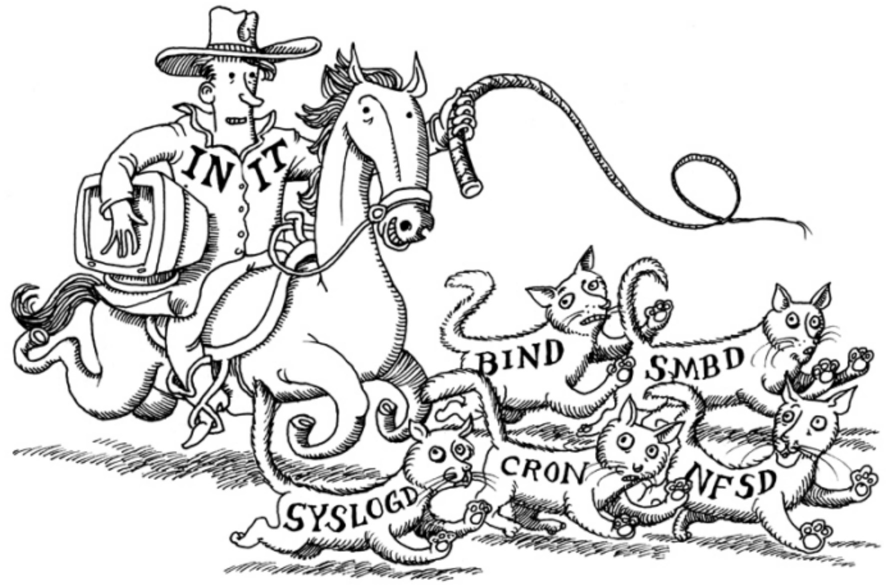

# Booting Up and Shutting Down

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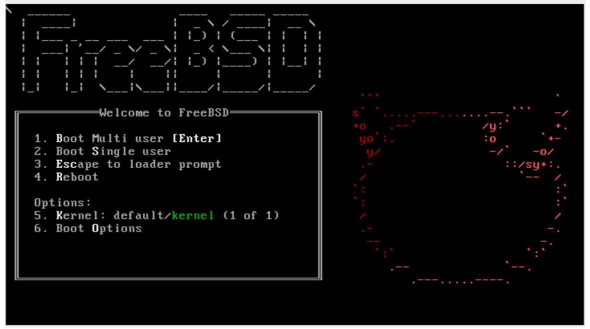
## Handbook and Manual pages

- Complete guide and be found at
  - https://www.freebsd.org/doc/en/books/handbook/boot.html
  - https://www.freebsd.org/doc/zh_TW/books/handbook/boot.html

# Booting Overview - After Powering On

- BIOS (Basic Input/Output System) - stored on motherboard
  - Find MBR in the bootable media (disk,cd,usb stick,...)
- MBR (Master Boot Record) - stored on the first sector of disk/media
  - Record partition information of the disk
  - Load boot loader in Boot Sector (prompt if multiple choices available)
- Boot Sector - stored in the each slice (outside of usual file system)
  - Recognize FreeBSD file system. Find kernel loader under /boot
- Kernel loader - stored in main file system (all below)
  - Show booting prompt and load selected kernel
- OS Kernel
  - Initialize hardware/drivers
- Init
  - Mount filesystem, acquire DHCP, start shell, ...



```
Welcome to FreeBSD

1. Boot Multi user [Enter]
2. Boot Single user
3. Escape to loader prompt
4. Reboot

Options:
5. Kernel: default/kernel (1 of 1)
6. Boot Options
```

