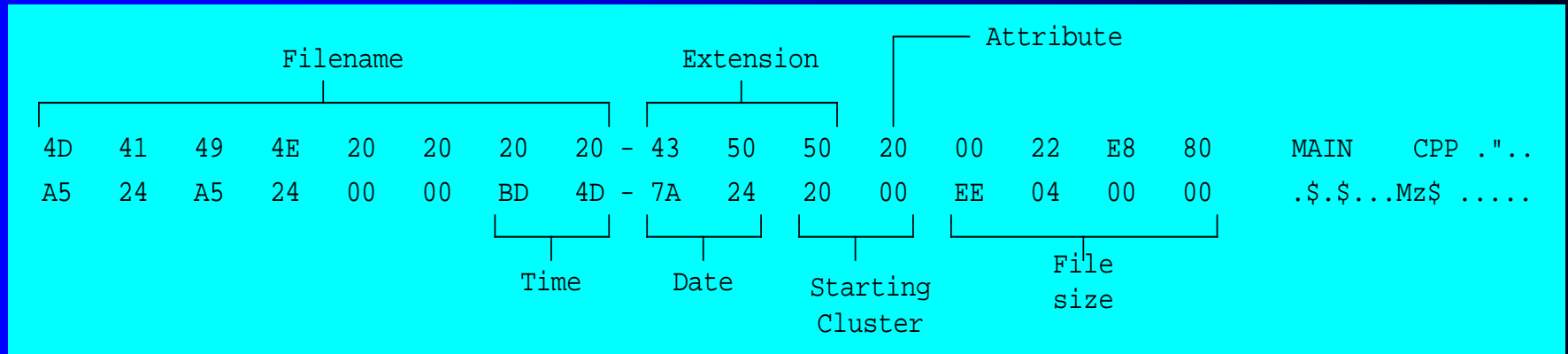
- MS-DOS Directory Structure
- Long Filenames in MS-Windows
- File Allocation Table

MS-DOS Directory Structure (1 of 2)

| Hexadecimal Offset | Field Name | Format |
|--------------------|-------------------------|---------------|
| 00-07 | Filename | ASCII |
| 08-0A | Extension | ASCII |
| 0B | Attribute | 8-bit binary |
| 0C-15 | Reserved by MS-DOS | |
| 16-17 | Time stamp | 16-bit binary |
| 18-19 | Date stamp | 16-bit binary |
| 1A-1B | Starting cluster number | 16-bit binary |
| 1C-1F | File size | 32-bit binary |

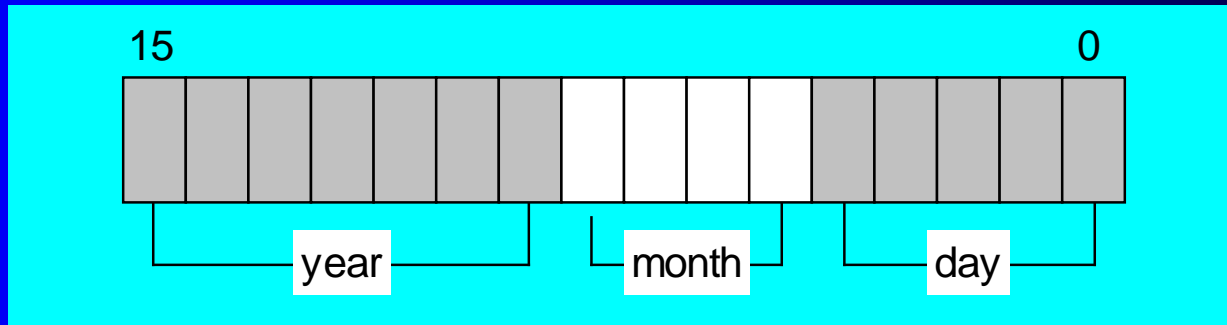
MS-DOS Directory Structure (2 of 2)

Time field equals 4DBDh (9:45:58), and the Date field equals 247Ah (March 26, 1998). Attribute is normal:

