FAT32 Boot Sector, Locating Files and Dirs

Classes COP4610 / CGS5765

Florida State University

Outline

- Recap of last week’s lecture
  - Introduction to project 3
  - Introduction to FAT32 structure
- Starting Project 3
  - How to parse the boot sector
  - Finding the root directory and files

Project 3

- **Reminder:** It's a group project

- 3 people in each group, everyone gets the same grade
- Email your group member's name before the next Friday
- Also email if you are looking for a group

Recap – Intro to Project 3 and FAT32

Project 3

- You will create a user-space utility to manipulate a FAT32 file system image
  - No more kernel programming!

FAT32 Manipulation Utility

Utility only recognizes the following built-in commands:

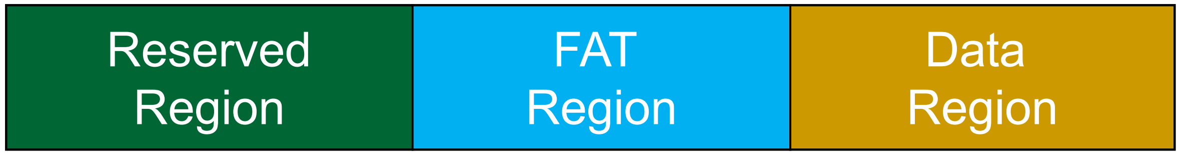
- open
- close
- create
- rm
- size
- cd
- ls
- mkdir
- rmdir
- read
- write

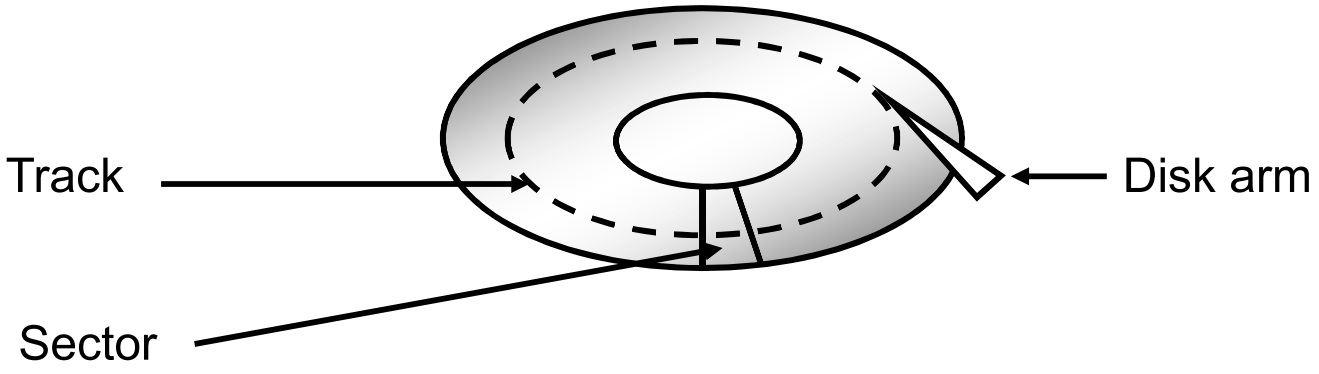
Terminology

- ***Byte*** – 8 bits of data, the smallest addressable unit in modern processors
- ***Sector*** – Smallest addressable unit on a storage device. Usually this is 512 bytes
- ***Cluster*** – FAT32-specific term. A group of sectors representing a chunk of data
- ***FAT*** – Stands for *file allocation table* and is a map of files to data

FAT32 Disk Layout

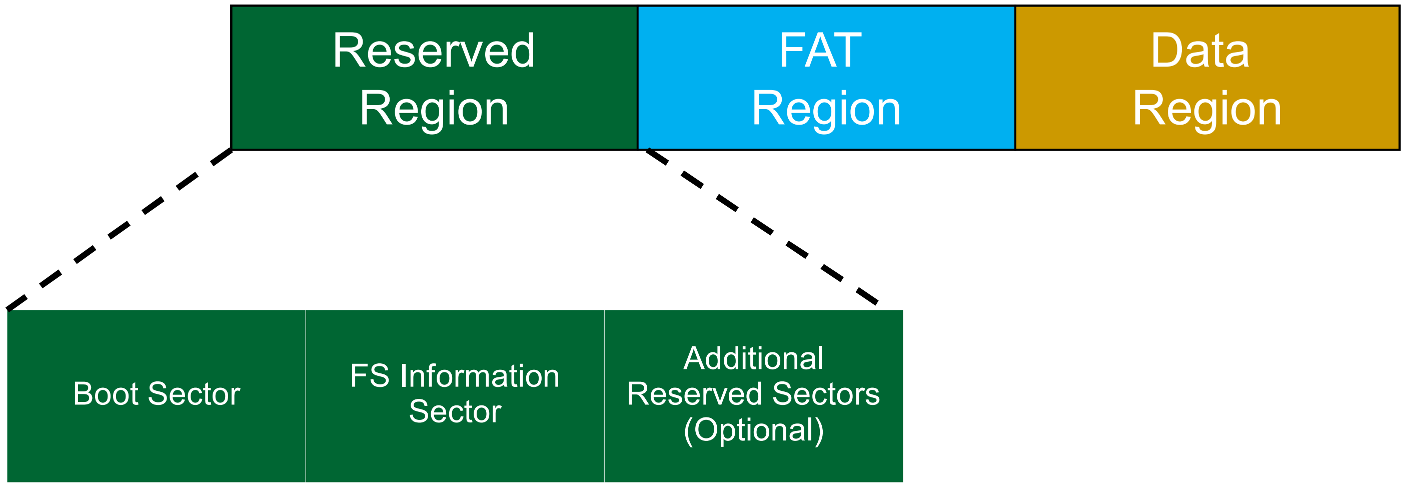
- 3 main regions…





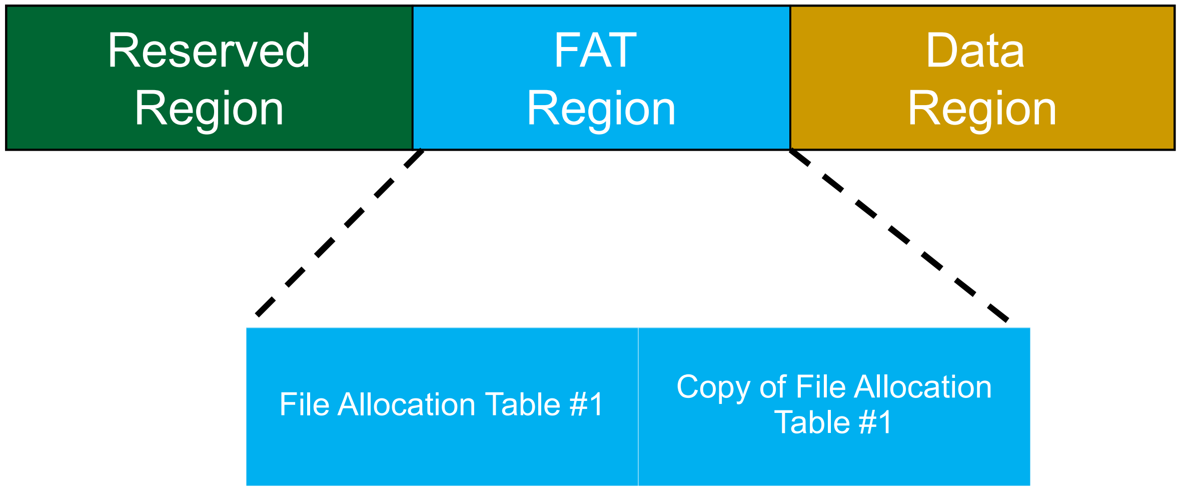
Reserved Region

- **Reserved Region** – Includes the boot sector, the extended boot sector, the file system information sector, and a few other reserved sectors



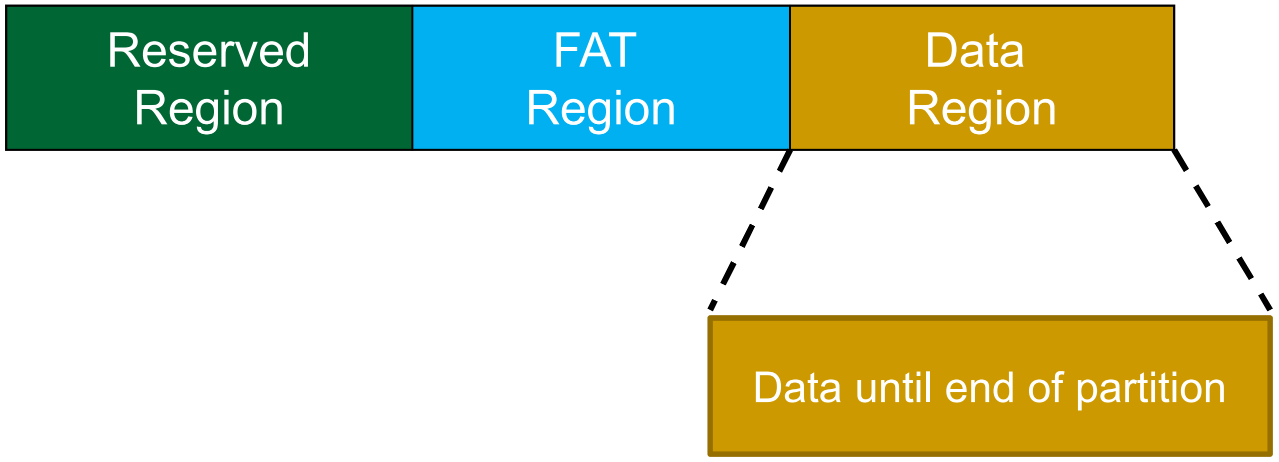
FAT Region

- **FAT Region** – A map used to traverse the data region. Contains mappings from cluster locations to cluster locations

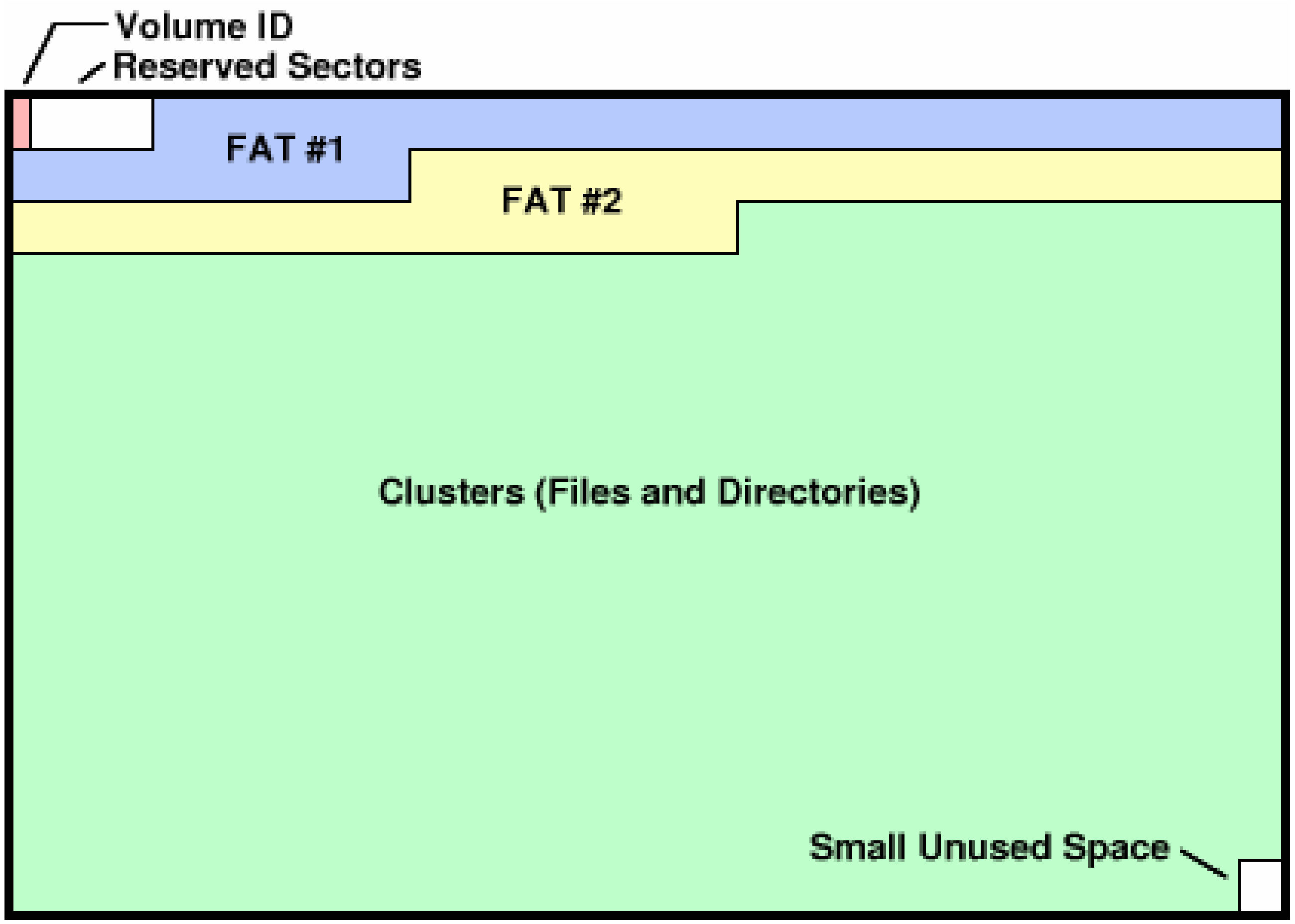


Data Region

- **Data Region** – Using the addresses from the FAT region, contains actual file/directory data



FAT32 Disk Layout



- In this project's context, Volume ID basically means the Boot Sector

Where to begin?