# MBR – Master Boot Record

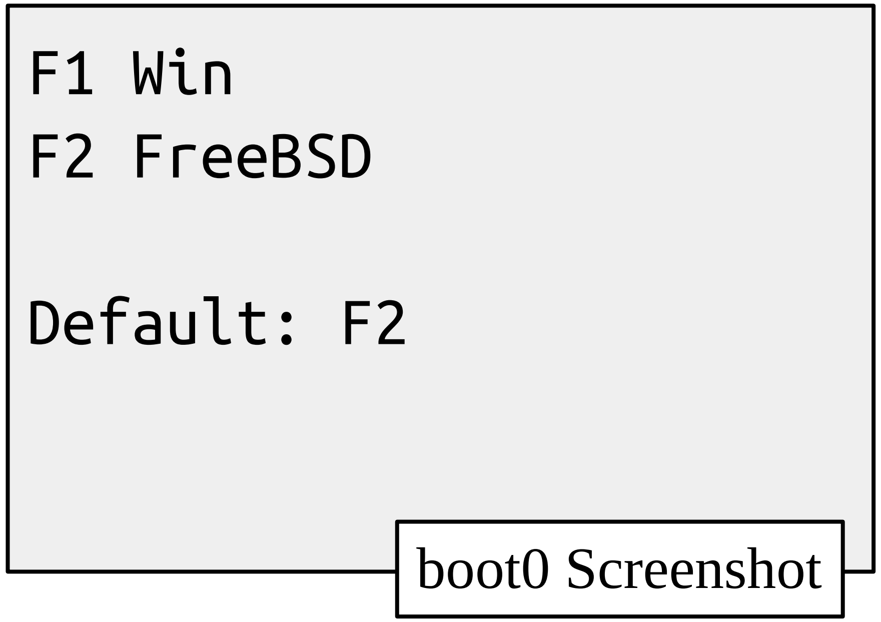
- First 512 bytes of disk, outside the FreeBSD filesystem
  - Last 2 Bytes are 0x55AA
  - Corresponding copy in FreeBSD is /boot/boot0 or /boot/mbr

```
$ ls -l /boot/boot0 /boot/mbr
-r--r--r--  1 root  wheel  512 Nov 12  2014 /boot/boot0
-r--r--r--  1 root  wheel  512 Nov 12  2014 /boot/mbr
```

```
$ xxd /boot/mbr
00000000: fc31 c08e c08e d88e d0bc 007c be1a 7cbf  .1.........|..|.
00000010: 1a06 b9e6 01f3 a4e9 008a 31f6 bbbe 07b1  ...........1.....
…
000001d0: 0000 0000 0000 0000 0000 0000 0000 0000  ................
000001e0: 0000 0000 0000 0000 0000 0000 0000 0000  ................
000001f0: 0000 0000 0000 0000 0000 0000 0000 55aa  ..............U.
```

# MBR – Master Boot Record (cont.)

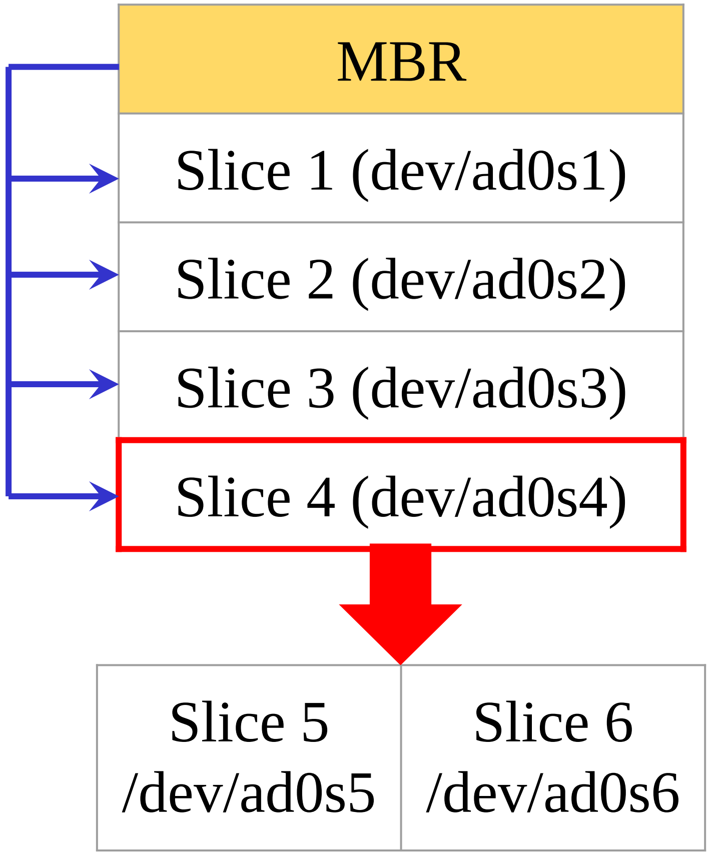
- 446 bytes - code for booting
- 64 bytes - partition table
- Responsible to find the boot code on the boot sector of bootable slice.



```
F1 Win
F2 FreeBSD

Default: F2
```

