

CSGE602055 Operating Systems

CSF2600505 Sistem Operasi

Week 09: Storage, Firmware, Bootloader, & Systemd

C. BinKadal

Sendirian Berhad

<https://docos.vlsm.org/Slides/os09.pdf>

Always check for the latest revision!

REV424: Tue 03 Sep 2024 20:00

OS242³): Operating Systems Schedule 2024 - 2

Week	Topic ¹⁾	OSC10 ²⁾
Week 00	Overview (1), Assignment of Week 00	Ch. 1, 2
Week 01	Overview (2), Virtualization & Scripting	Ch. 1, 2, 18.
Week 02	Security, Protection, Privacy, & C-language.	Ch. 16, 17.
Week 03	File System & FUSE	Ch. 13, 14, 15.
Week 04	Addressing, Shared Lib, & Pointer	Ch. 9.
Week 05	Virtual Memory	Ch. 10.
Week 06	Concurrency: Processes & Threads	Ch. 3, 4.
Week 07	Synchronization & Deadlock	Ch. 6, 7, 8.
Week 08	Scheduling + W06/W07	Ch. 5.
Week 09	Storage, Firmware, Bootloader, & Systemd	Ch. 11.
Week 10	I/O & Programming	Ch. 12.

¹⁾ For schedule, see <https://os.vlsm.org/#idx02>

²⁾ Silberschatz et. al.: **Operating System Concepts**, 10th Edition, 2018.

³⁾ This information will be on **EVERY** page two (2) of this course material.

STARTING POINT — <https://os.vlsm.org/>

- ☐ **Text Book** — Any recent/decent OS book. Eg. (**OSC10**) Silberschatz et. al.: **Operating System Concepts**, 10th Edition, 2018. (See <https://codex.cs.yale.edu/avi/os-book/OS10/>).
- ☐ **Resources** (<https://os.vlsm.org/#idx03>)
 - ☐ **SCELE** — <https://scele.cs.ui.ac.id/course/view.php?id=3841>.
The enrollment key is **XXX**.
 - ☐ **Download Slides and Demos from GitHub.com** —
(<https://github.com/os2xx/docos/>)
[os00.pdf \(W00\)](#), [os01.pdf \(W01\)](#), [os02.pdf \(W02\)](#), [os03.pdf \(W03\)](#), [os04.pdf \(W04\)](#), [os05.pdf \(W05\)](#),
[os06.pdf \(W06\)](#), [os07.pdf \(W07\)](#), [os08.pdf \(W08\)](#), [os09.pdf \(W09\)](#), [os10.pdf \(W10\)](#).
 - ☐ **Problems**
[195.pdf \(W00\)](#), [196.pdf \(W01\)](#), [197.pdf \(W02\)](#), [198.pdf \(W03\)](#), [199.pdf \(W04\)](#), [200.pdf \(W05\)](#),
[201.pdf \(W06\)](#), [202.pdf \(W07\)](#), [203.pdf \(W08\)](#), [204.pdf \(W09\)](#), [205.pdf \(W10\)](#).
 - ☐ **LFS** — <http://www.linuxfromscratch.org/lfs/view/stable/>
 - ☐ **This is How Me Do It!** — <https://doit.vlsm.org/>
 - ☐ PS: "Me" rhymes better than "I", duh!

Agenda

- 1 Start
- 2 OS242 Schedule
- 3 Agenda
- 4 Week 09
- 5 OSC10 (Silberschatz) Chapter 11
- 6 Storage, Firmware, Bootloader, & Systemd
- 7 Storage Management
- 8 RAID
- 9 Legacy BIOS
- 10 UEFI
- 11 Operating System (Boot) Loader
- 12 GRUB Map
- 13 init (SYSV legacy)
- 14 UpStart - Ubuntu
- 15 The All New "systemd"
- 16 systemctl

Week 09 Storage, Firmware, Bootloader, & Systemd: Topics¹

- Storage
- Storage Arrays
- BIOS
- Loader
- Systemd

¹Source: ACM IEEE CS Curricula

Week 09 Storage, Firmware, Bootloader, & Systemd: Learning Outcomes¹

- Storage [Usage]
- Storage Arrays [Usage]
- BIOS [Usage]
- Loader [Usage]
- Systemd [Usage]

