

CSGE602055 Operating Systems  
CSF2600505 Sistem Operasi  
Week 09: Storage, Firmware, Bootloader, & Systemd

C. BinKadal

Sendirian Berhad

<https://doc0S.vlsm.org/Slides/os09.pdf>

Always check for the latest revision!

REV418: Tue 30a Jan 2024 22:00

# OS241<sup>3</sup>): Operating Systems Schedule 2023 - 2

Week	Topic <sup>1)</sup>	OSC10 <sup>2)</sup>
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.

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

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

<sup>3)</sup> 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**, 10<sup>th</sup> 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=3743>.  
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/>
  - OSP4DISS** — <https://osp4diss.vlsm.org/>
  - This is How Me Do It!** — <https://doit.vlsm.org/>
    - PS: "Me" rhymes better than "I", duh!

# Agenda

- 1 Start
- 2 OS241 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: Topics<sup>1</sup>

- Storage
- Storage Arrays
- BIOS
- Loader
- Systemd

---

<sup>1</sup>Source: ACM IEEE CS Curricula

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

---

<sup>1</sup>Source: 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)<sup>1</sup>
  - 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

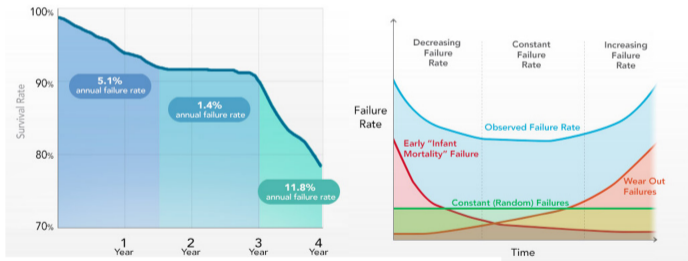
 Floppy Disk	1.4MB	 Hard Drive	5TB
 USB Drive	64GB	 Angry GF remembering all of my past mistakes	1,000,000 TB

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

- 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).

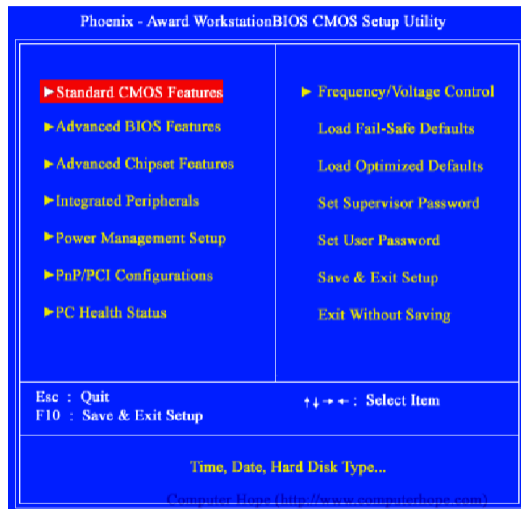


Figure: BIOS

- 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**.



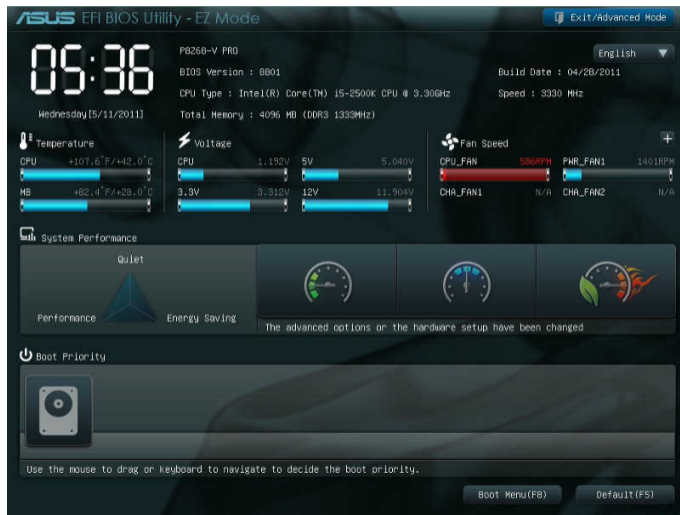


Figure: UEFI

## Platform Initialization (PI) Boot Phases

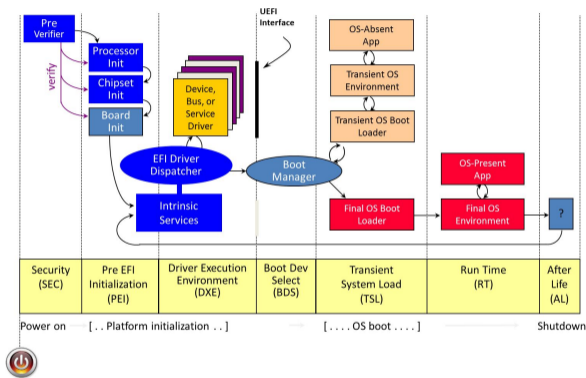


Figure: UEFI Boot Process<sup>1</sup>.

