OPERATING SYSTEMS PROJECT 2023

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PROBLEM STATEMENT:

Write a kernel module that lists all current tasks in a Linux system beginning from the **init** task. Refer to Chapter 2 in the text book (T1) for creating Linux kernel modules. Output the task name (known as executable name), state and process id of each task in a **tree** structure

SOLUTION:

1. Installing Linux Kernel Headers

To compile the kernel code ,linux headers which can be installed using following command

Install the kernel header files (already present in ubuntu)
(I used the first command)
1) sudo apt-get install linux-headers-$(uname -r) (If you are using apt)
2) sudo dnf install kernel-headers-$(uname -r) (If you are using dnf)

Installing Linux Headers

```
nagavenigowda@ubuntu-1:~$ su -
Password:
root@ubuntu-1:~# sudo apt-get install linux-headers-$(uname -r)
Reading package lists... Done
Building dependency tree... Done
Reading state information... Done
linux-headers-5.19.0-35-generic is already the newest version (5.19.0-35.36~22.04.1).
linux-headers-5.19.0-35-generic set to manually installed.
The following packages were automatically installed and are no longer required:
  libflashrom1 libftdi1-2 libllvm13 linux-headers-5.15.0-60
  linux-headers-5.15.0-60-generic linux-image-5.15.0-60-generic
  linux-modules-5.15.0-60-generic linux-modules-extra-5.15.0-60-generic
Use 'sudo apt autoremove' to remove them.
0 upgraded, 0 newly installed, 0 to remove and 60 not upgraded.
root@ubuntu-1:~#
```

Installing make

```
root@ubuntu-1:~# sudo apt install make
Reading package lists... Done
Building dependency tree... Done
Reading state information... Done
make is already the newest version (4.3-4.1build1).
make set to manually installed.
The following packages were automatically installed and are no longer required:
  libflashrom1 libftdi1-2 libllvm13 linux-headers-5.15.0-60 linux-headers-5.15.0-60-generic
  linux-image-5.15.0-60-generic linux-modules-5.15.0-60-generic
  linux-modules-extra-5.15.0-60-generic
Use 'sudo apt autoremove' to remove them.
0 upgraded, 0 newly installed, 0 to remove and 60 not upgraded.
root@ubuntu-1:~# make --version
GNU Make 4.3
Built for x86_64-pc-linux-gnu
Copyright (C) 1988-2020 Free Software Foundation, Inc.
License GPLv3+: GNU GPL version 3 or later <http://gnu.org/licenses/gpl.html>
This is free software: you are free to change and redistribute it.
There is NO WARRANTY, to the extent permitted by law.
root@ubuntu-1:~# ls /usr/bin/make
/usr/bin/make
```