boot0 Screenshot

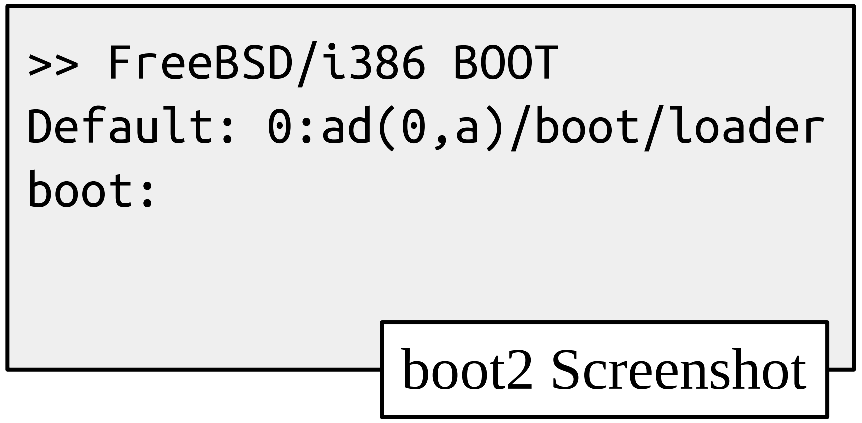


## FreeBSD Booting Stages

- Stage 0 (MBR)
  - /boot/mbr or /boot/boot0
  - Finds bootable partitions
- Stage 1 (Boot Sector)
  - /boot/boot1
  - Limited to 512 byte. Only recognize bsdlabel.
  - Find /boot/boot2 in somewhere of Boot Sector
- Stage 2 (Boot Sector)
  - /boot/boot2
  - Find /boot/loader or load kernel directly
- Stage 3 (BSD file system)
  - /boot/loader
  - Show prompt and load kernel