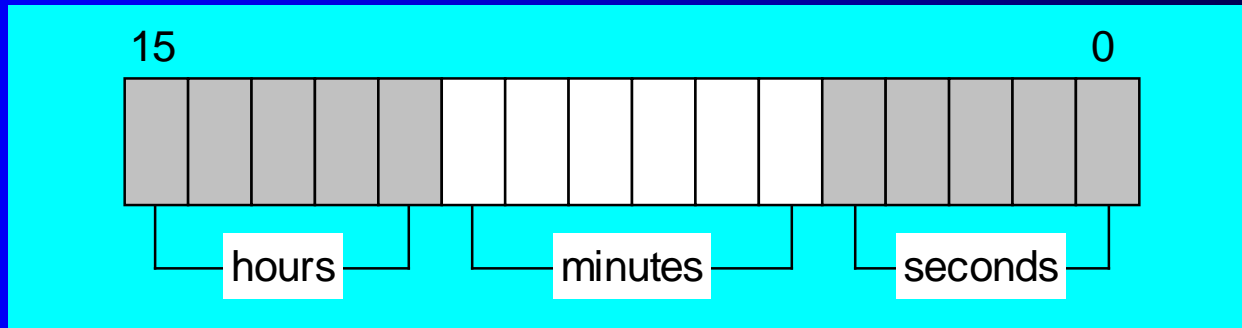


Date and Time Fields

- Date stamp field:

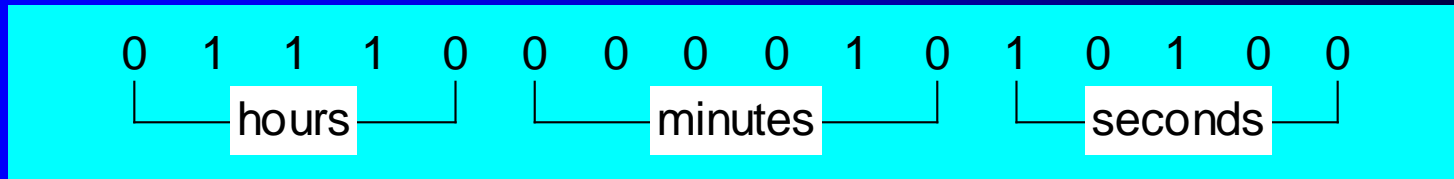


- Time stamp field:

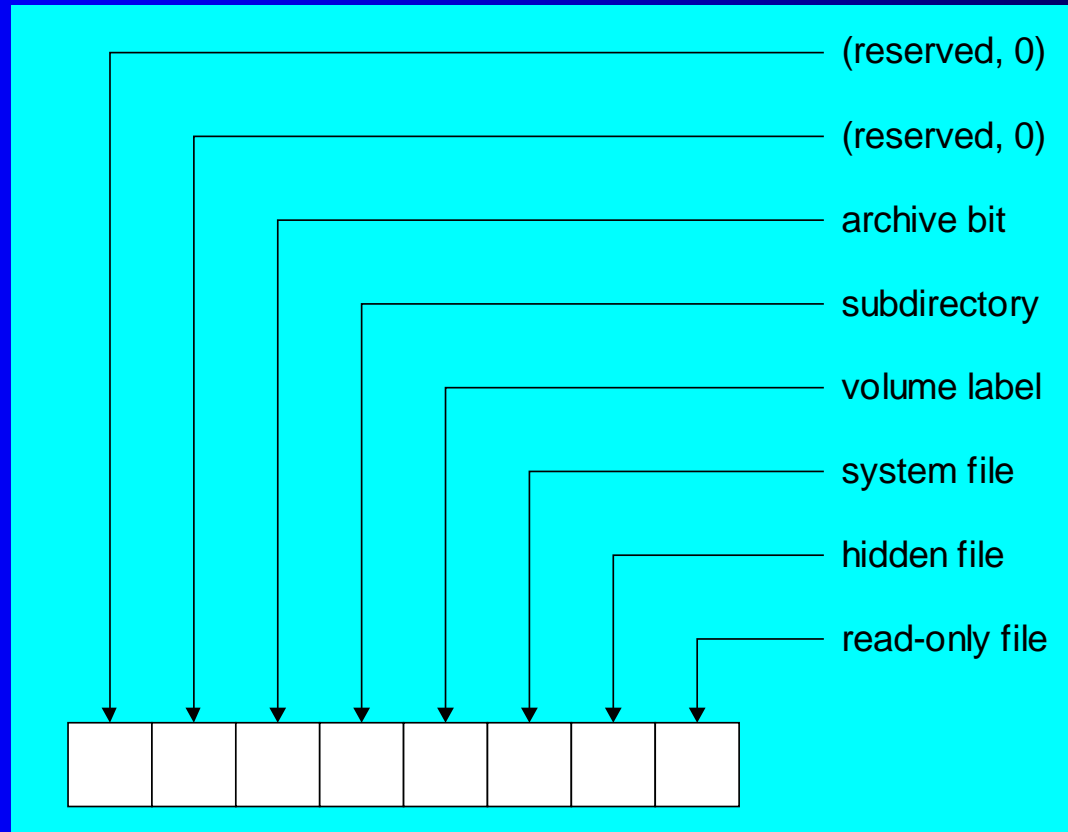


Your turn . . .

- What time value is represented here?



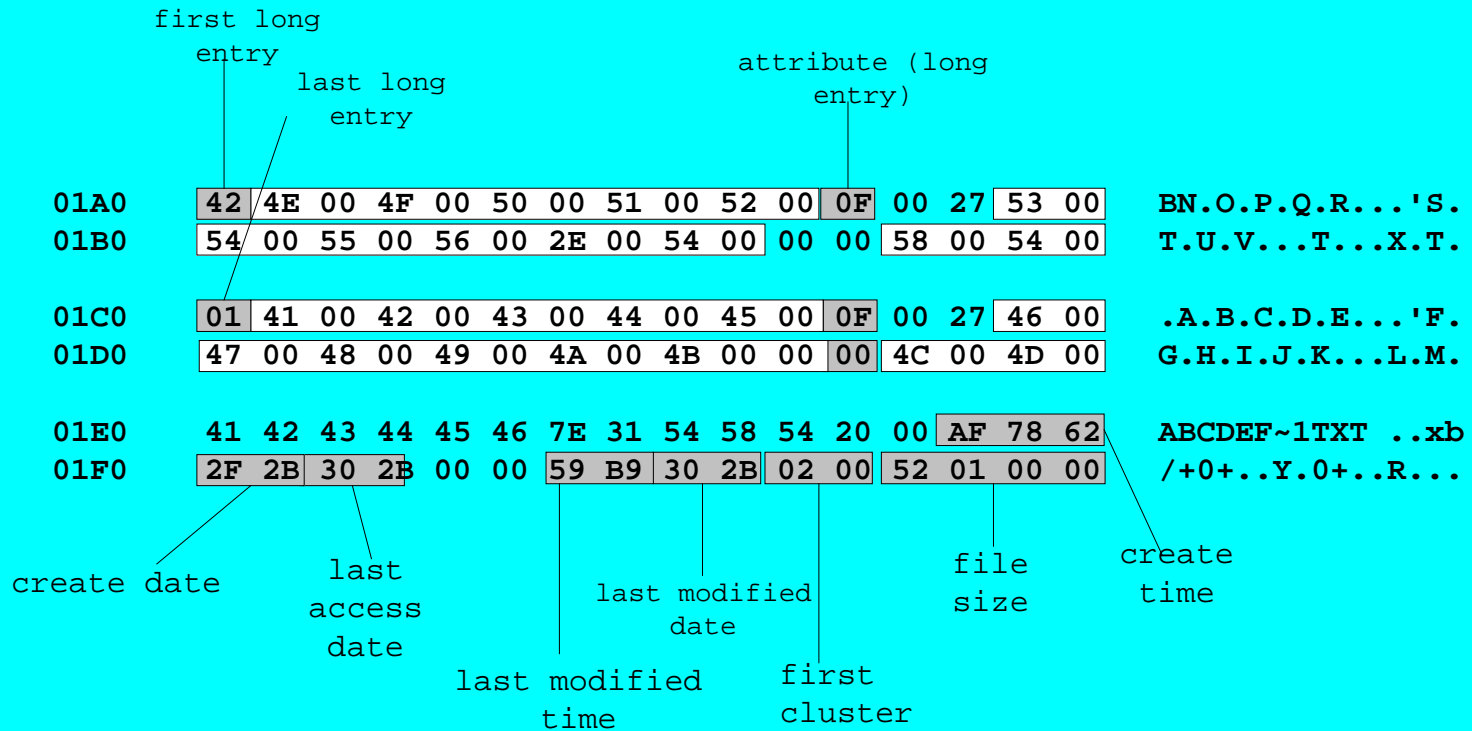
File Attribute Values



What type of file has attribute 00100111 . . . ?