¹Source: ACM IEEE CS Curricula

- OSC10 Chapter 11: Mass-Storage Systems
 - Overview of Mass Storage Structure
 - HDD Scheduling
 - NVM Scheduling
 - Error Detection and Correction
 - Storage Device Management
 - Swap-Space Management
 - Storage Attachment
 - RAID Structure

Storage, Firmware, Bootloader, & Systemd

- Reference: (OSC10-ch11)
- Storage Capacity (2019)¹
 - Legacy 3.5" Floppy Disk (1.4MB) – obsolete?
 - SuperDisk (up to 240 MB) — never took off.
 - 4.7" Compact Disc (700MB) – obsolete?
 - 4.7" Digital Versatile Disc (up to 9GB) – ?
 - 4.7" Blu Ray (up to 128 GB) ⇒ DVD++.
 - Tape Cartridge (up to 15TB)
 - Robotic System (up to 250 PB per unit)
 - NASA, Google, Microsoft are still using this!
 - Cheap but slow.
 - Hard Disk Drives (up to 16 TB).
 - From Perpendicular Magnetic Recording to Shingled Magnetic Recording technology (+25% – writing problems).
 - Mechanical Disk Arm Scheduling (Until When?).
 - Solid-State Disks (up to 16 TB).
 - SSD Price > HDD Price.
 - Write Speed >> Read Speed.
 - (What is a) Flash Disk?

Storage Capacity

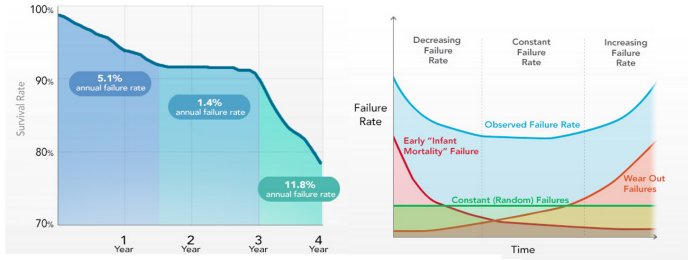
 Floppy Disk	1.4MB	 Hard Drive	5TB
 USB Drive	64GB	 Angry GF remembering all of my past mistakes	1,000,000 TB

Figure: Source: <https://linktr.ee/hackingarticles>

Storage Failure Rates

- MTDDL: Mean Time To Data Loss
- MTTF: Mean Time To Failure
- BackBlaze (Cloud Backup Services)

Drives Have 3 Distinct Failure Rates General Predicted Failure Rates
Hard Drive Survival Rates - Chart 1



<https://www.extremetech.com/computing/170748-how-long-do-hard-drives-actually-live-for>



Figure: BackBlaze — Failure Rates of 25000 DISKS

Storage Management

- Attached-Storage.
 - Host-Attached Storage: via I/O.
 - Network-Attached Storage (NAS): via distributed FileSystem.
 - Storage Area Network (SAN): dedicated Network.
- Formatting
 - Low Level (Physical)
 - High Level (FileSystem)
- Boot Block
- Disk Partition
 - "MBR"-scheme
 - upto 4 primary partition
 - upto 2 TB disk
 - "GPT"-scheme
 - "unlimited" partition
 - "unlimited" disk
 - redundancy
- Swap Space Management: On Partition or FileSystem?

RAID: Redundant Array of In* Disks

- RAID 0, 1, 5, 6, 10, 100
- Note (<http://www.commodore.ca/windows/raid5/raid5.htm>):
 - RAID was created to enhance data performance, reliability and availability.
 - Striping, parity checking and mirroring are three primary functions of RAID systems.
 - RAID performs its functions transparent to the operating system.
 - Systems are typically defined by ranks consisting of five disks each connected to one or two Disk Array Controllers.
 - Different RAID levels provide varying degrees of speed and data protection.
- Problems with RAID
- Stable-Storage Implementation

BIOS, Boot, & Systemd

- Firmware
 - BIOS: Basic Input Output System.
 - UEFI: Unified Extensible Firmware Interface.
 - ACPI: Advanced Configuration and Power Interface.
- Operating System (Boot) Loader
 - BOOTMGT: Windows Bootmanager / Bootloader.
 - LILO: Linux Loader.
 - GRUB: GRand Unified Bootloader.
- Operating System Initialization
 - Init (legacy)
 - UpStart
 - Systemd

Legacy BIOS

- Check Settings.
- Initialize CPU & RAM.
- POST: Power-On Self-Test.
- Initialize ports, LANS, etc.
- Load a Boot Loader.
- Handover to the Boot Loader.
- Provides "Native" (obsolete) Drivers only (not loadable).
- Provides "INT" services .
- Limitation.
 - Technology of 1970s.
 - 16 bits software.
 - 20 bits address space (1 MB).
 - 31 bits disk space (2 TB).