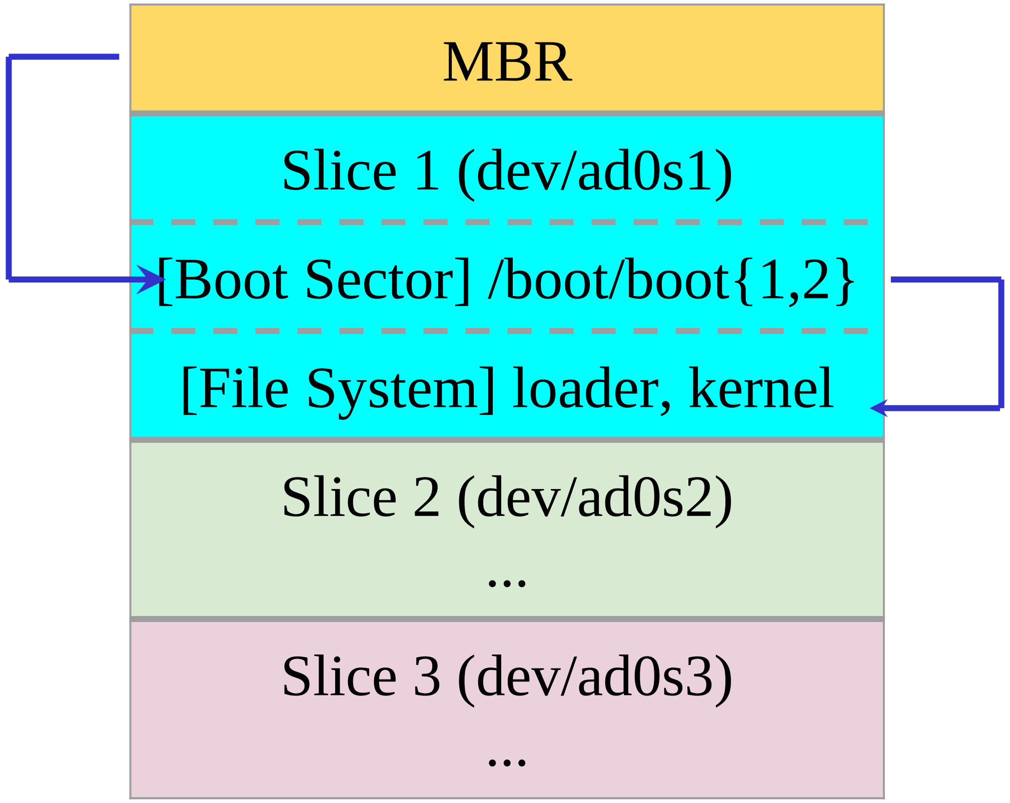
# Boot Stage One and Stage Two

- boot1 and boot2 (/boot/boot1 + /boot/boot2 = /boot/boot)
  - In boot sector of given partition (outside of FreeBSD file system)
  - They belongs to the same program, but divided into two parts because of space constraint
    - Copied from /boot/boot
  - Used to run the loader.



```
>> FreeBSD/i386 BOOT
Default: 0:ad(0,a)/boot/loader
boot:
```

boot2 Screenshot



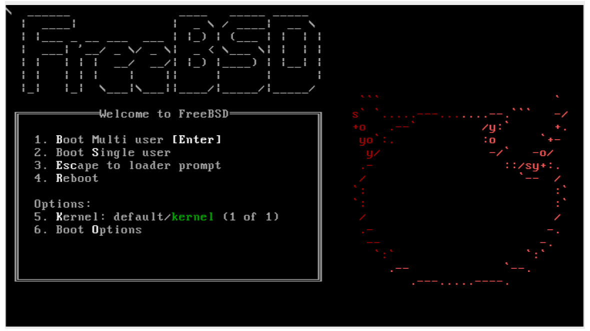
# Boot Stage One and Stage Two (cont.)

```
$ ls -l /boot/boot /boot/boot1 /boot/boot2
-r--r--r--  1 root  wheel  8192  4月  7  2023 /boot/boot
-r--r--r--  1 root  wheel   512  4月  7  2023 /boot/boot1
-r--r--r--  1 root  wheel  7680  4月  7  2023 /boot/boot2
```

```
$ xxd /boot/boot1
00000000: eb3c 0000 0000 0000 0000 0000 0200 0000  .<..............
00000010: 0000 0000 0000 0000 1200 0200 0000 0000  ................
…
000001e0: 0000 0000 0000 0000 0000 0000 0000 8000  ................
000001f0: 0100 a5fe ffff 0000 0000 50c3 0000 55aa  ..........P...U.
```

```
$ ls -l /boot/loader /boot/kernel/kernel
-r-xr-xr-x  1 root  wheel  29435976 10月 11 11:13 /boot/kernel/kernel*
-r-xr-xr-x  3 root  wheel    495616  8月  7 20:08 /boot/loader*
```

# Boot Stage Three



```
Welcome to FreeBSD

 1. Boot Multi user [Enter]
 2. Boot Single user
 3. Escape to loader prompt
 4. Reboot

 Options:
 5. Kernel: default/kernel (1 of 1)
 6. Boot Options
```

- Boot Stage Three: The loader
  - Provide a user-friendly interface to configure booting choice.
  - /boot/loader
    - Wait for 10 seconds then autoboot
    - Configuration
      - Kernel options, kernel modules, boot delay, ...

| Default loader behavior | User-defined loader behavior |
|---|---|
| /boot/defaults/loader.conf | /boot/loader.conf |

```
autoboot_delay="10"
zfs_load="YES"
```

/boot/loader.conf

## Files in /boot/

- /boot/mbr (Standard)
  - Simplified version of boot0, blindly boot the partition marked active
- /boot/boot0 (BootMgr)
  - bootmanager
- /boot/boot{1,2} = /boot/boot
  - boot1 is very simple, since it can only be 512 bytes in size, and knows just enough about the FreeBSD bsdlabel, which stores information about the slice, to find and execute boot2.
  - boot2 is slightly more sophisticated, and understands the FreeBSD file system enough to find files on it, and can provide a simple interface to choose the kernel or loader to run /boot/loader
- /boot/loader
  - load the kernel from disk
- /boot/kernel/kernel

## MBR recover

- If MBR is overwritten by Windows (or other OS), and you want to replace it with FreeBSD MBR:
  - Boot with FreeBSD CD/DVD or USB Drive
  - `$ fdisk -B -b /boot/boot0 ad0` or `boot0cfg -B /dev/ad0`
    - -B means reinitialize the boot code contained in sector 0 of the disk
    - -b is used to specify the boot code
- If you want to replace it with Windows MBR
  - Boot with Windows CD/DVD or USB Drive
  - C:\fdisk /mbr