- Mount the file system image with the OS FAT32 driver and take a look around
- Find the FAT32 spec from Microsoft in the lab website, have a look in it
  - This document is written for those who already know the FAT32 structure well, so may seem a bit difficult to understand at first.
  - However, it will be very useful once you start coding

Hint

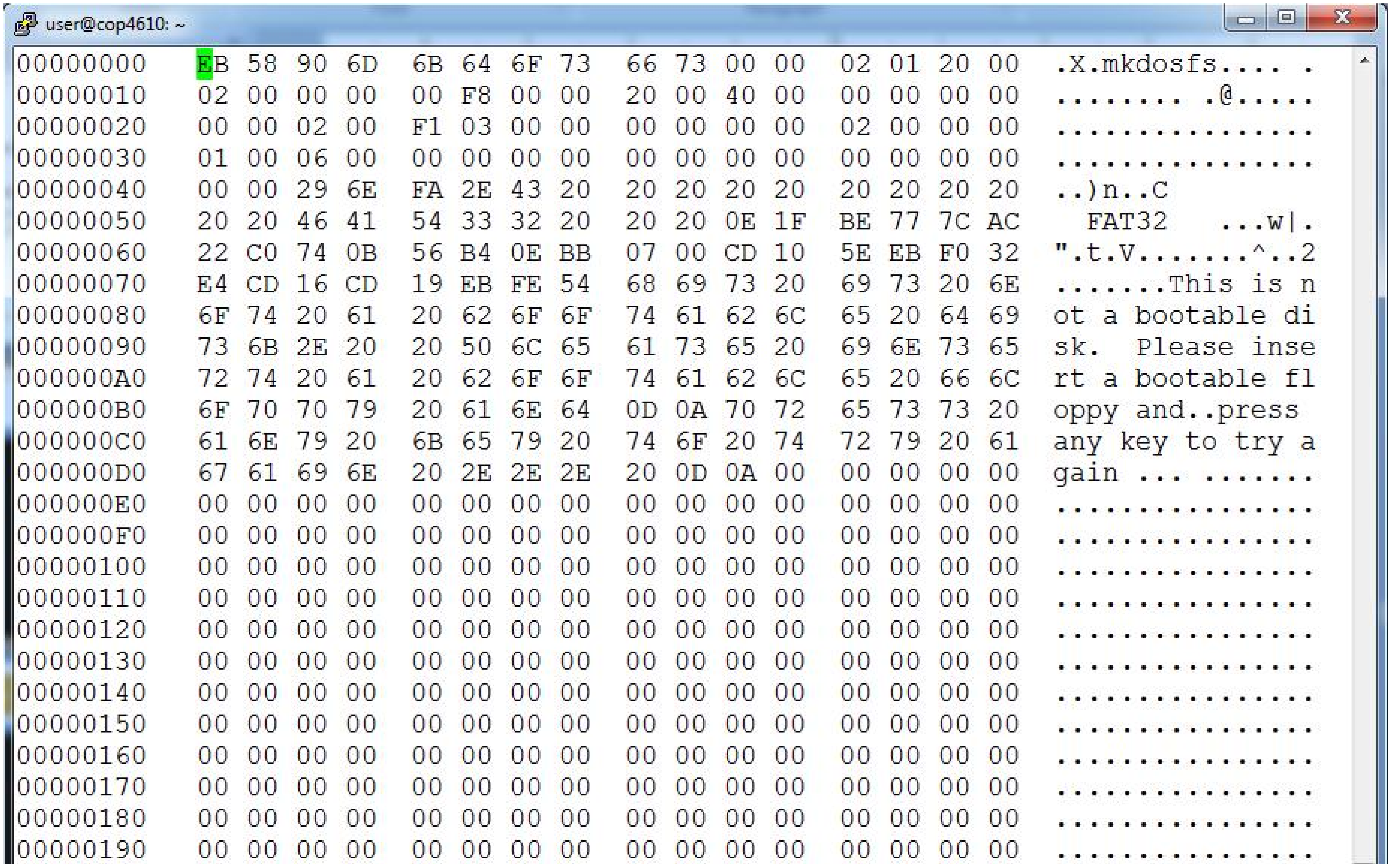
- As you work, it might make sense to first take a look at the raw file system image
- Hexedit to the rescue!

Hexedit

```
$> hexedit [filename]
```

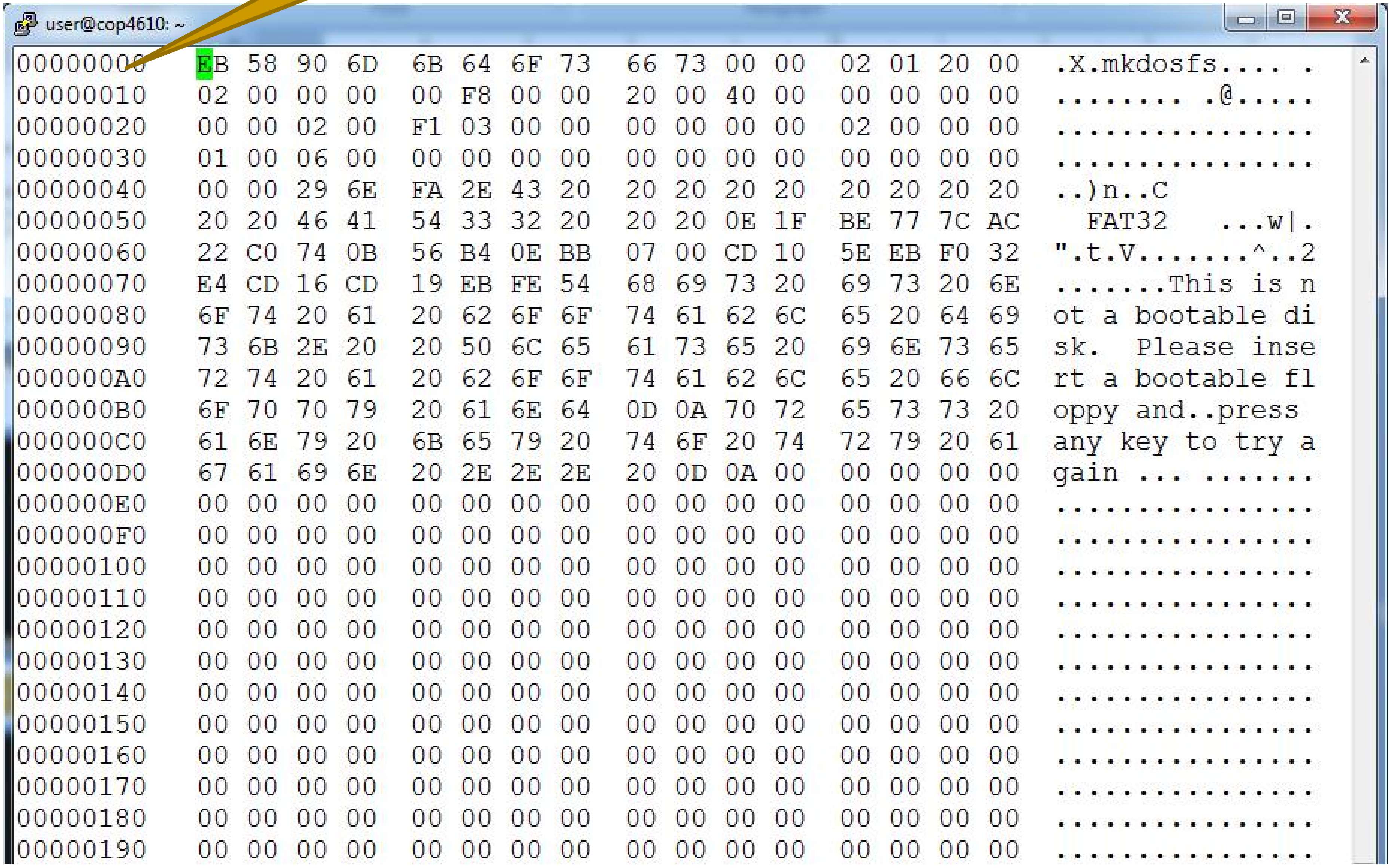
- View files in hexadecimal or ASCII
- Why wouldn’t you want to view the file system image file in your regular editor?

Hexedit



```
00000000   EB 58 90 6D  6B 64 6F 73  66 73 00 00  02 01 20 00   .X.mkdosfs.... .
00000010   02 00 00 00  00 F8 00 00  20 00 40 00  00 00 00 00   ........ .@.....
00000020   00 00 02 00  F1 03 00 00  00 00 00 00  02 00 00 00   ................
00000030   01 00 06 00  00 00 00 00  00 00 00 00  00 00 00 00   ................
00000040   00 00 29 6E  FA 2E 43 20  20 20 20 20  20 20 20 20   ..)n..C
00000050   20 20 46 41  54 33 32 20  20 20 0E 1F  BE 77 7C AC     FAT32   ...w|.
00000060   22 C0 74 0B  56 B4 0E BB  07 00 CD 10  5E EB F0 32   ".t.V.......^..2
00000070   E4 CD 16 CD  19 EB FE 54  68 69 73 20  69 73 20 6E   .......This is n
00000080   6F 74 20 61  20 62 6F 6F  74 61 62 6C  65 20 64 69   ot a bootable di
00000090   73 6B 2E 20  20 50 6C 65  61 73 65 20  69 6E 73 65   sk.  Please inse
000000A0   72 74 20 61  20 62 6F 6F  74 61 62 6C  65 20 66 6C   rt a bootable fl
000000B0   6F 70 70 79  20 61 6E 64  0D 0A 70 72  65 73 73 20   oppy and..press
000000C0   61 6E 79 20  6B 65 79 20  74 6F 20 74  72 79 20 61   any key to try a
000000D0   67 61 69 6E  20 2E 2E 2E  20 0D 0A 00  00 00 00 00   gain ... .......
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   ................
```

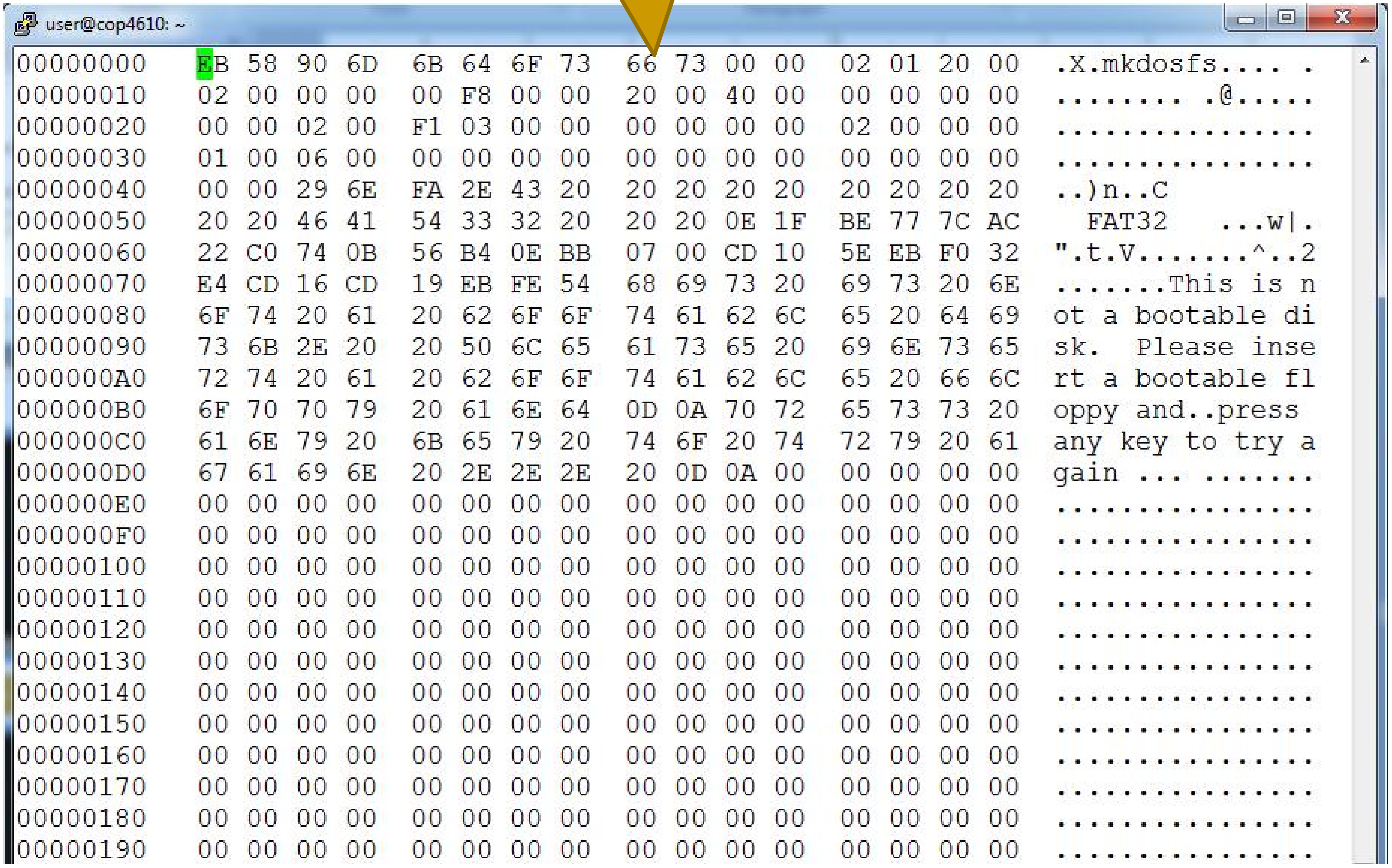
Hexedit



```
00000000   EB 58 90 6D   6B 64 6F 73   66 73 00 00   02 01 20 00   .X.mkdosfs.... .
00000010   02 00 00 00   00 F8 00 00   20 00 40 00   00 00 00 00   ........ .@.....
00000020   00 00 02 00   F1 03 00 00   00 00 00 00   02 00 00 00   ................
00000030   01 00 06 00   00 00 00 00   00 00 00 00   00 00 00 00   ................
00000040   00 00 29 6E   FA 2E 43 20   20 20 20 20   20 20 20 20   ..)n..C
00000050   20 20 46 41   54 33 32 20   20 20 0E 1F   BE 77 7C AC     FAT32   ...w|.
00000060   22 C0 74 0B   56 B4 0E BB   07 00 CD 10   5E EB F0 32   ".t.V.......^..2
00000070   E4 CD 16 CD   19 EB FE 54   68 69 73 20   69 73 20 6E   .......This is n
00000080   6F 74 20 61   20 62 6F 6F   74 61 62 6C   65 20 64 69   ot a bootable di
00000090   73 6B 2E 20   20 50 6C 65   61 73 65 20   69 6E 73 65   sk.  Please inse
000000A0   72 74 20 61   20 62 6F 6F   74 61 62 6C   65 20 66 6C   rt a bootable fl
000000B0   6F 70 70 79   20 61 6E 64   0D 0A 70 72   65 73 73 20   oppy and..press
000000C0   61 6E 79 20   6B 65 79 20   74 6F 20 74   72 79 20 61   any key to try a
000000D0   67 61 69 6E   20 2E 2E 2E   20 0D 0A 00   00 00 00 00   gain ... .......
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   ................
```