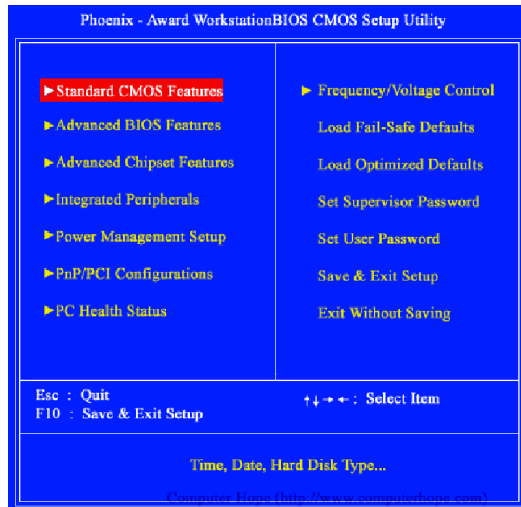


Figure: BIOS

- A Firmware Specification, not an Implementation!
- No (INT) service after boot.
- HII: Human Interface Infrastructure.
- Protected Mode.
- Flexible.
 - Technology of 2000s.
 - written in C.
 - (third party) loadable drivers and tools.
 - Emulate Legacy BIOS transition (MBR block, INT service).
 - UEFI Shell: environment shell for diagnostic (no need for DOS).
- Problems
 - Who controls the Hardware?
 - Is "Secure Boot" a good thing?
 - How about a **NASTY/LOCKING/TROJAN** UEFI implementation?
 - Different **DRIVERS**.

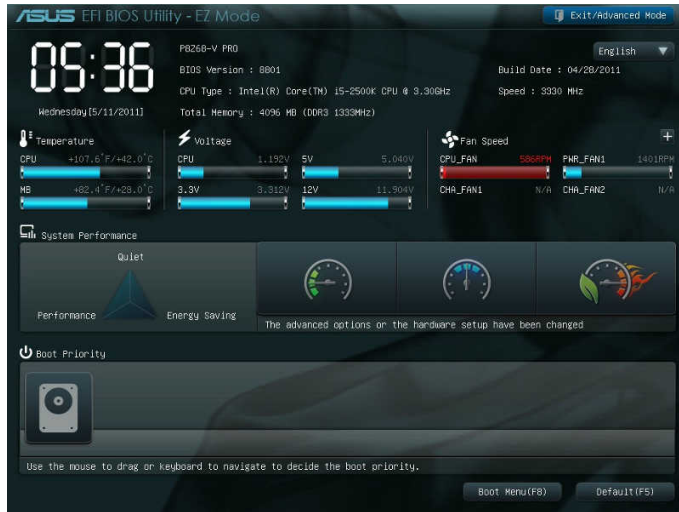


Figure: UEFI

Platform Initialization (PI) Boot Phases

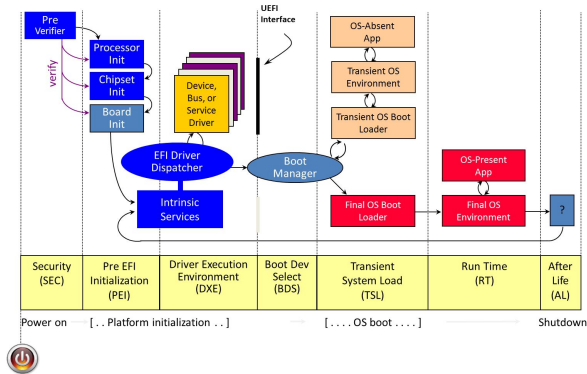


Figure: UEFI Boot Process¹.