## Single User Mode

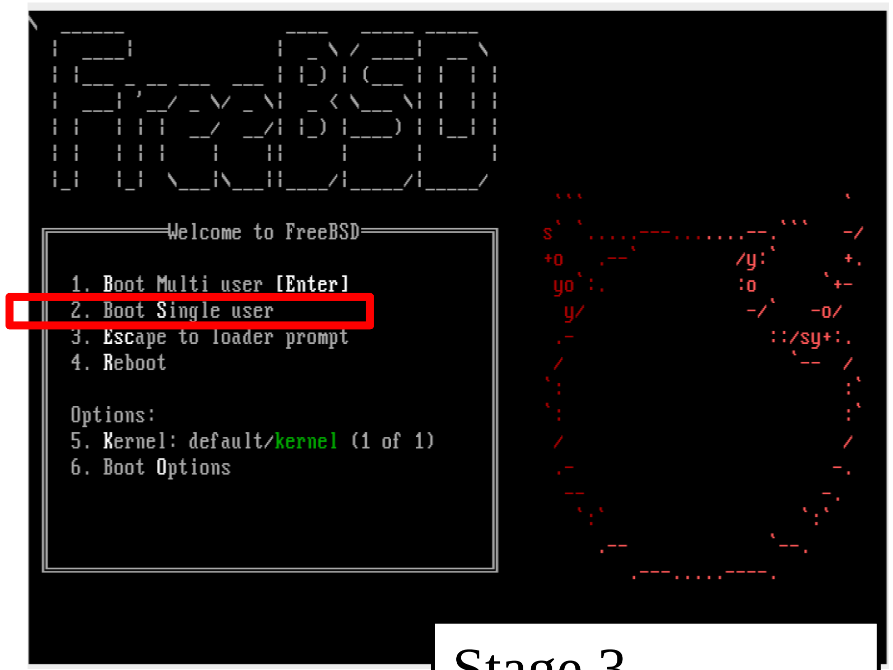
- Similar to Windows "Safe Mode"
- Repair system
  - Inconsistent file system
  - Error in a boot configuration
- Reset lost root password
  - Entering single user mode requires no password
- Full access to local file and configuration (root permission)
- No network access

# Boot in single user mode

| OS | Command |
|---|---|
| FreeBSD | Interrupt the boot loader (stage 2) and type ”/boot/loader -s”<br>or type "2" in the menu of kernel loader |
| Linux | Lilo: linux single<br>Grub: append 'single' in the boot menu<br>(You may need to press “ESC” to show Grub menu in Ubuntu.) |
| Solaris | Press "STOP" and "a" to enter the boot PROM and Press "boot -s" |

```
>> FreeBSD/i386 BOOT
Default: 0:ad(0,a)/boot/loader
boot: /boot/loader -s
```

Stage 2



```
Welcome to FreeBSD

 1. Boot Multi user [Enter]
 2. Boot Single user
 3. Escape to loader prompt
 4. Reboot

 Options:
 5. Kernel: default/kernel (1 of 1)
 6. Boot Options
```

Stage 3

## Insecure single user mode

- Single user mode requires no password by default
  - When the physical security to the console is considerable, set console to be insecure in /etc/ttys

```
# name  getty                          type    status      comments
#
# If console is marked "insecure", then init will ask
# for the root password
# when going to single-user mode.
# console none                          unknown off secure
console none                          unknown off insecure
```

/etc/ttys

## Using Single User Mode

- Only the root partition is mounted and mounted as read only
  - mount -u /
    - Indicates that the status of an already mounted file system should be changed
  - mount -a -t ufs (or other external types)
    - Mount all file systems with specific type
  - swapon -a
    - Enable all swap

## Multibooting (1)

- FreeBSD
  - FreeBSD  boot loader will try to detect bootable partitions
  - You can also declare the bootable partitions explicitly with boot0cfg
    - `$ boot0cfg -B -m 0x7 ad0`
      - -m means mask, Specify slices to be enabled/disabled,
    - E.g.  0x7 means 0111,boot menu will detect slice 1~3 to show the options (and slice 4 is disabled)