Hexedit

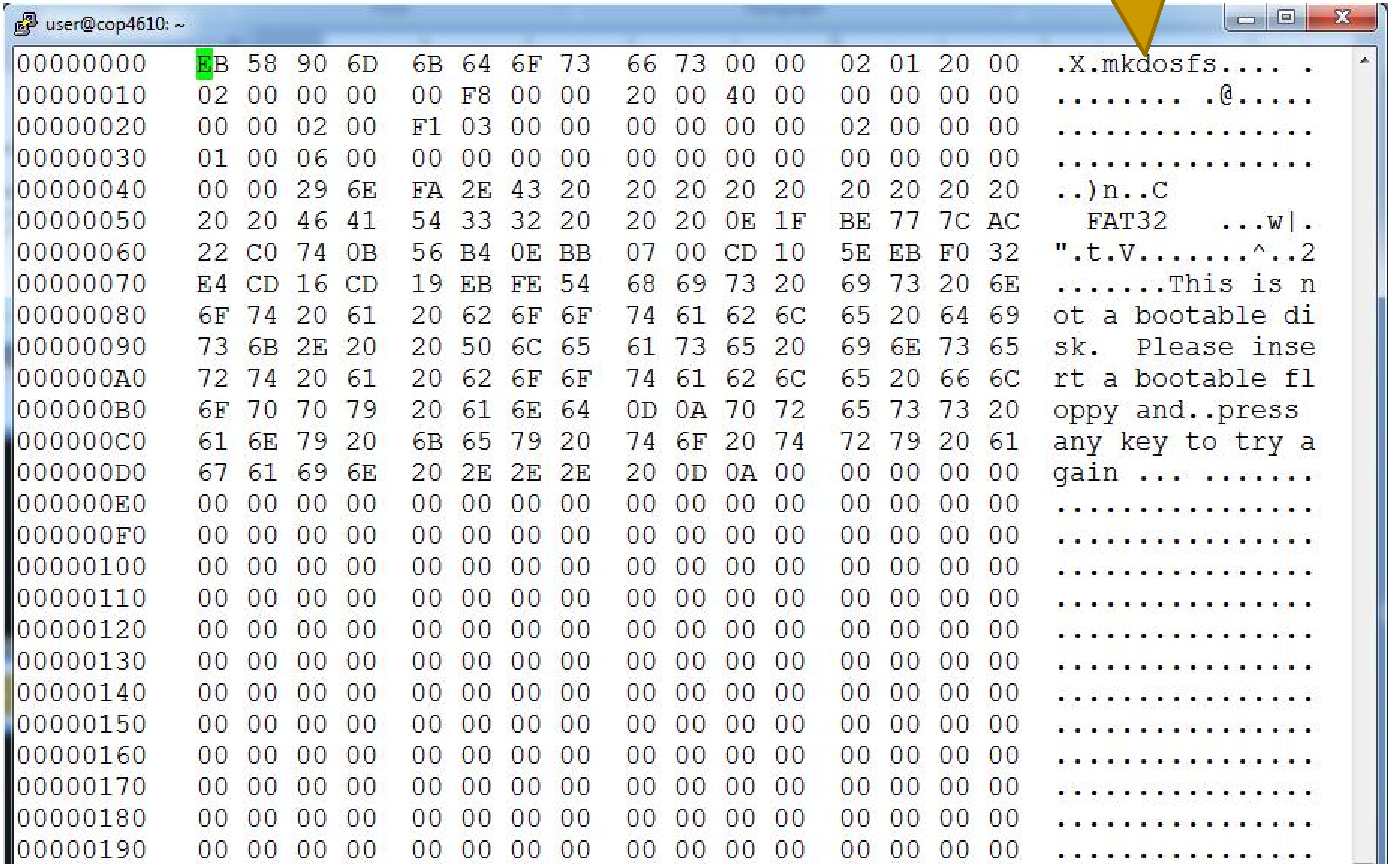
Content in hex



```
user@cop4610: ~
00000000   EB 58 90 6D  6B 64 6F 73  66 73 00 00  02 01 20 00   .X.mkdosfs.... .
00000010   02 00 00 00  00 F8 00 00  20 00 40 00  00 00 00 00   ........ .@.....
00000020   00 00 02 00  F1 03 00 00  00 00 00 00  02 00 00 00   ................
00000030   01 00 06 00  00 00 00 00  00 00 00 00  00 00 00 00   ................
00000040   00 00 29 6E  FA 2E 43 20  20 20 20 20  20 20 20 20   ..)n..C
00000050   20 20 46 41  54 33 32 20  20 20 0E 1F  BE 77 7C AC     FAT32   ...w|.
00000060   22 C0 74 0B  56 B4 0E BB  07 00 CD 10  5E EB F0 32   ".t.V.......^..2
00000070   E4 CD 16 CD  19 EB FE 54  68 69 73 20  69 73 20 6E   .......This is n
00000080   6F 74 20 61  20 62 6F 6F  74 61 62 6C  65 20 64 69   ot a bootable di
00000090   73 6B 2E 20  20 50 6C 65  61 73 65 20  69 6E 73 65   sk.  Please inse
000000A0   72 74 20 61  20 62 6F 6F  74 61 62 6C  65 20 66 6C   rt a bootable fl
000000B0   6F 70 70 79  20 61 6E 64  0D 0A 70 72  65 73 73 20   oppy and..press
000000C0   61 6E 79 20  6B 65 79 20  74 6F 20 74  72 79 20 61   any key to try a
000000D0   67 61 69 6E  20 2E 2E 2E  20 0D 0A 00  00 00 00 00   gain ... .......
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   ................
```

Hexedit

Content in printable ASCII



```
00000000   EB 58 90 6D  6B 64 6F 73  66 73 00 00  02 01 20 00   .X.mkdosfs.... .
00000010   02 00 00 00  00 F8 00 00  20 00 40 00  00 00 00 00   ........ .@.....
00000020   00 00 02 00  F1 03 00 00  00 00 00 00  02 00 00 00   ................
00000030   01 00 06 00  00 00 00 00  00 00 00 00  00 00 00 00   ................
00000040   00 00 29 6E  FA 2E 43 20  20 20 20 20  20 20 20 20   ..)n..C
00000050   20 20 46 41  54 33 32 20  20 20 0E 1F  BE 77 7C AC     FAT32   ...w|.
00000060   22 C0 74 0B  56 B4 0E BB  07 00 CD 10  5E EB F0 32   ".t.V.......^..2
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00000080   6F 74 20 61  20 62 6F 6F  74 61 62 6C  65 20 64 69   ot a bootable di
00000090   73 6B 2E 20  20 50 6C 65  61 73 65 20  69 6E 73 65   sk.  Please inse
000000A0   72 74 20 61  20 62 6F 6F  74 61 62 6C  65 20 66 6C   rt a bootable fl
000000B0   6F 70 70 79  20 61 6E 64  0D 0A 70 72  65 73 73 20   oppy and..press
000000C0   61 6E 79 20  6B 65 79 20  74 6F 20 74  72 79 20 61   any key to try a
000000D0   67 61 69 6E  20 2E 2E 2E  20 0D 0A 00  00 00 00 00   gain ... .......
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   ................
```

Hexadecimal Hints

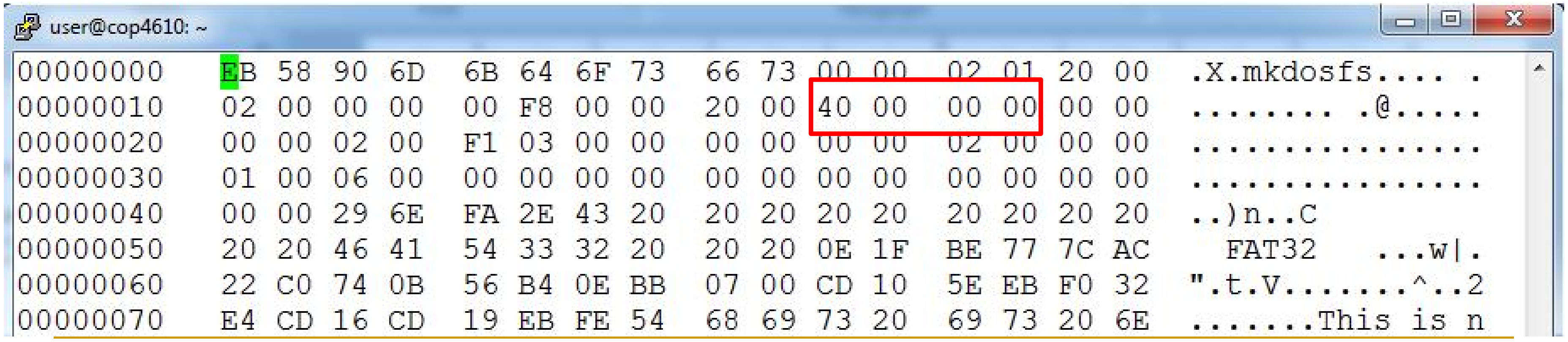
- Hex is base 16 – one hexadecimal can represent 0-15
- It takes 4 binary bits to represent values 0-15
    - 0000 = 0
    - 1111 = 15

Hexadecimal Hints

- If it takes ***4 bits*** to represent one hexadecimal number, it takes ***8 bits*** to represent two hexadecimal numbers
  - 8 bits = 1 byte
- Two hex numbers together symbolize one byte
  - That’s why hex numbers are in groups of two

Endianness

- FAT32 is represented in little endian byte order
  - Reading left to right, you encounter least-significant byte first
  - What 32-bit number is this? 0x0000040 or 0x40000000?