<sup>1</sup>Source Jarslstrom - 2014 - [www.tianocore.org](http://www.tianocore.org)

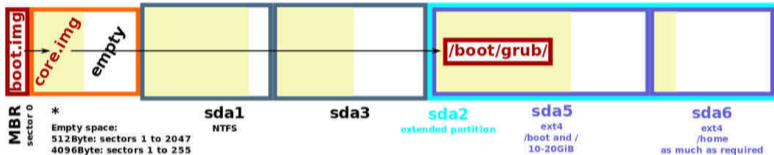
# Operating System (Boot) Loader

- 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

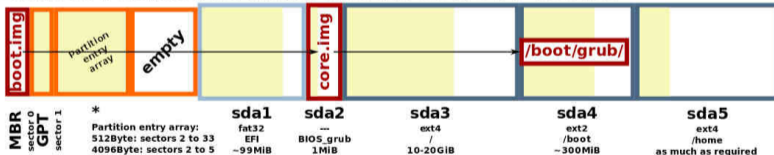


Figure: GRUB<sup>1</sup>.

<sup>1</sup>Source 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.

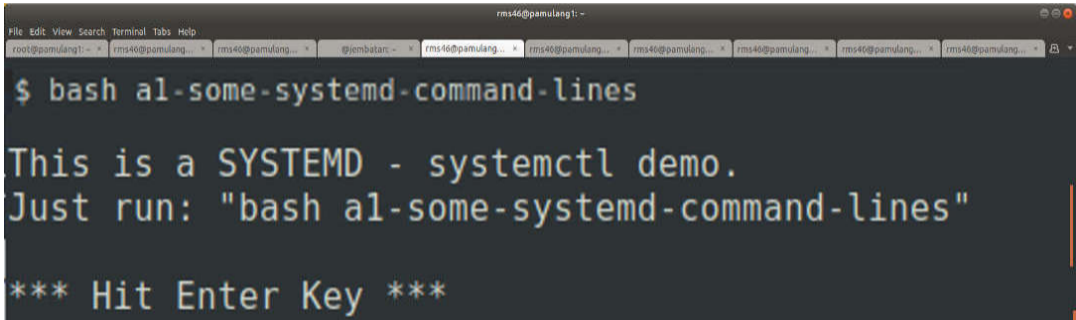
# The All New "systemd"