Long Filenames in Windows

Filename: ABCDEFGHIJKLMNOPQRSTUVWXYZ.TXT



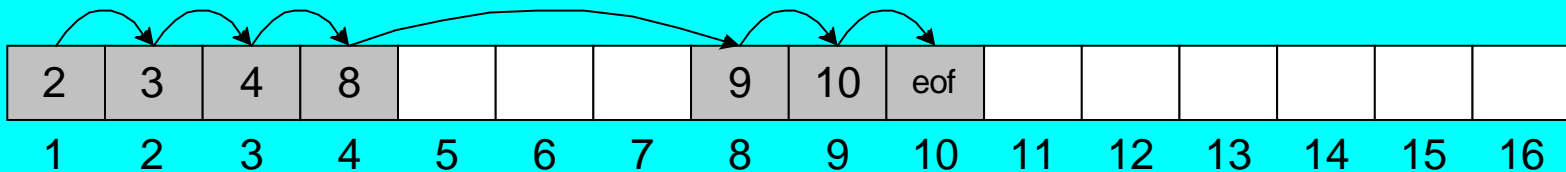
File Allocation Table (1 of 2)

- A map of all clusters on the disk, showing their ownership by specific files
- Each entry corresponds to a cluster number
- Each cluster contains one or more sectors
- Each file is represented in the FAT as a linked list, called a **cluster chain**.
- Three types of FAT's, named after the length of each FAT entry:
 - FAT-12
 - FAT-16
 - FAT-32

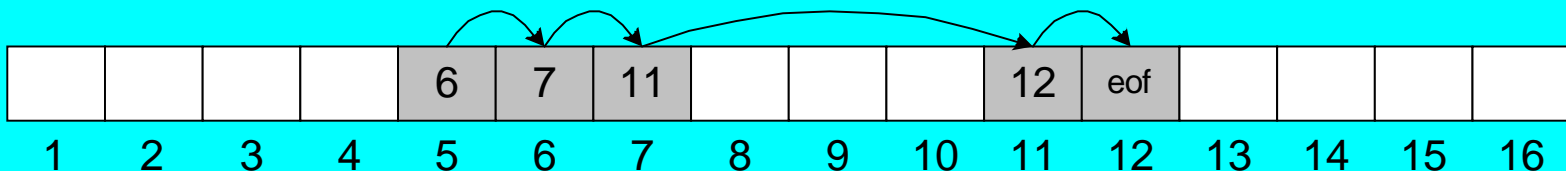
File Allocation Table (2 of 2)

- Each entry contains an n -bit integer that identifies the next entry. ($n=12,16$, or 32)
- Two cluster chains are shown in the following diagram, one for **File1**, and another for **File2**:

File1: starting cluster number = 1, size = 7 clusters



File2: starting cluster number = 5, size = 5 clusters



What's Next

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Reading and Writing Disk Sectors (7305h)

- INT 21h, Function 7305h (absolute disk read and write)
- Reads and writes logical disk sectors
- Runs only in 16-bit Real-address mode
- Does not work under Windows 2000, XP, Vista, Windows 7
 - Tight security!