¹Source Jarslstrom - 2014 - www.tianocore.org

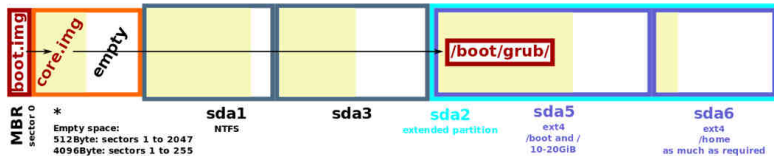
Operating System (Boot) Loader

- General
 - How/Where to start the operating system?
 - What to do?
 - How many ways to boot?
 - How many types of OS?
- Disk Partition
 - MBR: Master Boot Record (1983).
 - GPT: GUID (Globally Unique Identifiers) Partition Table (2010s).
- GRUB: GRand Unified Boot system
 - Stage 1: a small boot.img inside the MBR.
 - Stage 1.5 (core.img): FileSystem drivers after MBR.
 - Stage 2: Kernel Selection: Windows, Linux, BSD, etc.
- GRUB2
 - More flexible than GRUB legacy.
 - More automated than GRUB legacy.
 - Accept MBR and GPT.
 - Stage 1.5 (core.img): generated from diskboot.img.
 - No 1024 cylinder restriction.

GNU GRUB 2

Locations of *boot.img*, *core.img* and the */boot/grub/* directory

Example 1: an MBR-partitioned harddisc with sector size of 512 or 4096Bytes



Example 2: a GPT-partitioned harddisc with sector size of 512 or 4096Bytes

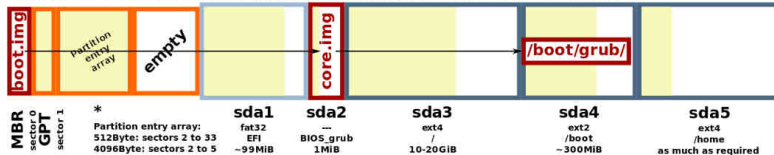


Figure: GRUB¹.

¹Source Shmuel Csaba Otto Traian 2013

init (SYSV legacy)

- File: `/etc/inittab`.
- Folders: `/etc/rcX.d` — `X` = runlevel.
 - Seven (7) different runlevels:
 - 0 (shutdown).
 - 1 (single-user/admin).
 - 2 (multi-user non net).
 - 3 (standard).
 - 4 (N/A).
 - 5 (3+GUI).
 - 6 (reboot).
 - `SXX-YYY`: Start
 - `KXX-YYY`: Kill.
- One script at a time in order.
- dependency is set manually.

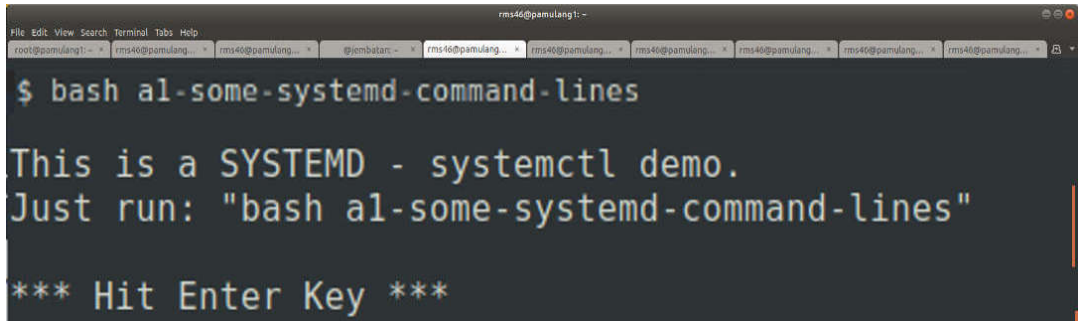
- Developer: Ubuntu.
- Folder: `/etc/init/`.
- Control: `initctl`.
 - `initctl list` – listing all processes managed by upstart.
- better support for hotplug devices.
- cleaner service management.
- faster service management.
- asynchronous.