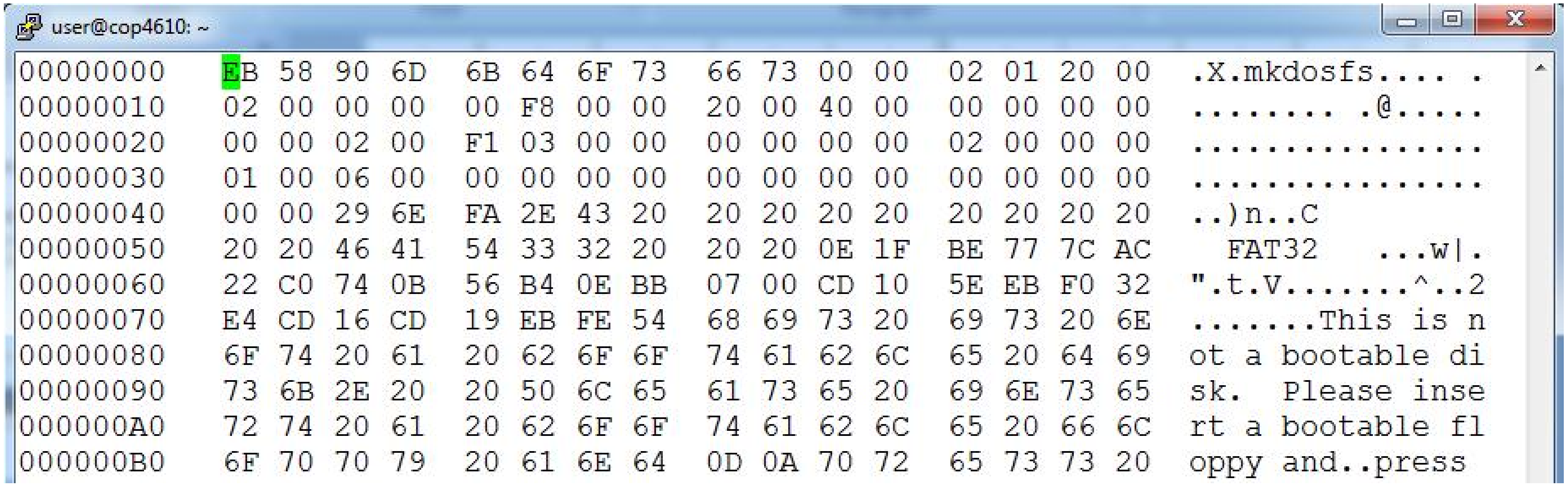


user@cop4610: ~

```
00000000   EB 58 90 6D  6B 64 6F 73  66 73 00 00  02 01 20 00   .X.mkdosfs.... .
00000010   02 00 00 00  00 F8 00 00  20 00 40 00  00 00 00 00   ........ .@.....
00000020   00 00 02 00  F1 03 00 00  00 00 00 00  02 00 00 00   ................
00000030   01 00 06 00  00 00 00 00  00 00 00 00  00 00 00 00   ................
00000040   00 00 29 6E  FA 2E 43 20  20 20 20 20  20 20 20 20   ..)n..C
00000050   20 20 46 41  54 33 32 20  20 20 0E 1F  BE 77 7C AC     FAT32    ...w|.
00000060   22 C0 74 0B  56 B4 0E BB  07 00 CD 10  5E EB F0 32   ".t.V.......^..2
00000070   E4 CD 16 CD  19 EB FE 54  68 69 73 20  69 73 20 6E   .......This is n
```

Endianness

- Why are characters in order (readable) if some numbers are not?


user@cop4610: ~

```
00000000   EB 58 90 6D  6B 64 6F 73  66 73 00 00  02 01 20 00  .X.mkdosfs.... .
00000010   02 00 00 00  00 F8 00 00  20 00 40 00  00 00 00 00  ........ .@.....
00000020   00 00 02 00  F1 03 00 00  00 00 00 00  02 00 00 00  ................
00000030   01 00 06 00  00 00 00 00  00 00 00 00  00 00 00 00  ................
00000040   00 00 29 6E  FA 2E 43 20  20 20 20 20  20 20 20 20  ..)n..C
00000050   20 20 46 41  54 33 32 20  20 20 0E 1F  BE 77 7C AC    FAT32   ...w|.
00000060   22 C0 74 0B  56 B4 0E BB  07 00 CD 10  5E EB F0 32  ".t.V.......^..2
00000070   E4 CD 16 CD  19 EB FE 54  68 69 73 20  69 73 20 6E  .......This is n
00000080   6F 74 20 61  20 62 6F 6F  74 61 62 6C  65 20 64 69  ot a bootable di
00000090   73 6B 2E 20  20 50 6C 65  61 73 65 20  69 6E 73 65  sk.  Please inse
000000A0   72 74 20 61  20 62 6F 6F  74 61 62 6C  65 20 66 6C  rt a bootable fl
000000B0   6F 70 70 79  20 61 6E 64  0D 0A 70 72  65 73 73 20  oppy and..press
```

Endianness

- You **must** account for little endianness across bytes when reading in numbers of size larger than one byte
  - Characters are only one byte, no re-ordering necessary

Starting Project 3

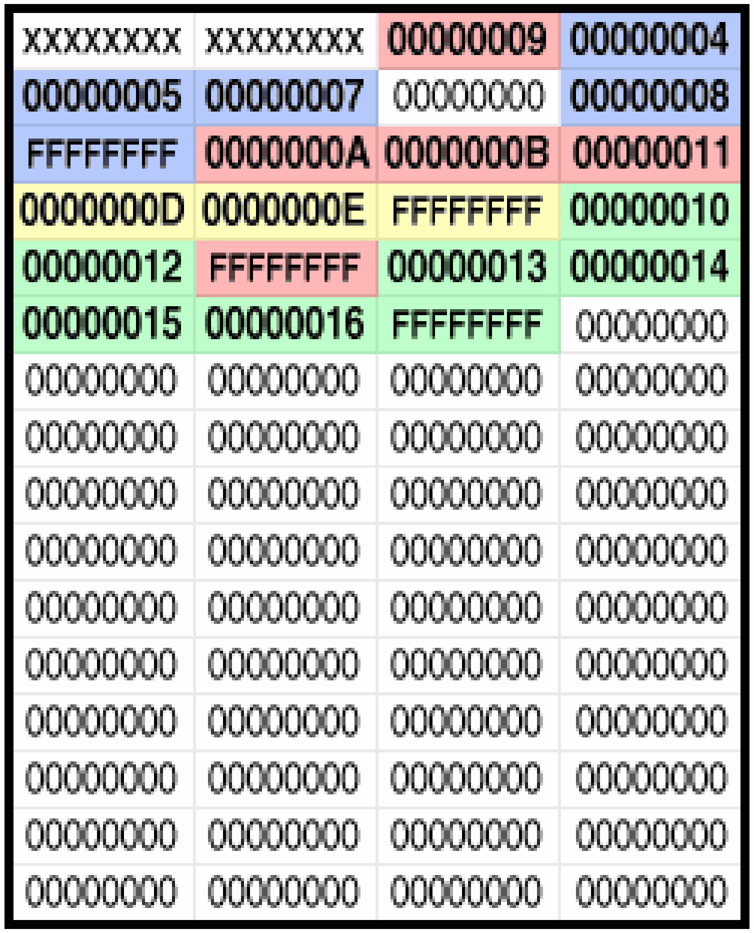
File Allocation Table (FAT)

- Contains a chain of all the clusters belonging to a particular file
- Basically a big array of **32 bit** integers (Hence the file system is called FAT32)

File Allocation Table (FAT)

- Each integer's position in the array corresponds to a cluster number
- The value stored there indicates the next cluster of the file
- An EoC value indicates the end of the cluster chain for that file

File Allocation Table (FAT)



XXXXXXXX	XXXXXXXX	00000009	00000004
00000005	00000007	00000000	00000008
FFFFFFFF	0000000A	0000000B	00000011
0000000D	0000000E	FFFFFFFF	00000010
00000012	FFFFFFFF	00000013	00000014
00000015	00000016	FFFFFFFF	00000000
00000000	00000000	00000000	00000000
00000000	00000000	00000000	00000000
00000000	00000000	00000000	00000000
00000000	00000000	00000000	00000000
00000000	00000000	00000000	00000000
00000000	00000000	00000000	00000000
00000000	00000000	00000000	00000000
00000000	00000000	00000000	00000000
00000000	00000000	00000000	00000000
00000000	00000000	00000000	00000000

Root Directory:
2, 9, A, B, 11

File #1:
3, 4, 5, 7, 8

File #2:
C, D, E

File #3:
F, 10, 12, 13, 14, 15, 16

Steps to read from a FAT32 image

- Locate, read, and extract important info from the Boot Sector
- Locate the Root Directory, get the list of files and folders
- Access the files and directories using information from the Root Directory and the FAT32 table

Parse the Boot Sector

- Where to find the Boot Sector?

  - First 512 bytes of the disk (or, in our case, the ‘image’)

Important Boot Sector Information

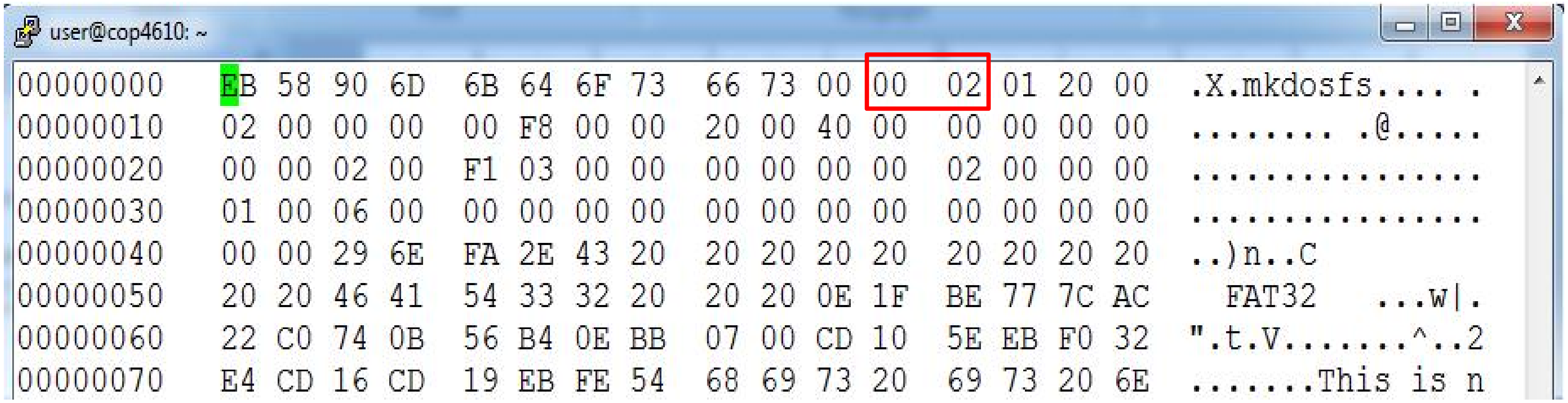
- Size of each region
  - BPB_BytesPerSec
  - BPB_SecPerClus
  - BPB_RsvdSecCnt
  - BPB_NumFATS
  - BPB_FATSz32
- Root directory (first directory in tree)
  - BPB_RootClus

Important Boot Sector Information

- Warning: this list is not exhaustive!
- Check the “*Boot Sector and BPB Structure*” in MS FAT32 File System Spec for:
  - The complete list of attributes
  - Their significance
  - Where they are located within the Boot Sector

Important Boot Sector Information

- Example: extracting BPB_BytesPerSector
  - Offset 11, size 2 bytes
  - 0x0200 = 512



```
00000000   EB 58 90 6D  6B 64 6F 73  66 73 00 00  02 01 20 00  .X.mkdosfs.... .
00000010   02 00 00 00  00 F8 00 00  20 00 40 00  00 00 00 00  ........ .@.....
00000020   00 00 02 00  F1 03 00 00  00 00 00 00  02 00 00 00  ................
00000030   01 00 06 00  00 00 00 00  00 00 00 00  00 00 00 00  ................
00000040   00 00 29 6E  FA 2E 43 20  20 20 20 20  20 20 20 20  ..)n..C
00000050   20 20 46 41  54 33 32 20  20 20 0E 1F  BE 77 7C AC    FAT32   ...w|.
00000060   22 C0 74 0B  56 B4 0E BB  07 00 CD 10  5E EB F0 32  ".t.V.......^..2
00000070   E4 CD 16 CD  19 EB FE 54  68 69 73 20  69 73 20 6E  .......This is n
```

Next Steps

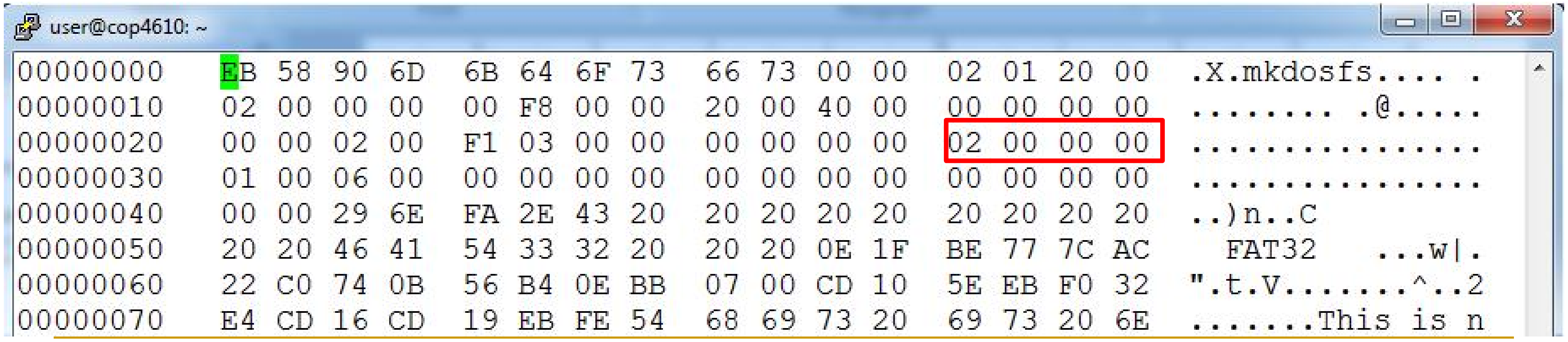
- After you have parsed the boot sector and saved key values, you may want to find the root directory