## Multibooting (2)

- Linux
  - Using lilo or grub

```
default 0
timeout 30
fallback 1

# For booting GNU/Linux
title  GNU/Linux
kernel (hd1,0)/vmlinuz root=/dev/hdb1

# For booting FreeBSD
title  FreeBSD
root   (hd0,2,a)
kernel /boot/loader

# For booting Windows NT or Windows95
title Windows NT / Windows 95 boot menu
root        (hd0,0)
makeactive
chainloader +1
```

## Steps in the boot process

- Loading and initialization of the kernel
- Device detection and configuration
- Creation of spontaneous system processes
- Execution of system startup scripts
- Multiuser operation

## Steps in the boot process – Kernel initialization

- Get kernel image into memory to be executed
- Perform memory test
  - Allocate internal data structures of kernel

| OS | Kernel Image Path |
|---|---|
| FreeBSD | /boot/kernel/kernel |
| Linux | /boot/vmlinuz |
| Solaris | /kernel/genunix |
| SunOS | /vmunix |

# Steps in the boot process – Hardware configuration

- Devices specified in kernel configuration file
  - Kernel will try to locate and initialize it
- Devices not specified in kernel configuration file
  - Kernel tries to determine other information by probing the bus
    - If the driver is missing or not responsible to the probe, device is disabled
  - We can load kernel module to support this device.
    - kldload, kldstat, kldunload
    - /boot/kernel/*.ko

```
if_em_load="YES"
vboxdrv_load="YES"
vboxnet_enable="YES"
```

/boot/loader.conf

# Steps in the boot process – System Processes

- Spontaneous process
- Not created by the normal UNIX fork mechanism

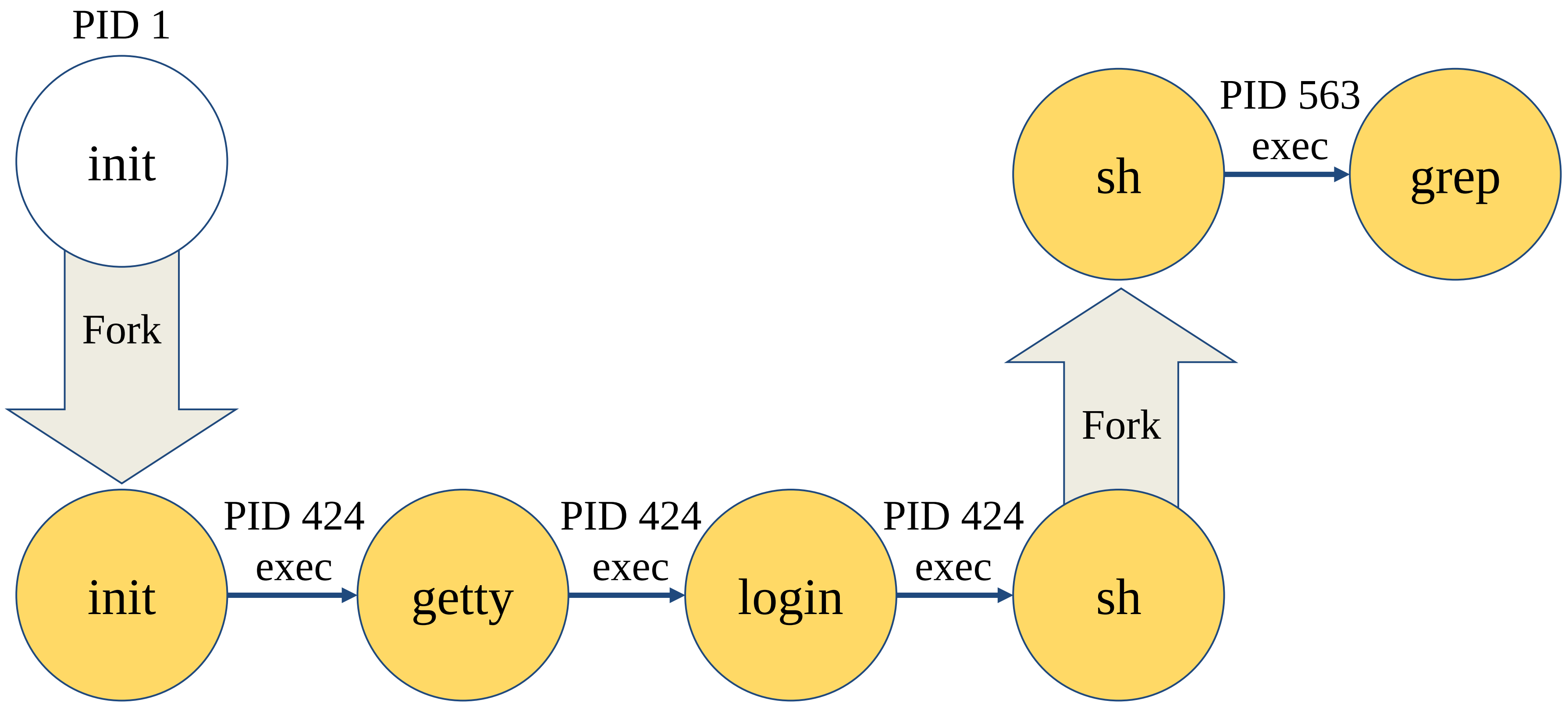
| OS | Pid 0 | Pid 1 | Pid 2 and more |
|---|---|---|---|
| FreeBSD | kernel | init | g_event |
| Linux | - | init | kthreadd, kflushed,kupdate kpiod,kswapd |
| SunOS | sched | init | pageout |