DISKIO Structure

- Used by Function 7305h:

```
DISKIO STRUCT
```

```
    startSector  DWORD 0          ; starting sector number
```

```
    numSectors   WORD 1           ; number of sectors
```

```
    bufferOfs    WORD buffer      ; buffer offset
```

```
    bufferSeg     WORD @DATA      ; buffer segment
```

```
DISKIO ENDS
```

Example

Example: Read one or more sectors from drive C:

```
.data
buffer BYTE 512 DUP(?)
diskStruct DISKIO <>
.code
    mov ax,7305h                ; absolute Read/Write
    mov cx,0FFFFh              ; always this value
    mov dl,3                    ; drive C
    mov bx,OFFSET diskStruct
    mov si,0                    ; read sector
    int 21h
```

Sector Display Program

Pseudocode:

```
Ask for starting sector number and drive number
do while (keystroke <> ESC)
    Display heading
    Read one sector
    If MS-DOS error then exit
    Display one sector
    Wait for keystroke
    Increment sector number
end do
```

[View the source code](#)

What's Next

- Disk Storage Systems
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- **System-Level File Functions**

System-Level File Functions

- Common Disk-Related Functions
- Get Disk Free Space
- Create Subdirectory
- Remove Subdirecrory
- Set Current Directory
- Get Current Directory

Common Disk-Related Functions

| Function Number | Function Name |
|-----------------|--------------------------------|
| 0Eh | Set default drive |
| 19h | Get default drive |
| 7303h | Get disk free space |
| 39h | Create subdirectory |
| 3Ah | Remove subdirectory |
| 3Bh | Set current directory |
| 41h | Delete file |
| 43h | Get/set file attribute |
| 47h | Get current directory path |
| 4Eh | Find first matching file |
| 4Fh | Find next matching file |
| 56h | Rename file |
| 57h | Get/set file date and time |
| 59h | Get extended error information |

ExtGetDskFreSpcStruc Structure (1 of 2)

Structure data returned by Fuction 7303h:

- **StructSize**: A return value that represents the size of the ExtGetDskFreSpcStruc structure, in bytes.
- **Level**: Always 0.
- **SectorsPerCluster**: The number of sectors inside each cluster.
- **BytesPerSector**: The number of bytes in each sector.
- **AvailableClusters**: The number of available clusters.
- **TotalClusters**: The total number of clusters in the volume.

ExtGetDskFreSpcStruc (2 of 2)

- **AvailablePhysSectors**: The number of physical sectors available in the volume, without adjustment for compression.
- **TotalPhysSectors**: The total number of physical sectors in the volume, without adjustment for compression.
- **AvailableAllocationUnits**: The number of available allocation units in the volume, without adjustment for compression.
- **TotalAllocationUnits**: The total number of allocation units in the volume, without adjustment for compression.
- **Rsvd**: Reserved member.

Function 7303h – Get Disk Free Space

- AX = 7303h
- ES:DI points to a ExtGetDskFreSpcStruc
- CX = size of the ExtGetDskFreSpcStruc variable
- DS:DX points to a null-terminated string containing the drive name

View the [DiskSpc.asm](#) program

Create Subdirectory

```
.data
pathname BYTE "\ASM",0

.code
    mov ah,39h                ; create subdirectory
    mov dx,OFFSET pathname
    int 21h
    jc  DisplayError
    .
    .
DisplayError:
```

Remove Subdirectory

```
.data
pathname  BYTE  'C:\ASM',0

.code
    mov  ah,3Ah                ; remove subdirectory
    mov  dx,OFFSET pathname
    int  21h
    jc   DisplayError
    .
    .
DisplayError:
```

Set Current Directory

```
.data
pathname  BYTE "C:\ASM\PROGS",0

.code
    mov ah,3Bh                ; set current directory
    mov dx,OFFSET pathname
    int 21h
    jc  DisplayError
    .
    .
DisplayError:
```

Get Current Directory

```
.data
pathname  BYTE 64 dup(0)    ; path stored here by MS-DOS

.code
    mov ah,47h              ; get current directory path
    mov dl,0                ; on default drive
    mov si,OFFSET pathname
    int 21h
    jc  DisplayError
    .
    .
DisplayError:
```

Your turn . . .

- Write a program that creates a hidden, read-only directory named `__secret`. Create a hidden file inside the new directory named `$$temp`. Try to remove the directory by calling Function 3Ah. Display the error code returned by MS-DOS.

Summary

- Disk controller: acts as a broker between the hardware and the operating system
- Disk characteristics
 - composed of tracks, cylinders, sectors
 - average seek time, data transfer rate
- Formatting & logical characteristics
 - master boot record, contains disk partition table
 - clusters – logical storage units
 - file allocation table – used by some systems
 - directory – root directory, subdirectories

The End