Finding the Root Directory

- Figure out the ***root directory cluster number*** from the boot sector

Finding the Root Directory

- BPB_RootClus
  - Offset 44, size 4 bytes
  - 0x00000002 = 2



user@cop4610: ~

```
00000000   EB 58 90 6D  6B 64 6F 73  66 73 00 00  02 01 20 00  .X.mkdosfs.... .
00000010   02 00 00 00  00 F8 00 00  20 00 40 00  00 00 00 00  ........ .@.....
00000020   00 00 02 00  F1 03 00 00  00 00 00 00  02 00 00 00  ................
00000030   01 00 06 00  00 00 00 00  00 00 00 00  00 00 00 00  ................
00000040   00 00 29 6E  FA 2E 43 20  20 20 20 20  20 20 20 20  ..)n..C
00000050   20 20 46 41  54 33 32 20  20 20 0E 1F  BE 77 7C AC    FAT32   ...w|.
00000060   22 C0 74 0B  56 B4 0E BB  07 00 CD 10  5E EB F0 32  ".t.V.......^..2
00000070   E4 CD 16 CD  19 EB FE 54  68 69 73 20  69 73 20 6E  .......This is n
```

Finding the Root Directory

- Figure out where the Data Region starts in the disk

```
FirstDataSector = BPB_ResvdSectCnt + (BPB_NumFATs *
            FATsz) + RootDirSectors
Here,
FATsz = BPB_FATSz32
RootDirSectors = ((BPB_RootEntCnt * 32) +
      (BPB_BytsPerSec -1)) / BPB_BytsPerSec;
      // Becomes 0 for FAT32
```

Finding the Root Directory

- Figure out where the Root Directory starts in the data region, where N=cluster number

```
FirstSectorofCluster =  ((N – 2) * BPB_SecPerClus) +
                  FirstDataSector;


For Root Directory, N = BPB_RootClus (usually 2)
```

Finding the Root Directory

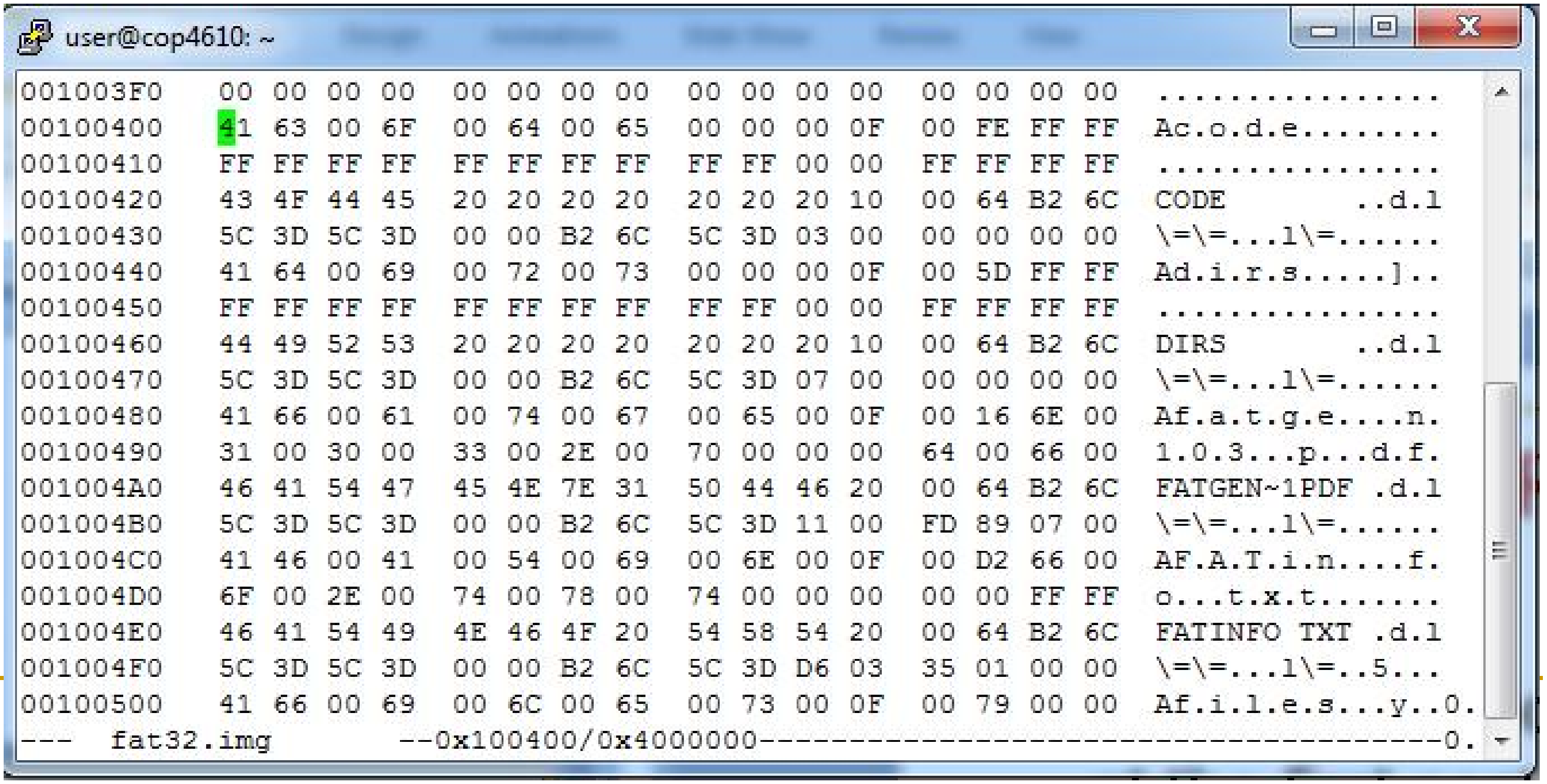
- Figure out where the Root Directory starts in the data region, where N=cluster number

```
FirstSectorofCluster =  ((N – 2) * BPB_SecPerClus) +
                          FirstDataSector;
```

- This gives the sector number of the first sector of any cluster N
- Check page 13 in MS FAT32 File System Spec for details

Finding the Root Directory

- Read in the root directory structure located at the first sector of the root directory cluster



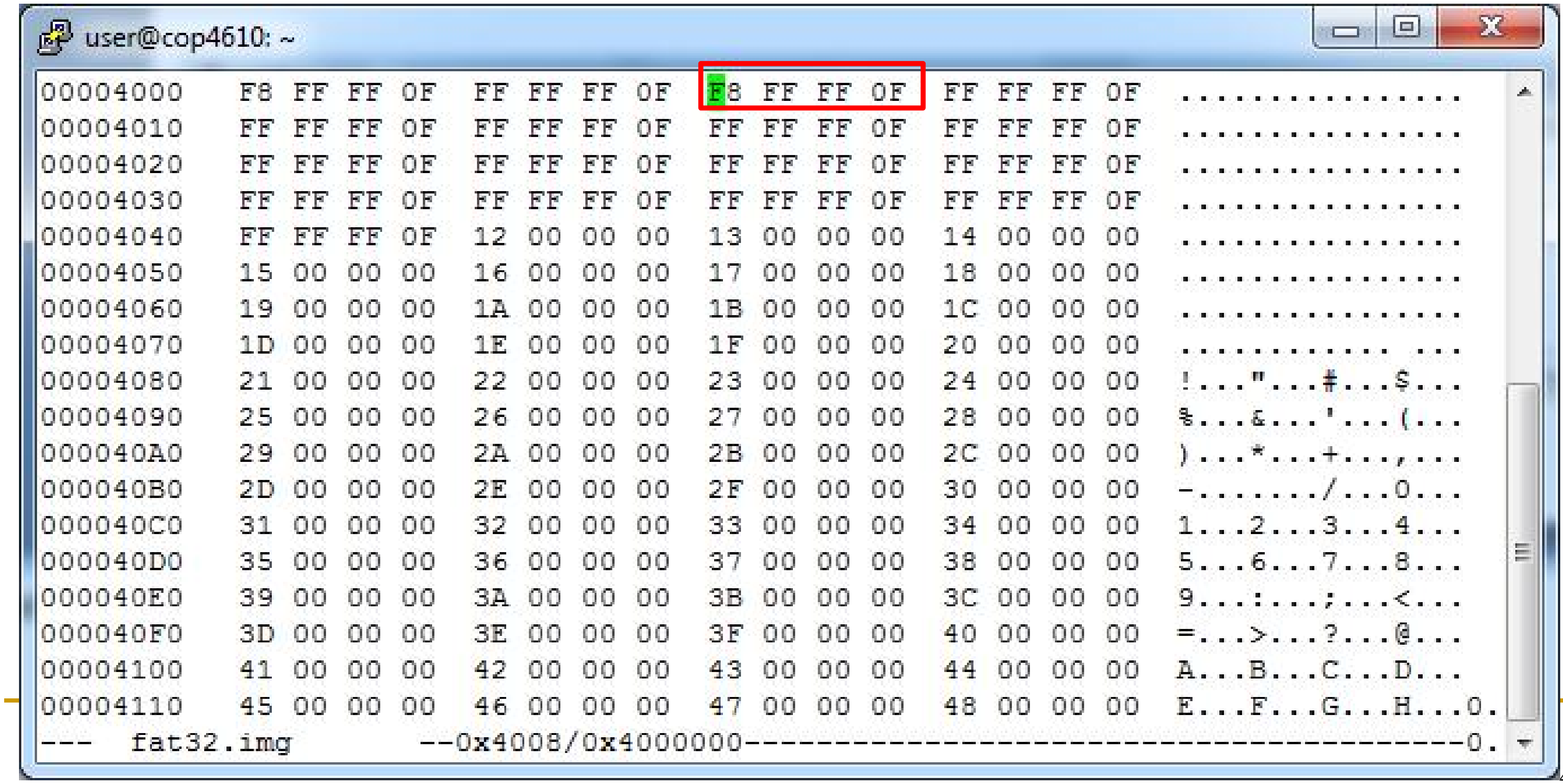
```
001003F0    00 00 00 00  00 00 00 00  00 00 00 00  00 00 00 00  ................
00100400    41 63 00 6F  00 64 00 65  00 00 00 0F  00 FE FF FF  Ac.o.d.e........
00100410    FF FF FF FF  FF FF FF FF  FF FF 00 00  FF FF FF FF  ................
00100420    43 4F 44 45  20 20 20 20  20 20 20 10  00 64 B2 6C  CODE       ..d.l
00100430    5C 3D 5C 3D  00 00 B2 6C  5C 3D 03 00  00 00 00 00  \=\=...l\=......
00100440    41 64 00 69  00 72 00 73  00 00 00 0F  00 5D FF FF  Ad.i.r.s.....]..
00100450    FF FF FF FF  FF FF FF FF  FF FF 00 00  FF FF FF FF  ................
00100460    44 49 52 53  20 20 20 20  20 20 20 10  00 64 B2 6C  DIRS       ..d.l
00100470    5C 3D 5C 3D  00 00 B2 6C  5C 3D 07 00  00 00 00 00  \=\=...l\=......
00100480    41 66 00 61  00 74 00 67  00 65 00 0F  00 16 6E 00  Af.a.t.g.e....n.
00100490    31 00 30 00  33 00 2E 00  70 00 00 00  64 00 66 00  1.0.3...p...d.f.
001004A0    46 41 54 47  45 4E 7E 31  50 44 46 20  00 64 B2 6C  FATGEN~1PDF .d.l
001004B0    5C 3D 5C 3D  00 00 B2 6C  5C 3D 11 00  FD 89 07 00  \=\=...l\=......
001004C0    41 46 00 41  00 54 00 69  00 6E 00 0F  00 D2 66 00  AF.A.T.i.n....f.
001004D0    6F 00 2E 00  74 00 78 00  74 00 00 00  00 00 FF FF  o...t.x.t.......
001004E0    46 41 54 49  4E 46 4F 20  54 58 54 20  00 64 B2 6C  FATINFO TXT .d.l
001004F0    5C 3D 5C 3D  00 00 B2 6C  5C 3D D6 03  35 01 00 00  \=\=...l\=..5...
00100500    41 66 00 69  00 6C 00 65  00 73 00 0F  00 79 00 00  Af.i.l.e.s...y..0.
---   fat32.img       --0x100400/0x4000000-------------------------------------0.
```

Finding the Root Directory

- Does the root directory span more than one cluster? Look up the ***next cluster number*** in the FAT.
  - Find `ThisFATSecNum` and `ThisFATEntOffset` for the current cluster number
  - Go to `ThisFATSecNum` and read the 32-bit unsigned value starting at offset `ThisFATEntOffset`
  - FAT will either give you the next cluster number in the directory or the **End of Cluster Chain** value