## Steps in the boot process – Execution of startup scripts

- The startup scripts are selected and run by init
- Typical works are:
  - Setting the name of the computer
  - Setting the time zone
  - Checking the disk with fsck
  - Mounting the system's disks
  - Removing files from /tmp directory
  - Configuring network interface
  - Starting up daemons and network services

# Steps in the boot process – Multiuser operation

- From now on, the system is fully operational, but no one can login
  - init will spawn getty processes to listen for login



## FreeBSD startup scripts

- The BSD-style booting
- init will run /etc/rc
- /etc/rc will reads the following configuration
    - /etc/defaults/rc.conf
    - /etc/rc.conf
    - /etc/rc.d
- rc(8)

## Ways to shutdown or reboot

- Turn off the power ← Please Don't
- Use the shutdown(8) command
  - Or using the halt and reboot command
    - halt = shutdown -h
    - reboot = shutdown -r

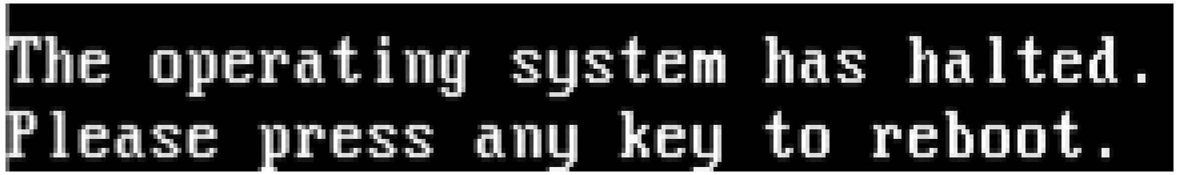
# Ways to shutdown or reboot – shutdown command

| OS | Pathname | Time | Reboot | Halt | Single User Mode | Skip Fsck |
|---|---|---|---|---|---|---|
| FreeBSD | /sbin/shutdown | time | -r | -h | | |
| Linux | /sbin/shutdown | time | -r | -h | | |
| Solaris | /usr/sbin/shutdown | -gsecs | -i6 | -i0 | -is | |
| SunOS | /usr/sbin/shutdown | +mins | -r | -h | | -f |

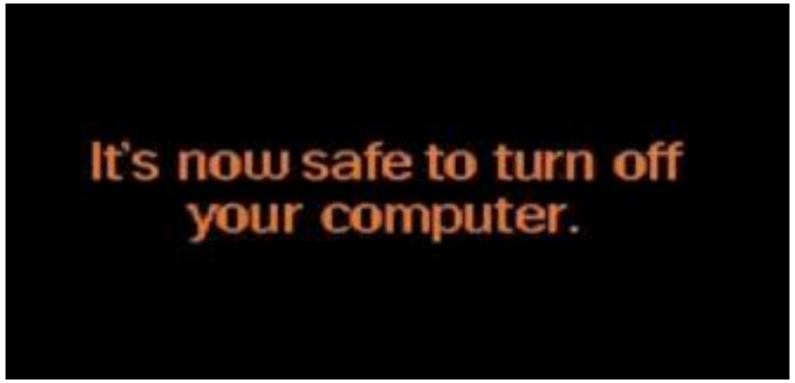
- Time format can be
  - +m
  - hh:mm => Linux
  - yymmddhhmm => FreeBSD