The All New "systemd"

- Replaces (SYSV) init and UpStart.
 - better concurrency handling: Faster!
 - better dependencies handling: No more "S(tarts)" and "K(ills)".
 - better crash handling: automatic restart option.
 - better security: group protection from anyone including superusers.
 - simpler config files: reliable and clean scripts.
 - hotplug: dynamic start/stop.
 - supports legacy systems (init).
 - overhead reducing.
 - unified management way for all distros.
 - bloated: doing more with more resources.
 - linux specific: NOT portable.

systemctl 01

```
for II in \
'systemctl list-unit-files | head -8; echo "(...)";
    systemctl list-unit-files| tail -8' \
'systemd-analyze blame | wc -l; echo "===";
    systemd-analyze blame | head -15' \
'systemctl --full | wc -l; echo "===";
    systemctl --full | head -10' \
'systemctl list-units | wc -l; echo "===";
    systemctl list-units | head -10' \
'systemctl list-units |grep .service|wc -l;echo "===";
    systemctl list-units|grep .service|head -10' \
'systemctl list-units | grep ssh.service' \
'systemctl status ssh.service' \
'systemctl is-enabled ssh' \
'journalctl' \
'journalctl -b' \
do
```

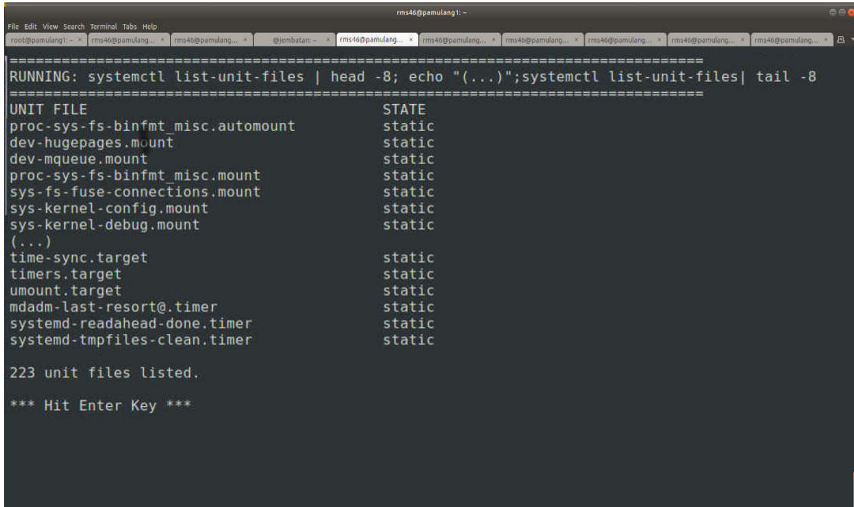
A terminal window titled 'rms46@pamulang1: ~' with a menu bar (File, Edit, View, Search, Terminal, Tabs, Help) and a tab bar showing multiple open tabs. The terminal displays the command '\$ bash a1-some-systemd-command-lines' and its output: 'This is a SYSTEMD - systemctl demo. Just run: "bash a1-some-systemd-command-lines" *** Hit Enter Key ***'.

```
$ bash a1-some-systemd-command-lines

This is a SYSTEMD - systemctl demo.
Just run: "bash a1-some-systemd-command-lines"

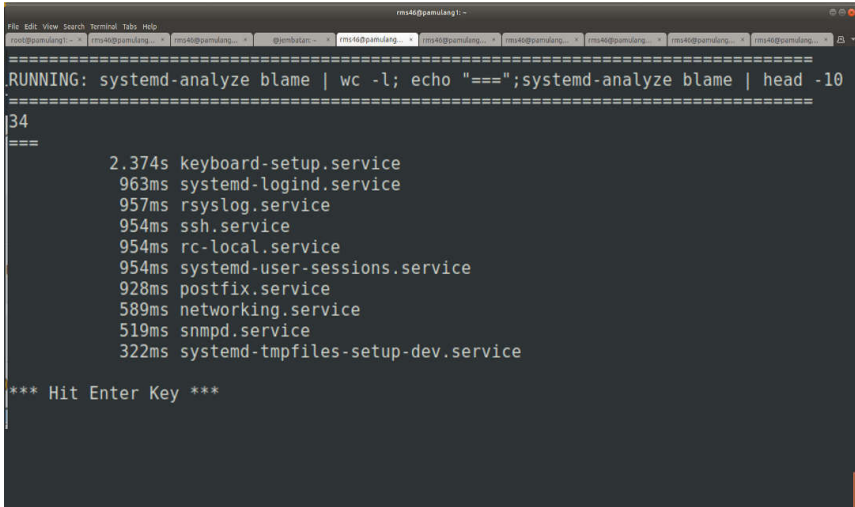
*** Hit Enter Key ***
```

