NetBSD/x86 BIOS Boot, Revision 5.11 (Fri Feb 14 00:06:28 UTC 2020) (from NetBSD 9.0)

Memory: 639/1047552 k

1. Boot normally
2. Boot single user
3. Drop to boot prompt

Choose an option: RETURN for default; SPACE to stop countdown.
Option 1 will be chosen in 5 seconds.
Booting up a web server

- power on hardware
- POST and other hardware initialization
- first stage boot loader
- second stage boot loader
- hypervisor kernel dom0 starts

- domU is started
- guest OS kernel starts
- kernel initializes (virtual) hardware

physical host

virtual host
Booting up a web server

- power on hardware
- POST and other hardware initialization
- first stage boot loader
- second stage boot loader
- hypervisor kernel dom0 starts
- domU is started
- guest OS kernel starts
- kernel initializes (virtual) hardware
- `init(8)` (or similar) starts
- system processes / daemons start
- web server runs, binds network socket, serves content
AMIBIOS(C)2007 American Megatrends, Inc.
ASUS P5KPL ACPI BIOS Revision 0603
CPU : Intel(R) Pentium(R) Dual CPU E2180 @ 2.00GHz
      Speed : 2.51 GHz    Count : 2

Press DEL to run Setup
Press F8 for BBS POPUP
DDR2-667 in Dual-Channel Interleaved Mode
Initializing USB Controllers .. Done.
3584MB OK

(C) American Megatrends, Inc.
64-0603-000001-00101111-022908-Bearlake-A0820000-Y2KC
MBR
Sector 0
512 bytes
Master Boot Record
• first sector (512 bytes) of storage device

Bytes 510, 511 contain boot signature 0x55 0xAA
Master Boot Record
• first sector (512 bytes) of storage device
• last two bytes contain boot signature
  \((0x55, 0xAA)\)

64 bytes

Bytes:  446 - 509
Master Boot Record
• first sector (512 bytes) of storage device
• last two bytes contain boot signature (0x55, 0xAA)
• 64 bytes allocated for partition table

64 bytes = 4 * 16 bytes
Master Boot Record
• first sector (512 bytes) of storage device
• last two bytes contain boot signature (0x55, 0xAA)
• 64 bytes allocated for partition table
• 4 “primary partitions”, 16 bytes each
Master Boot Record

• first sector (512 bytes) of storage device
• last two bytes contain boot signature (0x55, 0xAA)
• 64 bytes allocated for partition table
• 4 “primary partitions”, 16 bytes each
• 446 bytes for stage 1 boot loader

![Partition Table Entry 1](image1)
![Partition Table Entry 2](image2)
![Partition Table Entry 3](image3)
![Partition Table Entry 4](image4)
Master Boot Record
• first sector (512 bytes) of storage device
• last two bytes contain boot signature (0x55, 0xAA)
• 64 bytes allocated for partition table
• 4 “primary partitions”, 16 bytes each
• 446 bytes for stage 1 boot loader
• stage 1 may reach into other sectors of first track or jump to boot code found on the OS partition for stage 2
Partition Table Entry

16 bytes
Partition Table Entry

16 bytes

Offset: 0x00

1 byte status: 0x80 = “active”
Partition Table Entry

16 bytes

Offset: 0x00

1 byte status: 0x80 = "active"

0x01

3 bytes CHS of first sector
Partition Table Entry

16 bytes

Limits:
1 Byte Head $\Rightarrow 2^8 \Rightarrow 256$

Offset:
- 0x00
- 0x01

1 Byte status: 0x80 = “active”

1 Byte Head
Partition Table Entry
16 bytes

Limits:
1 Byte Head => $2^8$ => 256
6 Bits Sector => $2^6$ => 64

Offset:
0x00
0x01

1 byte status: 0x80 = “active”
1 byte Head
2 bits high bits of Cylinder, 6 bits Sector
Partition Table Entry

16 bytes

Limits:

1 Byte Head $\Rightarrow 2^8 \Rightarrow 256$
6 Bits Sector $\Rightarrow 2^6 \Rightarrow 64$
10 Bits Cylinder $\Rightarrow 2^{10} \Rightarrow 1024$