# Halt ? Poweroff ?

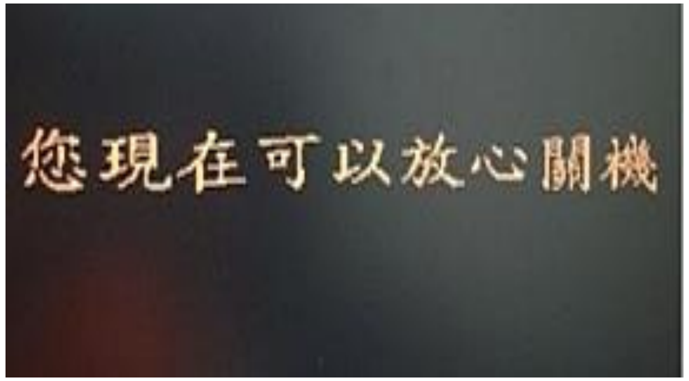
- Halt
    - Terminate all processes, write data back to disks
    - When everything is ready, tell user to turn off the power
        - Or reboot by pressing any key
    - In older systems, you need to manually do so



```
The operating system has halted.
Please press any key to reboot.
```



It's now safe to turn off
your computer.



您現在可以放心關機

## Poweroff

- Halt + Turn off the power
- ACPI / APM
  - Advanced Configuration and Power Interface
  - Advanced Power Management
- In FreeBSD
  - Try “shutdown -p now” (or poweroff)

In case it does not work…

1. Compile this into kernel
   - device apm0 at nexus?flag 0x20
2. Rebuild the kernel
3. Edit /etc/rc.conf
   - apm_enable="YES"
   - apmd_enable="YES"
4. Reboot
5. Try “shtudown -p now” (or poweroff)

## Other Booting Manager

- Besides BSD-style booting, another line is System-V
  - Used by many Linux distributions
    - Solaris, Debian

# System-V Startup Scripts

- Run-level
  - /etc/inittab
  - init follow the inittab from level 0 to level k
- Example: inittab in sun1

| Run Level | Startup scripts | Meaning |
|---|---|---|
| 0 | /etc/rc.d/rc0.d/ | Halt |
| 1 | /etc/rc.d/rc1.d/ | Single user mode |
| 2 | /etc/rc.d/rc2.d/ | Multiuser without NFS |
| 3 | /etc/rc.d/rc3.d/ | Full multiuser mode |
| 4 | /etc/rc.d/rc4.d/ | User defined |
| 5 | /etc/rc.d/rc5.d/ | Multiuser with graphical interface |
| 6 | /etc/rc.d/rc6.d/ | Reboot |

## Ways to shutdown or reboot – telinit

- Only for SystemV systems (and Systemd)
- telinit: change run-level
- Halt/poweroff
  - `$ telinit 0`
- Reboot
  - `$ telinit 6`
- Single user mode
  - `$ telinit 1`

## Systemd

- Modern system/service manager for many Linux distributions
  - Ubuntu, Debian, …
- Evolved from System-V
  - Another booting manager beside BSD
  - Used by older versions of Linux distributions
  - Debian < 8.0 : System-V
  - Debian >= 8.0 : Systemd
- Similar to System-V, but faster and easier to use

## Systemd

- Use 'targets' to replace run-levels

| SysV Run Level | Systemd targets | Meaning |
|---|---|---|
| 0 | runlevel0.target, poweroff.target | Poweroff |
| 1 | runlevel1.target, rescue.target | Single user mode |
| 2 | runlevel2.target, multi-user.target | User defined. Default: same as level 3 |
| 3 | runlevel3.target, multi-user.target | Multiuser mode |
| 4 | runlevel4.target, multi-user.target | User defined. Default: same as level 3 |
| 5 | runlevel5.target, graphical.target | Multiuser with graphical interface |
| 6 | runlevel6.target, reboot.target | Reboot |