Installing build -essential---command is a package of essential tools and utilities that are required for building and compiling software

```
root@ubuntu-1:~# sudo apt install build-essential
Reading package lists... Done
Building dependency tree... Done
Reading state information... Done
build-essential is already the newest version (12.9ubuntu3).
The following packages were automatically installed and are no longer required:
  libflashrom1 libftdi1-2 libllvm13
Use 'sudo apt autoremove' to remove them.
0 upgraded, 0 newly installed, 0 to remove and 49 not upgraded.
root@ubuntu-1:~# dpkg -s build-essential
Package: build-essential
Status: install ok installed
Priority: optional
Section: devel
Installed-Size: 21
Maintainer: Ubuntu Developers <ubuntu-devel-discuss@lists.ubuntu.com>
Architecture: amd64
Version: 12.9ubuntu3
Depends: libc6-dev | libc-dev, gcc (>= 4:10.2), g++ (>= 4:10.2), make, dpkg-dev (>= 1.17.11)
Description: Informational list of build-essential packages
 If you do not plan to build Debian packages, you don't need this
 package.  Starting with dpkg (>= 1.14.18) this package is required
 for building Debian packages.
 .
 This package contains an informational list of packages which are
 considered essential for building Debian packages.  This package also
 depends on the packages on that list, to make it easy to have the
 build-essential packages installed.
 .
 If you have this package installed, you only need to install whatever
 a package specifies as its build-time dependencies to build the
 package.  Conversely, if you are determining what your package needs
 to build-depend on, you can always leave out the packages this
 package depends on.
 .
 This package is NOT the definition of what packages are
 build-essential; the real definition is in the Debian Policy Manual.
 This package contains merely an informational list, which is all
 most people need.   However, if this package and the manual disagree,
 the manual is correct.
Original-Maintainer: Matthias Klose <doko@debian.org>
root@ubuntu-1:~#
```
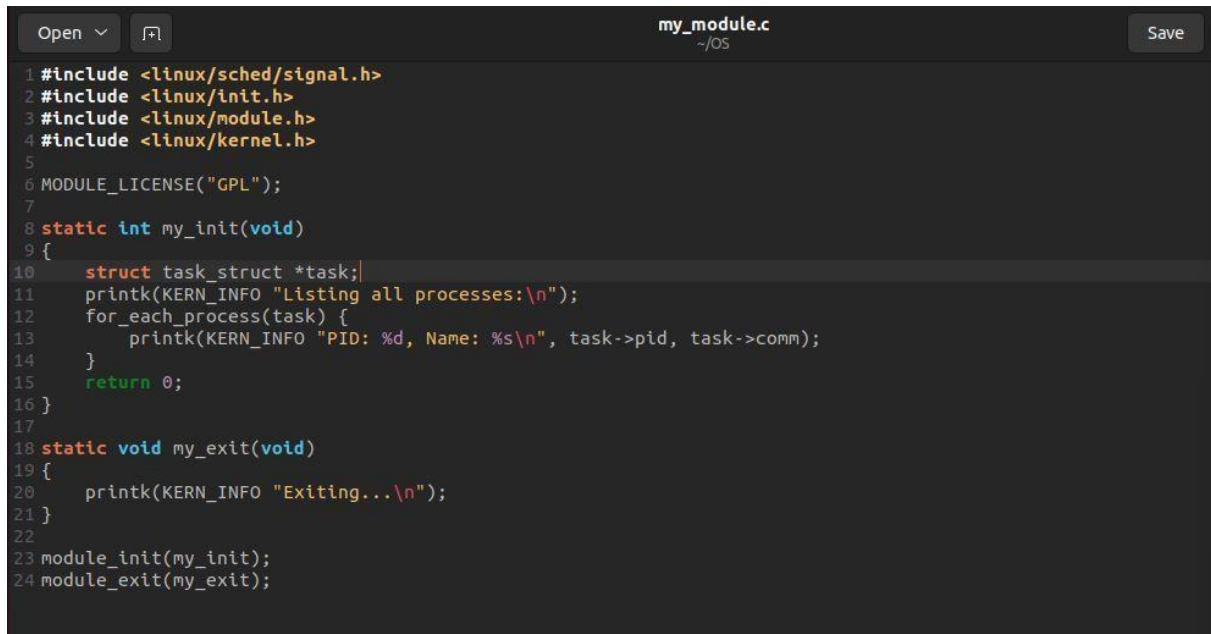
2.Creating a Makefile