Figure: bash a1-some-systemd-command-lines



```
rms46@pamulang1: ~  
File Edit View Search Terminal Tabs Help  
root@pamulang1:~ * rms46@pamulang... * @jombatan:~ * rms46@pamulang... * rms46@pamulang... * rms46@pamulang... * rms46@pamulang... * rms46@pamulang... * rms46@pamulang... *  
=====   
RUNNING: systemctl list-unit-files | head -8; echo "...";systemctl list-unit-files| tail -8  
=====   
UNIT FILE                                STATE  
proc-sys-fs-binfmt_misc.automount        static  
dev-hugepages.mount                      static  
dev-mqueue.mount                         static  
proc-sys-fs-binfmt_misc.mount            static  
sys-fs-fuse-connections.mount            static  
sys-kernel-config.mount                  static  
sys-kernel-debug.mount                   static  
(...)  
time-sync.target                         static  
timers.target                           static  
umount.target                           static  
mdadm-last-resort@.timer                  static  
systemd-readahead-done.timer              static  
systemd-tmpfiles-clean.timer              static  
  
223 unit files listed.  
  
*** Hit Enter Key ***
```

Figure: systemctl list-unit-files



```
rms46@pamulang1: ~  
File Edit View Search Terminal Tabs Help  
root@pamulang1: ~ x rms46@pamulang... x rms46@pamulang... x @jenbaten: ~ x rms46@pamulang... x rms46@pamulang... x rms46@pamulang... x rms46@pamulang... x rms46@pamulang... x rms46@pamulang... x  
=====
```

RUNNING: systemd-analyze blame | wc -l; echo "===";systemd-analyze blame | head -10

```
=====
```

34

```
=====
```

2.374s	keyboard-setup.service
963ms	systemd-logind.service
957ms	rsyslog.service
954ms	ssh.service
954ms	rc-local.service
954ms	systemd-user-sessions.service
928ms	postfix.service
589ms	networking.service
519ms	snmpd.service
322ms	systemd-tmpfiles-setup-dev.service