- 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
```

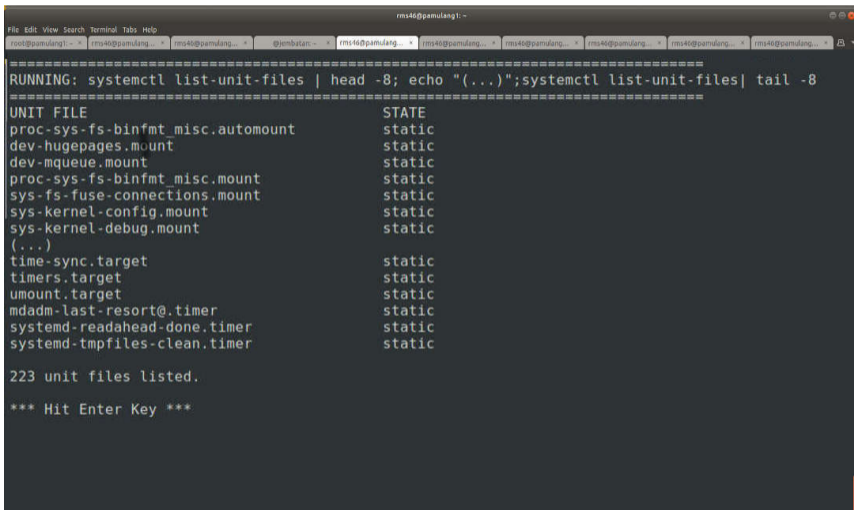




A terminal window titled "rms46@pamulang1: ~" with a menu bar (File, Edit, View, Search, Terminal, Tabs, Help) and several open tabs. The terminal content is as follows:

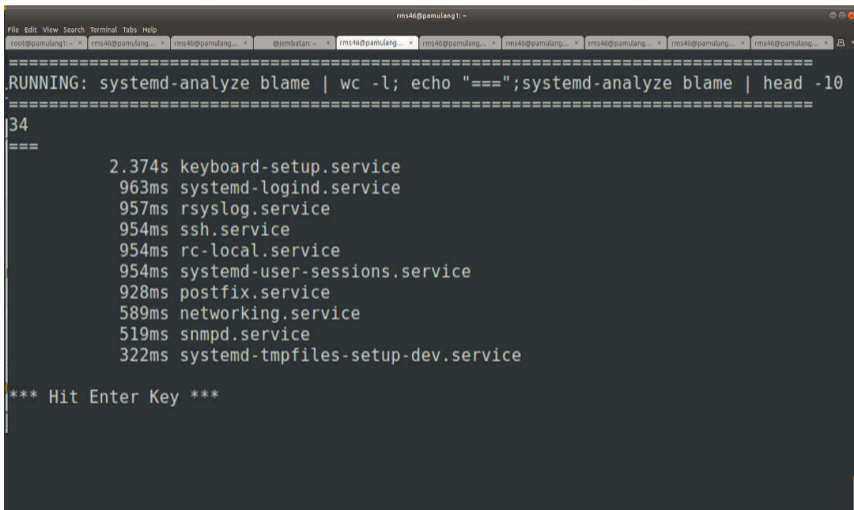
```
$ bash a1-some-systemd-command-lines  
This is a SYSTEMD - systemctl demo.  
Just run: "bash a1-some-systemd-command-lines"  
*** Hit Enter Key ***
```

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



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

*** Hit Enter Key ***

RUNNING: systemctl list-units | wc -l; echo "===";systemctl list-units | head -6
=====
07
===
UNIT                                LOAD    ACTIVE SUB    DESCRIPTION
proc-sys-fs-binfmt_misc.automount  loaded active waiting Arbitrary Executable File Formats File System Automount Point
sys-devices-pci0000:00-0000:00:05.0-host0-target0:0:0:0:0-block-sda-sda1.device loaded active plugged QEMU_HARDDISK 1
sys-devices-pci0000:00-0000:00:05.0-host0-target0:0:0:0:0-block-sda-sda2.device loaded active plugged QEMU_HARDDISK 2
sys-devices-pci0000:00-0000:00:05.0-host0-target0:0:0:0:0-block-sda.device loaded active plugged QEMU_HARDDISK
sys-devices-pci0000:00-0000:00:05.0-host0-target0:0:1:0:0:1:0-block-sdb-sdb1.device 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
===
icct.service                        loaded active exited LSB: process and login accounting
icpid.service                       loaded active running ACPI event daemon
console-setup.service              loaded active exited Set console font and keymap
cron.service                       loaded active running Regular background program processing daemon
ibus.service                       loaded active running D-Bus System Message Bus
jetty@tty1.service                 loaded active running Getty on tty1

*** Hit Enter Key ***

```

Figure: systemctl –full; systemctl list-units

```
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 list-units | grep ssh.service

```
=====
```

ssh.service loaded active running OpenBSD Secure Shell server

\*\*\* Hit Enter Key \*\*\*

```
=====
```

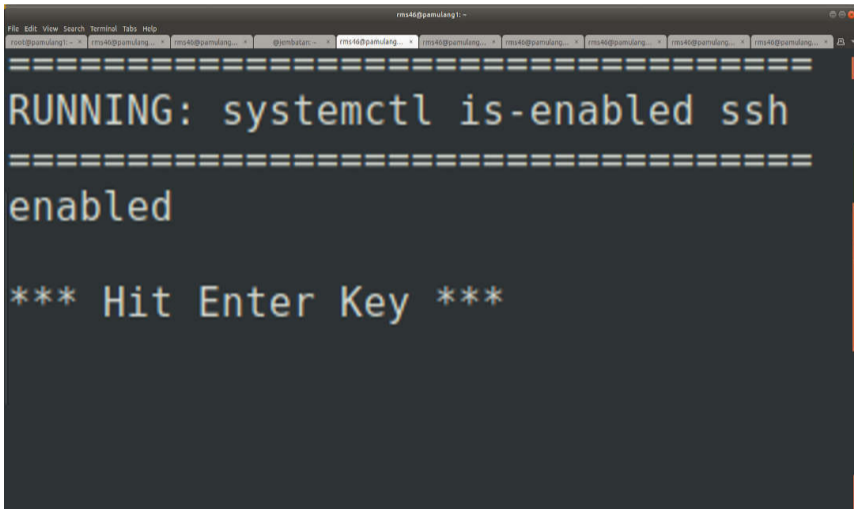
RUNNING: systemctl status ssh.service

```
=====
```

- 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



```
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 is-enabled ssh  
=====  
enabled  
  
*** Hit Enter Key ***
```

Figure: systemctl is-enabled ssh