mkdir OS
cd OS
make : compile kernel code using this command

```
nagavenigowda@ubuntu-1:~$ mkdir OS
nagavenigowda@ubuntu-1:~$ cd OS
nagavenigowda@ubuntu-1:~/OS$
nagavenigowda@ubuntu-1:~/OS$
nagavenigowda@ubuntu-1:~/OS$
nagavenigowda@ubuntu-1:~/OS$
nagavenigowda@ubuntu-1:~/OS$
nagavenigowda@ubuntu-1:~/OS$
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nagavenigowda@ubuntu-1:~/OS$
nagavenigowda@ubuntu-1:~/OS$
nagavenigowda@ubuntu-1:~/OS$
nagavenigowda@ubuntu-1:~/OS$
nagavenigowda@ubuntu-1:~/OS$
nagavenigowda@ubuntu-1:~/OS$
nagavenigowda@ubuntu-1:~/OS$ gedit my_module.c
nagavenigowda@ubuntu-1:~/OS$ gedit Makefile
nagavenigowda@ubuntu-1:~/OS$ make
make -C /lib/modules/5.19.0-35-generic/build M=/home/nagavenigowda/OS modules
make[1]: Entering directory '/usr/src/linux-headers-5.19.0-35-generic'
warning: the compiler differs from the one used to build the kernel
  The kernel was built by: x86_64-linux-gnu-gcc (Ubuntu 11.3.0-1ubuntu1~22.04) 11.3.0
  You are using:           gcc (Ubuntu 11.3.0-1ubuntu1~22.04) 11.3.0
  CC [M]  /home/nagavenigowda/OS/my_module.o
  MODPOST /home/nagavenigowda/OS/Module.symvers
  CC [M]  /home/nagavenigowda/OS/my_module.mod.o
  LD [M]  /home/nagavenigowda/OS/my_module.ko
  BTF [M] /home/nagavenigowda/OS/my_module.ko
Skipping BTF generation for /home/nagavenigowda/OS/my_module.ko due to unavailability of vmlinux
make[1]: Leaving directory '/usr/src/linux-headers-5.19.0-35-generic'
nagavenigowda@ubuntu-1:~/OS$
```
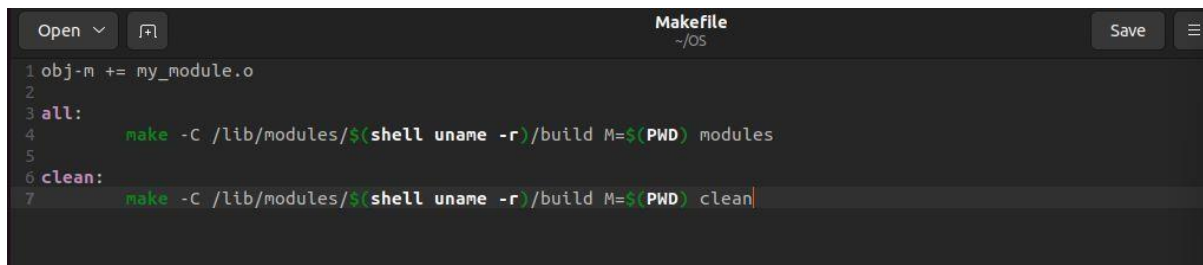
3. Write Some Code