*** Hit Enter Key ***

Figure: systemd-analyze blame

```

rms46@pamulang: ~
File Edit View Search Terminal Tabs Help
root@pamulang:~ * rms46@pamulang... * rms46@pamulang... * @jombatan:~ * rms46@pamulang... * rms46@pamulang... * rms46@pamulang... * rms46@pamulang... * rms46@pamulang... * rms46@pamulang... *
RUNNING: systemctl --full | wc -l; echo "===";systemctl --full | head -6
=====
07
name
UNIT
proc-sys-fs-binfmt_misc.automount
sys-devices-pci0000:00-0000:00:05.0-host0-target0:0:0:0:0-block-sda-sda1.device
sys-devices-pci0000:00-0000:00:05.0-host0-target0:0:0:0:0-block-sda-sda2.device
sys-devices-pci0000:00-0000:00:05.0-host0-target0:0:0:0:0-block-sda.device
sys-devices-pci0000:00-0000:00:05.0-host0-target0:0:1:0:1:0-block-sdb-sdb1.device
LOAD ACTIVE SUB DESCRIPTION
loaded active waiting Arbitrary Executable File Formats File System Automount Point
loaded active plugged QEMU_HARDDISK 1
loaded active plugged QEMU_HARDDISK 2
loaded active plugged QEMU_HARDDISK
loaded active plugged QEMU_HARDDISK 1
*** Hit Enter Key ***

RUNNING: systemctl list-units | wc -l; echo "===";systemctl list-units | head -6
=====
07
name
UNIT
proc-sys-fs-binfmt_misc.automount
sys-devices-pci0000:00-0000:00:05.0-host0-target0:0:0:0:0-block-sda-sda1.device
sys-devices-pci0000:00-0000:00:05.0-host0-target0:0:0:0:0-block-sda-sda2.device
sys-devices-pci0000:00-0000:00:05.0-host0-target0:0:0:0:0-block-sda.device
sys-devices-pci0000:00-0000:00:05.0-host0-target0:0:1:0:1:0-block-sdb-sdb1.device
LOAD ACTIVE SUB DESCRIPTION
loaded active waiting Arbitrary Executable File Formats File System Automount Point
loaded active plugged QEMU_HARDDISK 1
loaded active plugged QEMU_HARDDISK 2
loaded active plugged QEMU_HARDDISK
loaded active plugged QEMU_HARDDISK 1
*** Hit Enter Key ***

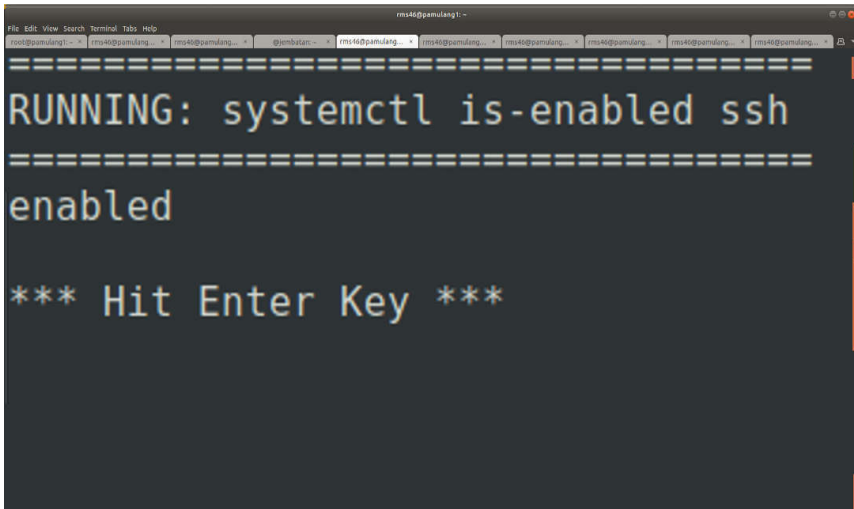
RUNNING: systemctl list-units |grep .service|wc -l;echo "===";systemctl list-units|grep .service|head -6
=====
12
name
icct.service
icpid.service
console-setup.service
cron.service
ibus.service
jetty@tty1.service
loaded active exited LSB: process and login accounting
loaded active running ACPI event daemon
loaded active exited Set console font and keymap
loaded active running Regular background program processing daemon
loaded active running D-Bus System Message Bus
loaded active running Getty on tty1
*** Hit Enter Key ***

```

Figure: systemctl –full; systemctl list-units

```
rms46@pamulang1: ~  
File Edit View Search Terminal Tabs Help  
root@pamulang1: ~ * rms46@pamulang... * rms46@pamulang... * @jenbaten: ~ * rms46@pamulang... * rms46@pamulang... * rms46@pamulang... * rms46@pamulang... * rms46@pamulang... * rms46@pamulang... *  
=====  
RUNNING: systemctl list-units | grep ssh.service  
=====  
ssh.service                                loaded active running    OpenBSD Secure Shell server  
*** Hit Enter Key ***  
=====  
RUNNING: systemctl status ssh.service  
=====  
● ssh.service - OpenBSD Secure Shell server  
   Loaded: loaded (/lib/systemd/system/ssh.service; enabled)  
   Active: active (running) since Sun 2020-04-26 03:00:24 WIB; 3h 33min ago  
   Process: 653 ExecStartPre=/usr/sbin/sshd -t (code=exited, status=0/SUCCESS)  
   Main PID: 686 (sshd)  
   CGroup: /system.slice/ssh.service  
           └─ 686 /usr/sbin/sshd -D  
              └─ 3247 sshd: demo [priv]  
                 └─ 3253 sshd: demo@pts/0  
                    └─ 3254 -bash  
                       └─ 3391 bash a1-some-systemd-command-lines  
                          └─ 3550 systemctl status ssh.service  
*** Hit Enter Key ***
```

Figure: systemctl status ssh.service

A terminal window titled 'rms46@pamulang: ~' with multiple tabs. The active tab shows the command 'systemctl status ssh' and its output. The output is displayed in a monospaced font with a dark background and light-colored text. The text is as follows:

```
=====  
RUNNING: systemctl is-enabled ssh  
=====
```

enabled

*** Hit Enter Key ***

Figure: systemctl is-enabled ssh