Offset:

0x00
0x01

1 byte status: 0x80 = “active”

1 byte Head

2 bits high bits of Cylinder, 6 bits Sector

8 bits of Cylinder
Limits:

1 Byte Head => $2^8$ => 256
6 Bits Sector => $2^6$ => 64
10 Bits Cylinder => $2^{10}$ => 1024

Partition Table Entry

16 bytes

Offset:

0x00
0x01
0x04

1 byte status: 0x80 = “active”
1 byte Head
2 bits high bits of Cylinder, 6 bits Sector
8 bits of Cylinder
1 byte partition type
Partition Table Entry

16 bytes

Limits:

1 Byte Head => $2^8$ => 256
6 Bits Sector => $2^6$ => 64
10 Bits Cylinder => $2^{10}$ => 1024

Offset:

0x00
0x01

1 byte status: 0x80 = “active”

0x04
0x05

1 byte Head
2 bits high bits of Cylinder, 6 bits Sector
8 bits of Cylinder

1 byte partition type

3 bytes CHS of last sector
Partition Table Entry

16 bytes

Offset:

0x00

1 byte status: 0x80 = "active"

0x01

1 byte Head

2 bits high bits of Cylinder, 6 bits Sector

8 bits of Cylinder

0x04

1 byte partition type

0x05

1 byte Head

2 bits high bits of Cylinder, 6 bits Sector

8 bits of Cylinder

Limits:

1 Byte Head => 2^8  => 256
6 Bits Sector => 2^6  => 64
10 Bits Cylinder => 2^10 => 1024
Partition Table Entry

16 bytes

Limits:
- 1 Byte Head => $2^8$ => 256
- 6 Bits Sector => $2^6$ => 64
- 10 Bits Cylinder => $2^{10}$ => 1024

Offset:
- 0x00
- 0x01
- 0x04
- 0x05
- 0x08

- 1 byte status: 0x80 = "active"
- 1 byte Head
- 2 bits high bits of Cylinder, 6 bits Sector
- 8 bits of Cylinder
- 1 byte partition type
- 1 byte Head
- 2 bits high bits of Cylinder, 6 bits Sector
- 8 bits of Cylinder
- 4 bytes LBA of first sector
Partition Table Entry

16 bytes

Limits:

1 Byte Head => $2^8 = 256$
6 Bits Sector => $2^6 = 64$
10 Bits Cylinder => $2^{10} = 1024$

<table>
<thead>
<tr>
<th>Offset</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x00</td>
<td>1 byte status: 0x80 = “active”</td>
</tr>
<tr>
<td>0x01</td>
<td>1 byte Head</td>
</tr>
<tr>
<td>0x04</td>
<td>1 byte partition type</td>
</tr>
<tr>
<td>0x05</td>
<td>1 byte Head</td>
</tr>
<tr>
<td>0x08</td>
<td>4 bytes LBA of first sector</td>
</tr>
<tr>
<td>0x0C</td>
<td>4 bytes number of sectors</td>
</tr>
</tbody>
</table>
To translate LBA to CHS:

- **Cylinder** = LBA / (Heads per Cylinder * Sectors Per Track)
- **Remainder** = LBA % (Heads per Cylinder * Sectors Per Track)
- **Head** = Remainder / Sectors Per Track
- **Sector** = (Remainder % Sectors Per Track) + 1
Disk: /dev/rxbd1
NetBSD disklabel disk geometry:
cylinders: 3072, heads: 1, sectors/track: 2048 (2048 sectors/cylinder)
total sectors: 6291456, bytes/sector: 512

BIOS disk geometry:
cylinders: 391, heads: 255, sectors/track: 63 (16065 sectors/cylinder)
total sectors: 6291456