gedit my_module.c

```c
1  #include <linux/sched/signal.h>
2  #include <linux/init.h>
3  #include <linux/module.h>
4  #include <linux/kernel.h>
5
6  MODULE_LICENSE("GPL");
7
8  static int my_init(void)
9  {
10     struct task_struct *task;
11     printk(KERN_INFO "Listing all processes:\n");
12     for_each_process(task) {
13         printk(KERN_INFO "PID: %d, Name: %s\n", task->pid, task->comm);
14     }
15     return 0;
16 }
17
18 static void my_exit(void)
19 {
20     printk(KERN_INFO "Exiting...\n");
21 }
22
23 module_init(my_init);
24 module_exit(my_exit);
```
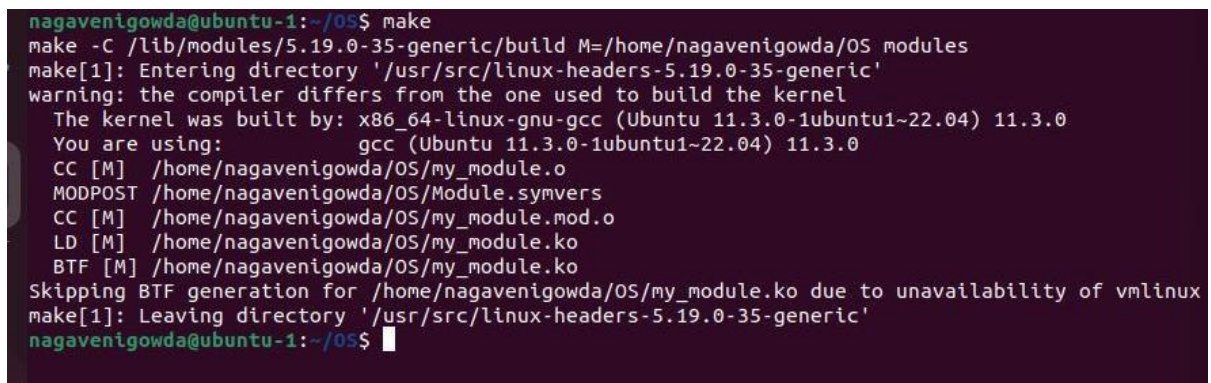
gedit Makefile

```makefile
1  obj-m += my_module.o
2
3  all:
4          make -C /lib/modules/$(shell uname -r)/build M=$(PWD) modules
5
6  clean:
7          make -C /lib/modules/$(shell uname -r)/build M=$(PWD) clean
```
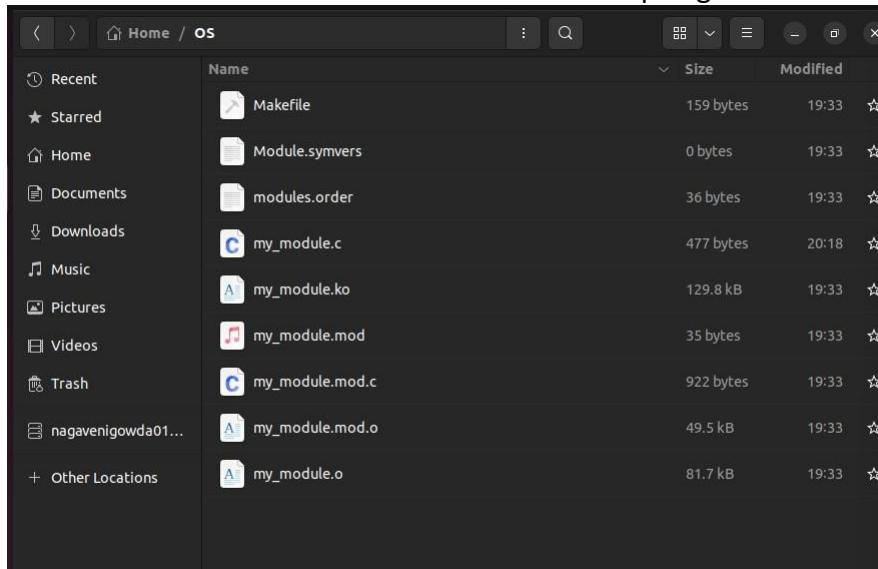
4 .Compile The Code
make

```
nagavenigowda@ubuntu-1:~/OS$ make
make -C /lib/modules/5.19.0-35-generic/build M=/home/nagavenigowda/OS modules
make[1]: Entering directory '/usr/src/linux-headers-5.19.0-35-generic'
warning: the compiler differs from the one used to build the kernel
  The kernel was built by: x86_64-linux-gnu-gcc (Ubuntu 11.3.0-1ubuntu1~22.04) 11.3.0
  You are using:           gcc (Ubuntu 11.3.0-1ubuntu1~22.04) 11.3.0
  CC [M]  /home/nagavenigowda/OS/my_module.o
  MODPOST /home/nagavenigowda/OS/Module.symvers
  CC [M]  /home/nagavenigowda/OS/my_module.mod.o
  LD [M]  /home/nagavenigowda/OS/my_module.ko
  BTF [M] /home/nagavenigowda/OS/my_module.ko
Skipping BTF generation for /home/nagavenigowda/OS/my_module.ko due to unavailability of vmlinux
make[1]: Leaving directory '/usr/src/linux-headers-5.19.0-35-generic'
nagavenigowda@ubuntu-1:~/OS$
```
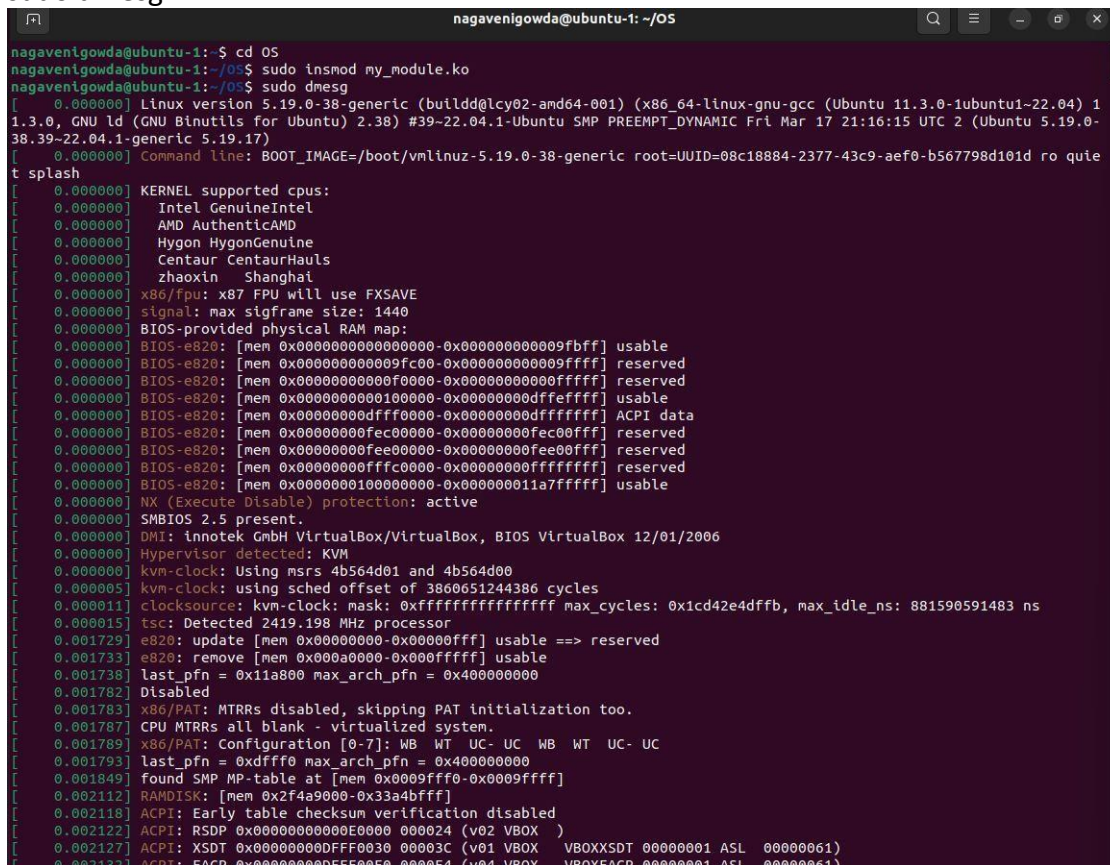
5. Screenshot of files which are created after compiling the code