Finding the Root Directory

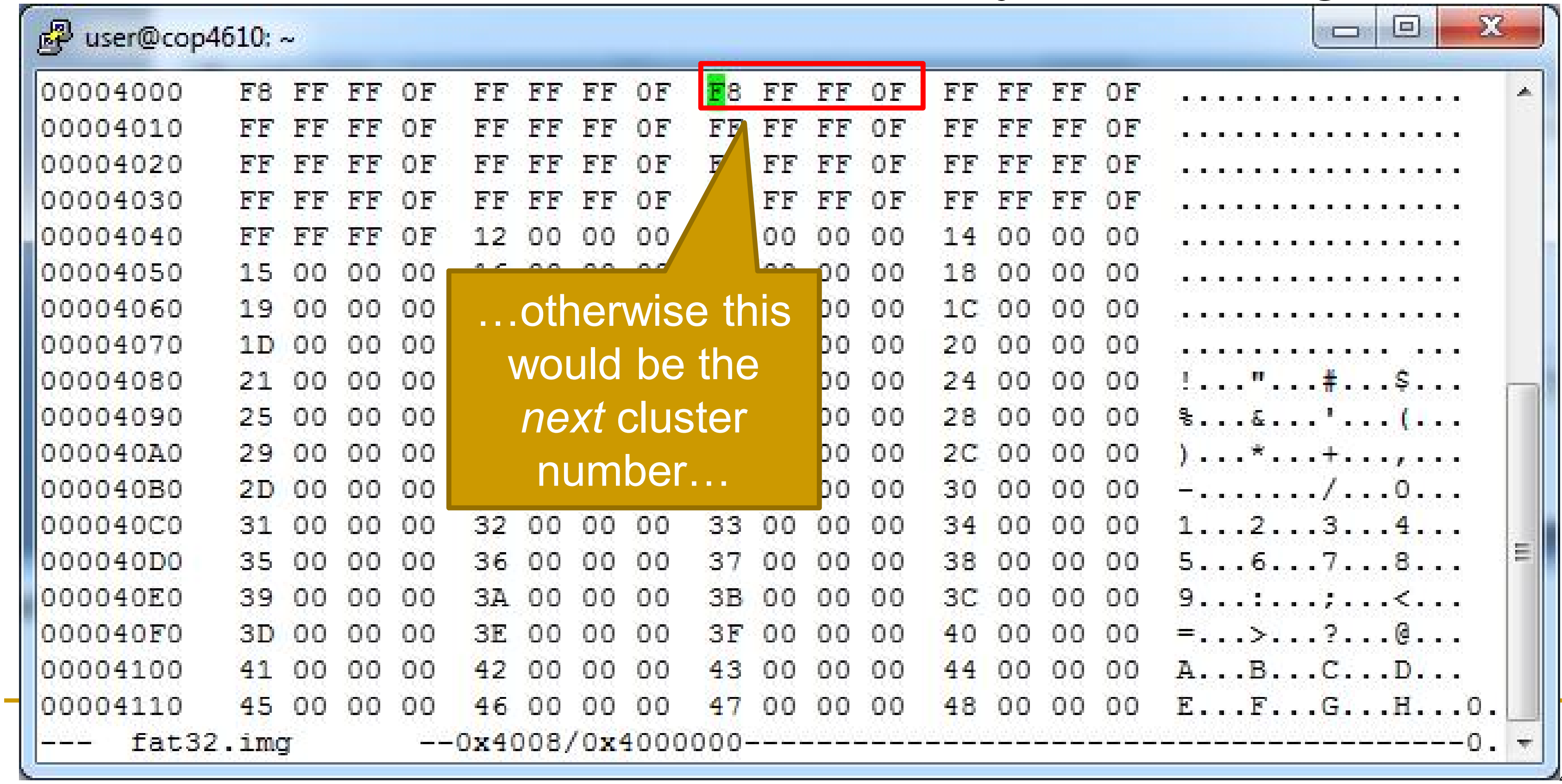
- Next cluster number of root directory in FAT



```
00004000    F8 FF FF 0F  FF FF FF 0F  F8 FF FF 0F  FF FF FF 0F   ................
00004010    FF FF FF 0F  FF FF FF 0F  FF FF FF 0F  FF FF FF 0F   ................
00004020    FF FF FF 0F  FF FF FF 0F  FF FF FF 0F  FF FF FF 0F   ................
00004030    FF FF FF 0F  FF FF FF 0F  FF FF FF 0F  FF FF FF 0F   ................
00004040    FF FF FF 0F  12 00 00 00  13 00 00 00  14 00 00 00   ................
00004050    15 00 00 00  16 00 00 00  17 00 00 00  18 00 00 00   ................
00004060    19 00 00 00  1A 00 00 00  1B 00 00 00  1C 00 00 00   ................
00004070    1D 00 00 00  1E 00 00 00  1F 00 00 00  20 00 00 00   ............ ...
00004080    21 00 00 00  22 00 00 00  23 00 00 00  24 00 00 00   !..."...#...$...
00004090    25 00 00 00  26 00 00 00  27 00 00 00  28 00 00 00   %...&...'...(...
000040A0    29 00 00 00  2A 00 00 00  2B 00 00 00  2C 00 00 00   )...*...+...,...
000040B0    2D 00 00 00  2E 00 00 00  2F 00 00 00  30 00 00 00   -......./...0...
000040C0    31 00 00 00  32 00 00 00  33 00 00 00  34 00 00 00   1...2...3...4...
000040D0    35 00 00 00  36 00 00 00  37 00 00 00  38 00 00 00   5...6...7...8...
000040E0    39 00 00 00  3A 00 00 00  3B 00 00 00  3C 00 00 00   9...:...;...<...
000040F0    3D 00 00 00  3E 00 00 00  3F 00 00 00  40 00 00 00   =...>...?...@...
00004100    41 00 00 00  42 00 00 00  43 00 00 00  44 00 00 00   A...B...C...D...
00004110    45 00 00 00  46 00 00 00  47 00 00 00  48 00 00 00   E...F...G...H...0.
---  fat32.img      --0x4008/0x4000000----------------------------------------0.
```

Finding the Root Directory

- Next cluster number of root directory in FAT
  - EoC=0x0FFFFFF8 – directory does not go on



user@cop4610: ~

```
00004000    F8 FF FF 0F  FF FF FF 0F  F8 FF FF 0F  FF FF FF 0F  ................
00004010    FF FF FF 0F  FF FF FF 0F  FF FF FF 0F  FF FF FF 0F  ................
00004020    FF FF FF 0F  FF FF FF 0F  F  FF FF 0F  FF FF FF 0F  ................
00004030    FF FF FF 0F  FF FF FF 0F     FF FF 0F  FF FF FF 0F  ................
00004040    FF FF FF 0F  12 00 00 00     00 00 00  14 00 00 00  ................
00004050    15 00 00 00                     00 00  18 00 00 00  ................
00004060    19 00 00 00                     00 00  1C 00 00 00  ................
00004070    1D 00 00 00                     00 00  20 00 00 00  ............. ...
00004080    21 00 00 00                     00 00  24 00 00 00  !..."...#...$...
00004090    25 00 00 00                     00 00  28 00 00 00  %...&...'...(...
000040A0    29 00 00 00                     00 00  2C 00 00 00  )...*...+...,...
000040B0    2D 00 00 00                     00 00  30 00 00 00  -......./...0...
000040C0    31 00 00 00  32 00 00 00  33 00 00 00  34 00 00 00  1...2...3...4...
000040D0    35 00 00 00  36 00 00 00  37 00 00 00  38 00 00 00  5...6...7...8...
000040E0    39 00 00 00  3A 00 00 00  3B 00 00 00  3C 00 00 00  9...:...;...<...
000040F0    3D 00 00 00  3E 00 00 00  3F 00 00 00  40 00 00 00  =...>...?...@...
00004100    41 00 00 00  42 00 00 00  43 00 00 00  44 00 00 00  A...B...C...D...
00004110    45 00 00 00  46 00 00 00  47 00 00 00  48 00 00 00  E...F...G...H...0.
---  fat32.img      --0x4008/0x4000000------------------------------------0.
```

…otherwise this would be the *next* cluster number…

Directory Structure

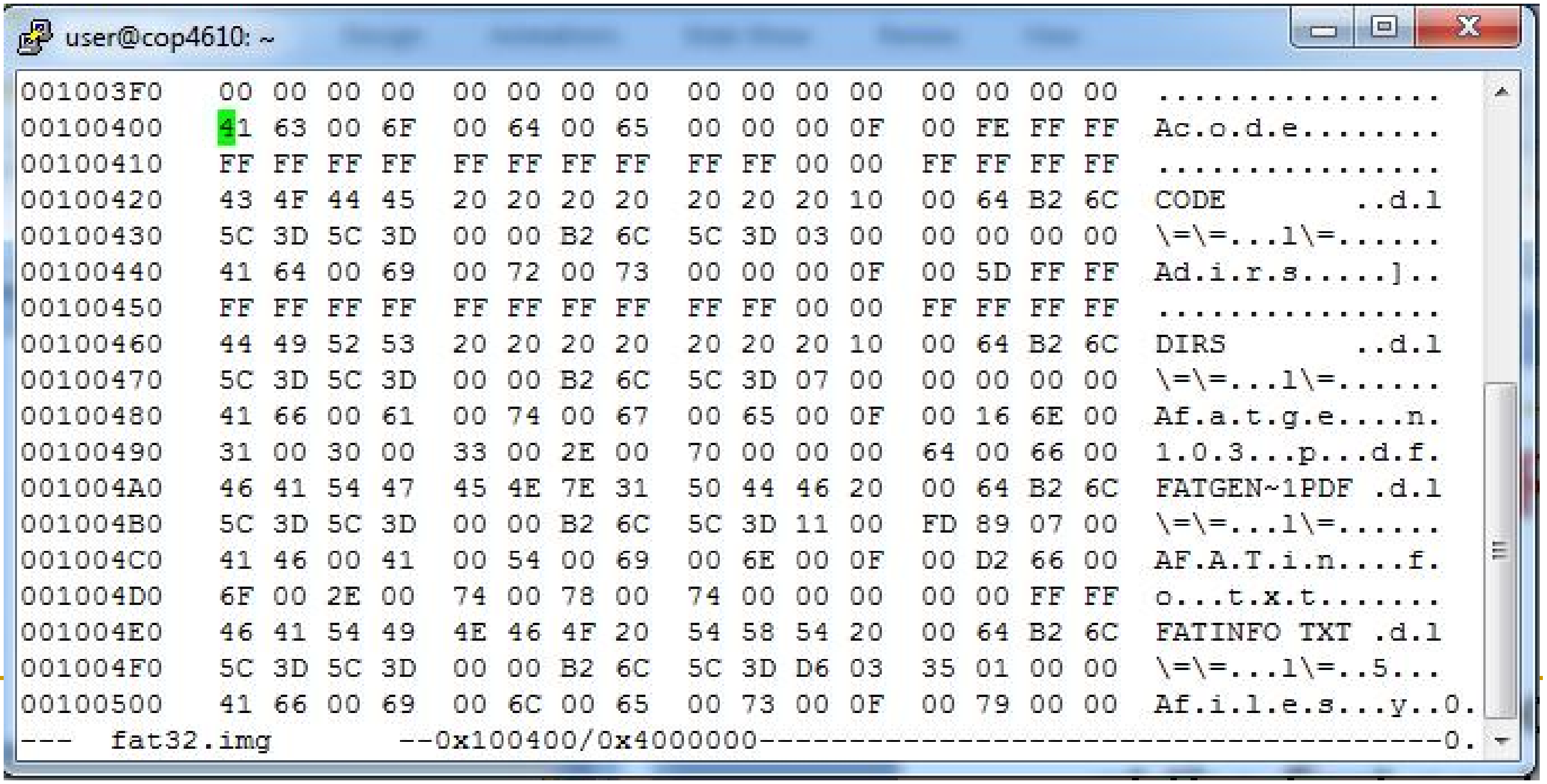
- Each directory is made up of one or more ***directory entries*** that contain
  - File name (or sub-directory name)
  - Attributes
  - First cluster number
    - Cluster number where file or directory in question starts
  - More…
- Check *FAT Directory Structure* (page 22) in MS FAT32 File System Spec for details

Finding Files and Directories

- Files and sub-directory entries can be found by going to their ***first cluster number***
  - The directory entry for a file or sub-directory contains its *first cluster number, remember?*

Finding fatgen103.pdf

- Suppose we have read in the root direcotry and want to find the file ‘fatgen103.pdf’