Partitions aligned to 16065 sector boundaries, offset 63

Partition table:
0: <UNUSED>
1: <UNUSED>
2: <UNUSED>
3: <UNUSED>
Bootselector disabled.
No active partition.
Drive serial number: 0 (0x00000000)

```
ip-10-10-0-43# dd if=/dev/xbd1 count=1 2>/dev/null | hexdump -C
00000000  00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00  |.................|
*
00000200
ip-10-10-0-43#  
```

fdisk: Cannot determine the number of heads
Disk: /dev/rdbd1
NetBSD disklabel disk geometry:
cylinders: 3072, heads: 1, sectors/track: 2048 (2)
total sectors: 6291456, bytes/sector: 512

BIOS disk geometry:
cylinders: 391, heads: 255, sectors/track: 63 (16065 sectors/cylinder)
total sectors: 6291456

Partitions aligned to 2048 sector boundaries, offset 0

Partition table:
0: NetBSD (sysid 169)
  start 0, size 0, Active
    beg: cylinder 0, head 0, sector 0
    end: cylinder 0, head 0, sector 0
  PBR appears to be bootable
1: <UNUSED>
2: <UNUSED>
3: <UNUSED>
First active partition: 0
Drive serial number: 0 (0x00000000)
ip-10-10-0-43#  

beg: cylinder 0, head 32, sector 33
end: cylinder 0, head 0, sector 0
PBR appears to be bootable

1: <UNUSED>
2: <UNUSED>
3: <UNUSED>
First active partition: 0
Drive serial number: 0 (0x00000000)

```
ip-10-10-0-43# echo $(( 6291455 / 16065 ))
391
ip-10-10-0-43# echo $(( 6291455 % 16065 ))
10040
ip-10-10-0-43# echo $(( 10040 / 63 ))
159
ip-10-10-0-43# export H=$(printf '%x\n' $(( 10040 / 63 )))
ip-10-10-0-43# echo $H
9f
ip-10-10-0-43# echo $(( 10040 % 63 + 1 ))
24
ip-10-10-0-43# (echo obase=2; echo $(( 10040 % 63 + 1 ))); | bc
110000
ip-10-10-0-43# (echo obase=2; echo 391; ) | bc
110000111
ip-10-10-0-43#
```
fdisk: Cannot determine the number of heads

Disk: /dev/rxbd1

NetBSD disklabel disk geometry:
cylinders: 3072, heads: 1, sectors/track: 2048 (2048 sectors/cylinder)
total sectors: 6291456, bytes/sector: 512

BIOS disk geometry:
cylinders: 391, heads: 255, sectors/track: 63 (16065 sectors/cylinder)
total sectors: 6291456

Partitions aligned to 2048 sector boundaries, offset 0

Partition table:
0: NetBSD (sysid 169)
  start 0, size 0, Active
    beg: cylinder 0, head 32, sector 33
    end: cylinder 391, head 159, sector 24
    PBR appears to be bootable
1: <UNUSED>
2: <UNUSED>
3: <UNUSED>

First active partition: 0
Drive serial number: 0 (0x00000000)
ip-10-10-0-43#
Simplified Boot Sequence

- basic firmware (e.g., BIOS, UEFI, Open Firmware / OpenBoot)
  - Power-on Self-Test
  - tests/initializes hardware
- transfer of execution to first-stage boot loader (Master Boot Record, GUID Partition Table, netbooting, …)
- second-stage boot loader (e.g., GRUB)
- load kernel
- kernel transfers control to init(8)

Note: in virtualized environments, some of these steps are skipped, repeated, or simulated.
Exercises

• Use the ‘aws ec2 get-console-output’ command to get the output from the (virtual) console of different OS instances. Compare, paying particular attention to the filesystem specific parts. Can you explain what’s happening in each?

Sample boot sequences at:
https://stevens.netmeister.org/615/boot-sequence/

• How do you know if your system is trustworthy once it boots up? Review “remote attestation” of software, “secure boot” mechanisms, and “Trusted Computing”.

We still haven’t gotten to the filesystem… let’s fix that in our next video.
Links

File Systems and Storage Models:

BIOS: https://en.wikipedia.org/wiki/BIOS
Booting: https://en.wikipedia.org/wiki/Booting

Manual pages:
boot(8), disklabel(8), fdisk(8), gpt(8), installboot(8), mbr(8), mbrlabel(8)