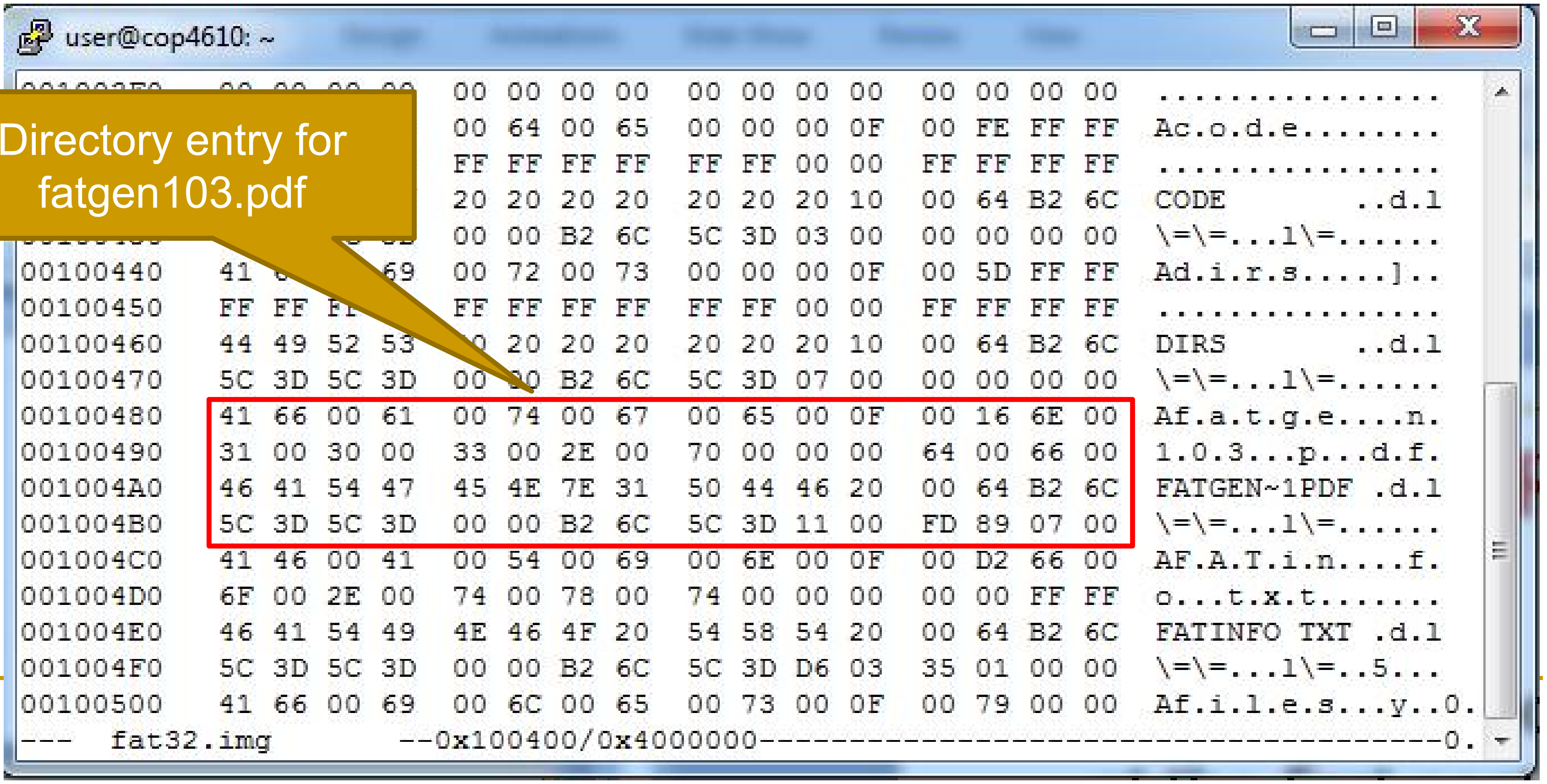


user@cop4610: ~

```
001003F0   00 00 00 00  00 00 00 00  00 00 00 00  00 00 00 00  ................
00100400   41 63 00 6F  00 64 00 65  00 00 00 0F  00 FE FF FF  Ac.o.d.e........
00100410   FF FF FF FF  FF FF FF FF  FF FF 00 00  FF FF FF FF  ................
00100420   43 4F 44 45  20 20 20 20  20 20 20 10  00 64 B2 6C  CODE       ..d.l
00100430   5C 3D 5C 3D  00 00 B2 6C  5C 3D 03 00  00 00 00 00  \=\=...l\=......
00100440   41 64 00 69  00 72 00 73  00 00 00 0F  00 5D FF FF  Ad.i.r.s.....]..
00100450   FF FF FF FF  FF FF FF FF  FF FF 00 00  FF FF FF FF  ................
00100460   44 49 52 53  20 20 20 20  20 20 20 10  00 64 B2 6C  DIRS       ..d.l
00100470   5C 3D 5C 3D  00 00 B2 6C  5C 3D 07 00  00 00 00 00  \=\=...l\=......
00100480   41 66 00 61  00 74 00 67  00 65 00 0F  00 16 6E 00  Af.a.t.g.e....n.
00100490   31 00 30 00  33 00 2E 00  70 00 00 00  64 00 66 00  1.0.3...p...d.f.
001004A0   46 41 54 47  45 4E 7E 31  50 44 46 20  00 64 B2 6C  FATGEN~1PDF .d.l
001004B0   5C 3D 5C 3D  00 00 B2 6C  5C 3D 11 00  FD 89 07 00  \=\=...l\=......
001004C0   41 46 00 41  00 54 00 69  00 6E 00 0F  00 D2 66 00  AF.A.T.i.n....f.
001004D0   6F 00 2E 00  74 00 78 00  74 00 00 00  00 00 FF FF  o...t.x.t.......
001004E0   46 41 54 49  4E 46 4F 20  54 58 54 20  00 64 B2 6C  FATINFO TXT .d.l
001004F0   5C 3D 5C 3D  00 00 B2 6C  5C 3D D6 03  35 01 00 00  \=\=...l\=..5...
00100500   41 66 00 69  00 6C 00 65  00 73 00 0F  00 79 00 00  Af.i.l.e.s...y..0.
---   fat32.img      --0x100400/0x4000000------------------------------------0.
```

Finding fatgen103.pdf

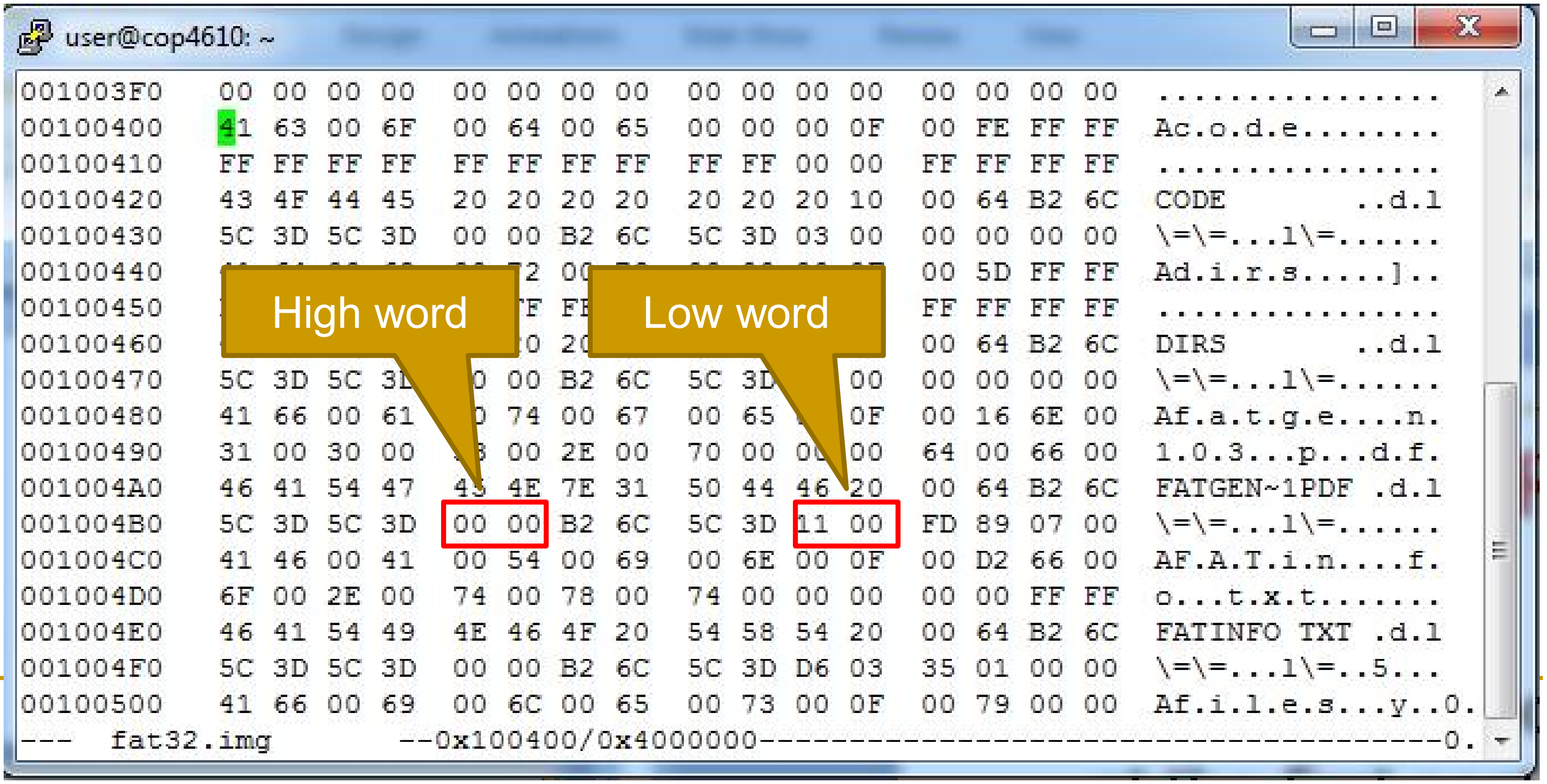
- Suppose we have read in the root direcotry and want to find the file ‘fatgen103.pdf’



```
001003F0    00 00 00 00   00 00 00 00   00 00 00 00   00 00 00 00   ................
                          00 64 00 65   00 00 00 0F   00 FE FF FF   Ac.o.d.e........
                          FF FF FF FF   FF FF 00 00   FF FF FF FF   ................
                          20 20 20 20   20 20 20 10   00 64 B2 6C   CODE        ..d.l
                          00 00 B2 6C   5C 3D 03 00   00 00 00 00   \=\=...l\=......
00100440    41          69   00 72 00 73   00 00 00 0F   00 5D FF FF   Ad.i.r.s.....]..
00100450    FF FF FF         FF FF FF FF   FF FF 00 00   FF FF FF FF   ................
00100460    44 49 52 53   20 20 20 20   20 20 20 10   00 64 B2 6C   DIRS        ..d.l
00100470    5C 3D 5C 3D   00 00 B2 6C   5C 3D 07 00   00 00 00 00   \=\=...l\=......
00100480    41 66 00 61   00 74 00 67   00 65 00 0F   00 16 6E 00   Af.a.t.g.e....n.
00100490    31 00 30 00   33 00 2E 00   70 00 00 00   64 00 66 00   1.0.3...p...d.f.
001004A0    46 41 54 47   45 4E 7E 31   50 44 46 20   00 64 B2 6C   FATGEN~1PDF .d.l
001004B0    5C 3D 5C 3D   00 00 B2 6C   5C 3D 11 00   FD 89 07 00   \=\=...l\=......
001004C0    41 46 00 41   00 54 00 69   00 6E 00 0F   00 D2 66 00   AF.A.T.i.n....f.
001004D0    6F 00 2E 00   74 00 78 00   74 00 00 00   00 00 FF FF   o...t.x.t.......
001004E0    46 41 54 49   4E 46 4F 20   54 58 54 20   00 64 B2 6C   FATINFO TXT .d.l
001004F0    5C 3D 5C 3D   00 00 B2 6C   5C 3D D6 03   35 01 00 00   \=\=...l\=..5...
00100500    41 66 00 69   00 6C 00 65   00 73 00 0F   00 79 00 00   Af.i.l.e.s...y..0.
---   fat32.img       --0x100400/0x4000000-------------------------------------0.
```

Finding fatgen103.pdf

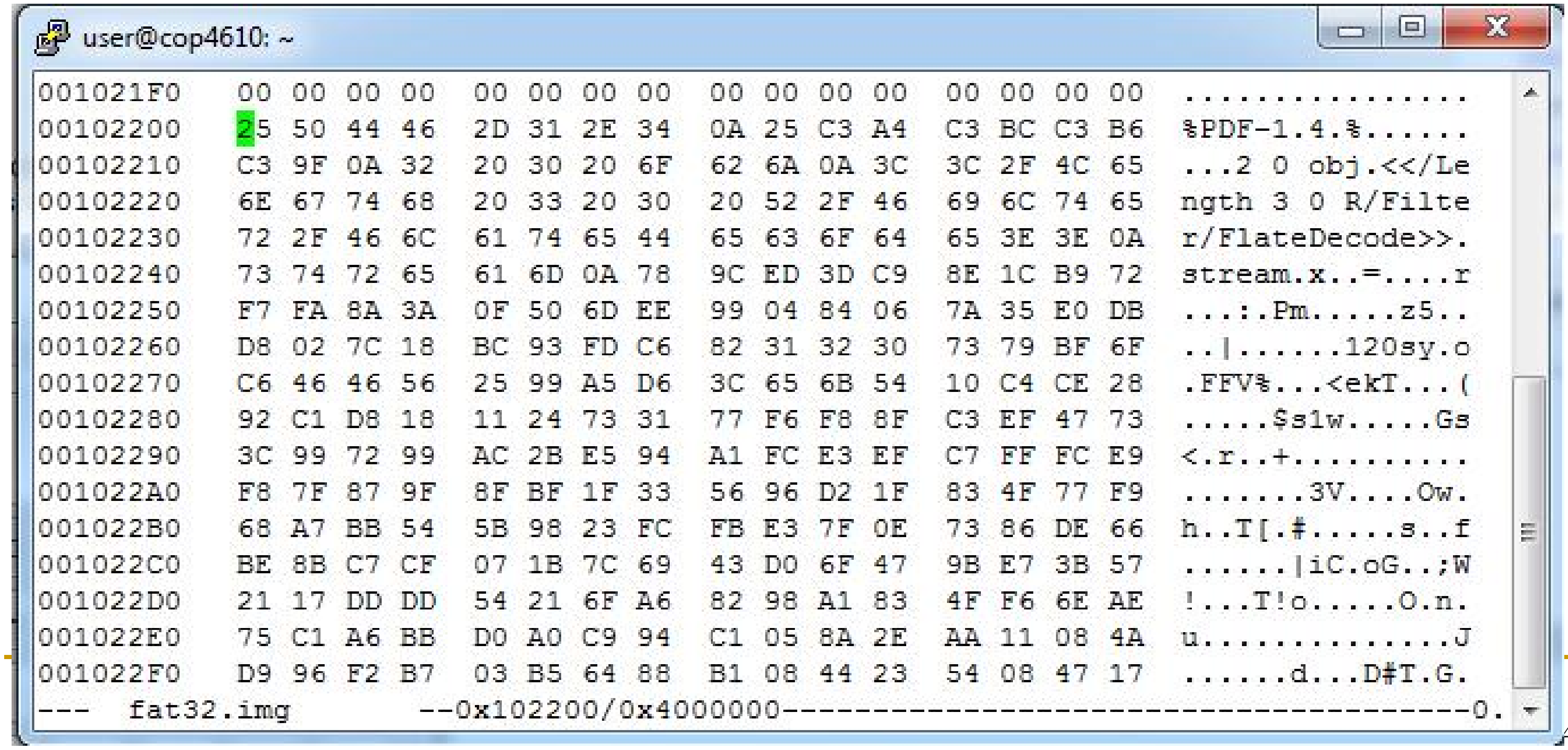
- Entry’s first cluster number
  - 0x000011 = 17



```
001003F0    00 00 00 00  00 00 00 00  00 00 00 00  00 00 00 00  ................
00100400    41 63 00 6F  00 64 00 65  00 00 00 0F  00 FE FF FF  Ac.o.d.e........
00100410    FF FF FF FF  FF FF FF FF  FF FF 00 00  FF FF FF FF  ................
00100420    43 4F 44 45  20 20 20 20  20 20 20 10  00 64 B2 6C  CODE       ..d.l
00100430    5C 3D 5C 3D  00 00 B2 6C  5C 3D 03 00  00 00 00 00  \=\=...l\=......
00100440    [illegible] 2 00 [illegible]                00 5D FF FF  Ad.i.r.s.....]..
00100450    [illegible]       F FF [illegible]          FF FF FF FF  ................
00100460    [illegible]       0 20 [illegible]          00 64 B2 6C  DIRS       ..d.l
00100470    5C 3D 5C 3[illegible] 00 B2 6C  5C 3[illegible] 00  00 00 00 00  \=\=...l\=......
00100480    41 66 00 61  [illegible] 74 00 67  00 65 [illegible] 0F  00 16 6E 00  Af.a.t.g.e....n.
00100490    31 00 30 00  [illegible] 00 2E 00  70 00 0[illegible] 00  64 00 66 00  1.0.3...p...d.f.
001004A0    46 41 54 47  4[illegible] 4E 7E 31  50 44 46 20  00 64 B2 6C  FATGEN~1PDF .d.l
001004B0    5C 3D 5C 3D  00 00 B2 6C  5C 3D 11 00  FD 89 07 00  \=\=...l\=......
001004C0    41 46 00 41  00 54 00 69  00 6E 00 0F  00 D2 66 00  AF.A.T.i.n....f.
001004D0    6F 00 2E 00  74 00 78 00  74 00 00 00  00 00 FF FF  o...t.x.t.......
001004E0    46 41 54 49  4E 46 4F 20  54 58 54 20  00 64 B2 6C  FATINFO TXT .d.l
001004F0    5C 3D 5C 3D  00 00 B2 6C  5C 3D D6 03  35 01 00 00  \=\=...l\=..5...
00100500    41 66 00 69  00 6C 00 65  00 73 00 0F  00 79 00 00  Af.i.l.e.s...y..0.
---   fat32.img       --0x100400/0x4000000---------------------------------------0.
```

Finding fatgen103.pdf

- Plug N=17 into `FirstSectorofCluster` equation, go to that sector…

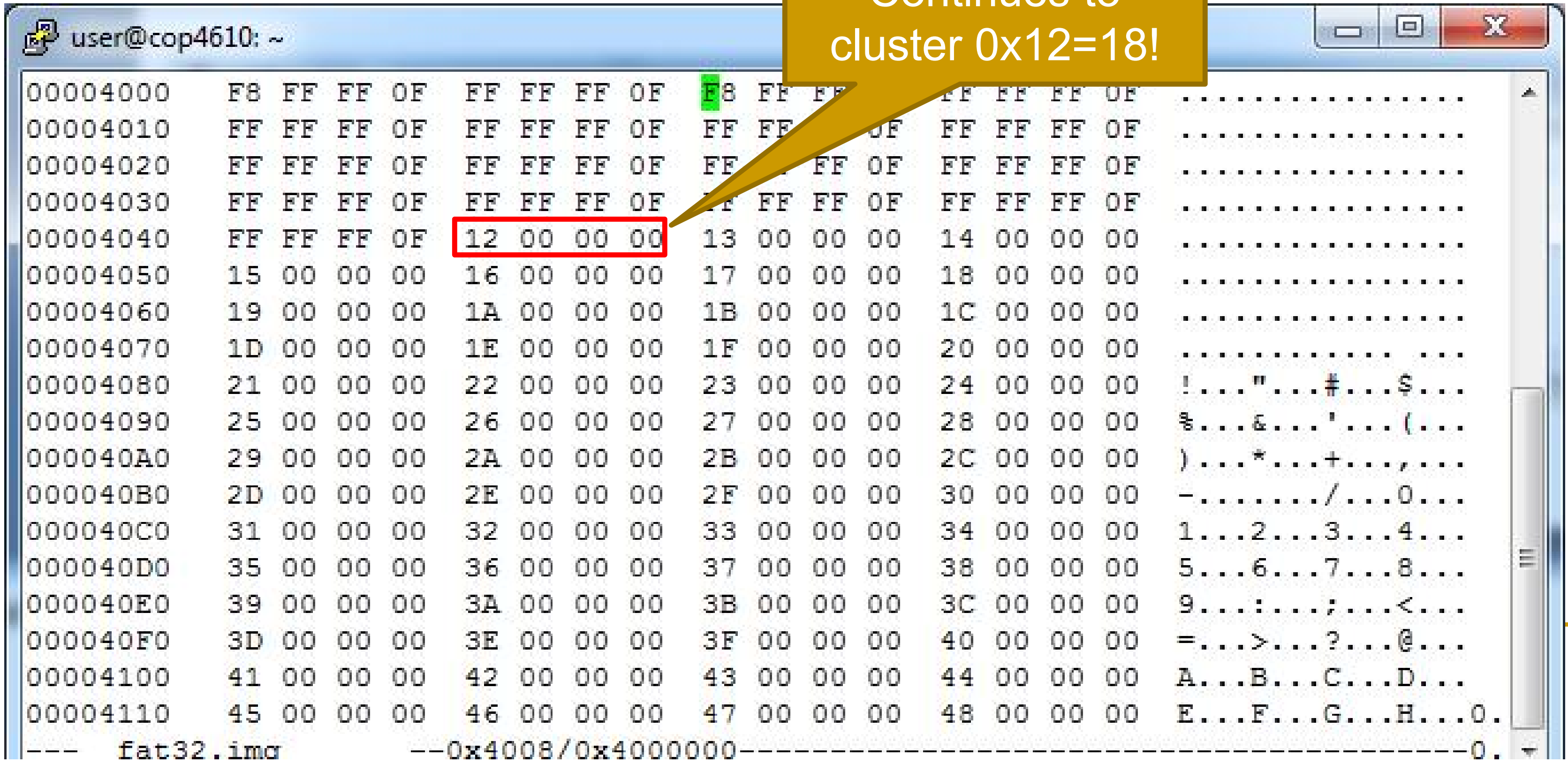

user@cop4610: ~

```
001021F0    00 00 00 00  00 00 00 00  00 00 00 00  00 00 00 00  ................
00102200    25 50 44 46  2D 31 2E 34  0A 25 C3 A4  C3 BC C3 B6  %PDF-1.4.%......
00102210    C3 9F 0A 32  20 30 20 6F  62 6A 0A 3C  3C 2F 4C 65  ...2 0 obj.<</Le
00102220    6E 67 74 68  20 33 20 30  20 52 2F 46  69 6C 74 65  ngth 3 0 R/Filte
00102230    72 2F 46 6C  61 74 65 44  65 63 6F 64  65 3E 3E 0A  r/FlateDecode>>.
00102240    73 74 72 65  61 6D 0A 78  9C ED 3D C9  8E 1C B9 72  stream.x..=....r
00102250    F7 FA 8A 3A  0F 50 6D EE  99 04 84 06  7A 35 E0 DB  ...:.Pm.....z5..
00102260    D8 02 7C 18  BC 93 FD C6  82 31 32 30  73 79 BF 6F  ..|......120sy.o
00102270    C6 46 46 56  25 99 A5 D6  3C 65 6B 54  10 C4 CE 28  .FFV%...<ekT...(
00102280    92 C1 D8 18  11 24 73 31  77 F6 F8 8F  C3 EF 47 73  .....$s1w.....Gs
00102290    3C 99 72 99  AC 2B E5 94  A1 FC E3 EF  C7 FF FC E9  <.r..+..........
001022A0    F8 7F 87 9F  8F BF 1F 33  56 96 D2 1F  83 4F 77 F9  .......3V....Ow.
001022B0    68 A7 BB 54  5B 98 23 FC  FB E3 7F 0E  73 86 DE 66  h..T[.#.....s..f
001022C0    BE 8B C7 CF  07 1B 7C 69  43 D0 6F 47  9B E7 3B 57  ......|iC.oG..;W
001022D0    21 17 DD DD  54 21 6F A6  82 98 A1 83  4F F6 6E AE  !...T!o.....O.n.
001022E0    75 C1 A6 BB  D0 A0 C9 94  C1 05 8A 2E  AA 11 08 4A  u..............J
001022F0    D9 96 F2 B7  03 B5 64 88  B1 08 44 23  54 08 47 17  ......d...D#T.G.
---   fat32.img      --0x102200/0x4000000-----------------------------------0.
```

Finding fatgen103.pdf

- Does the file continue after this cluster?
  - Look up current cluster number 17 in FAT…

Continues to cluster 0x12=18!



user@cop4610: ~

```
00004000    F8 FF FF 0F   FF FF FF 0F   F8 FF FF      FF FF FF 0F   ................
00004010    FF FF FF 0F   FF FF FF 0F   FF FF    0F   FF FF FF 0F   ................
00004020    FF FF FF 0F   FF FF FF 0F   FF    FF 0F   FF FF FF 0F   ................
00004030    FF FF FF 0F   FF FF FF 0F   FF FF FF 0F   FF FF FF 0F   ................
00004040    FF FF FF 0F   12 00 00 00   13 00 00 00   14 00 00 00   ................
00004050    15 00 00 00   16 00 00 00   17 00 00 00   18 00 00 00   ................
00004060    19 00 00 00   1A 00 00 00   1B 00 00 00   1C 00 00 00   ................
00004070    1D 00 00 00   1E 00 00 00   1F 00 00 00   20 00 00 00   ............ ...
00004080    21 00 00 00   22 00 00 00   23 00 00 00   24 00 00 00   !..."...#...$...
00004090    25 00 00 00   26 00 00 00   27 00 00 00   28 00 00 00   %...&...'...(...
000040A0    29 00 00 00   2A 00 00 00   2B 00 00 00   2C 00 00 00   )...*...+...,...
000040B0    2D 00 00 00   2E 00 00 00   2F 00 00 00   30 00 00 00   -......./...0...
000040C0    31 00 00 00   32 00 00 00   33 00 00 00   34 00 00 00   1...2...3...4...
000040D0    35 00 00 00   36 00 00 00   37 00 00 00   38 00 00 00   5...6...7...8...
000040E0    39 00 00 00   3A 00 00 00   3B 00 00 00   3C 00 00 00   9...:...;...<...
000040F0    3D 00 00 00   3E 00 00 00   3F 00 00 00   40 00 00 00   =...>...?...@...
00004100    41 00 00 00   42 00 00 00   43 00 00 00   44 00 00 00   A...B...C...D...
00004110    45 00 00 00   46 00 00 00   47 00 00 00   48 00 00 00   E...F...G...H...0.
---   fat32.img       --0x4008/0x4000000--------------------------------------0.
```

Summary of Finding Files/Dirs

- Find ***first cluster number*** in directory entry of the file or directory at hand
- Figure out the sector to read using cluster number and `FirstSectorofCluster` equation
- Read that cluster
- Figure out if the file or directory continues past cluster by looking up FAT[current cluster number]
  - If EoC mark stop
  - Else go to 3 with cluster=FAT[current cluster number]

To Do

- Write code to parse the Boot Sector. Get the necessary values, print them and check.
- Access the Boot Directory. Get the list of files and folders. Print them and check.
- Open a particular file and read from it. Use FAT Table info to get all the clusters associated with it.

Next Time

- Discussion of specific file operations (For example: writing to files, creating and deleting files and directories etc.)
- More discussion of directory entries