6. Loading The Kernel Module

sudo insmod my_module.ko
sudo dmesg

```
[    0.002148] ACPI: SSDT 0x00000000DFFF02B0 00036C (v01 VBOX   VBOXCPUT 00000002 INTL 20100528)
[    0.002150] ACPI: Reserving FACP table memory at [mem 0xdfff00f0-0xdfff01e3]
[    0.002151] ACPI: Reserving DSDT table memory at [mem 0xdfff0620-0xdfff2972]
[    0.002151] ACPI: Reserving FACS table memory at [mem 0xdfff0200-0xdfff023f]
[    0.002152] ACPI: Reserving FACS table memory at [mem 0xdfff0200-0xdfff023f]
[    0.002153] ACPI: Reserving APIC table memory at [mem 0xdfff0240-0xdfff02ab]
[    0.002153] ACPI: Reserving SSDT table memory at [mem 0xdfff02b0-0xdfff061b]
[    0.003084] No NUMA configuration found
[    0.003085] Faking a node at [mem 0x0000000000000000-0x000000011a7fffff]
[    0.003091] NODE_DATA(0) allocated [mem 0x11a7d3000-0x11a7fdfff]
[    0.003813] Zone ranges:
[    0.003814]   DMA      [mem 0x0000000000001000-0x0000000000ffffff]
[    0.003816]   DMA32    [mem 0x0000000001000000-0x00000000ffffffff]
[    0.003817]   Normal   [mem 0x0000000100000000-0x000000011a7fffff]
[    0.003818]   Device   empty
[    0.003818] Movable zone start for each node
[    0.003820] Early memory node ranges
[    0.003820]   node   0: [mem 0x0000000000001000-0x000000000009efff]
[    0.003821]   node   0: [mem 0x0000000000100000-0x00000000dffeffff]
[    0.003822]   node   0: [mem 0x0000000100000000-0x000000011a7fffff]
[    0.003823] Initmem setup node 0 [mem 0x0000000000001000-0x000000011a7fffff]
[    0.003857] On node 0, zone DMA: 1 pages in unavailable ranges
[    0.004476] On node 0, zone DMA: 97 pages in unavailable ranges
[    0.169736] On node 0, zone Normal: 16 pages in unavailable ranges
[    0.173375] On node 0, zone Normal: 22528 pages in unavailable ranges
[    0.175014] ACPI: PM-Timer IO Port: 0x4008
[    0.175262] IOAPIC[0]: apic_id 4, version 32, address 0xfec00000, GSI 0-23
[    0.175267] ACPI: INT_SRC_OVR (bus 0 bus_irq 0 global_irq 2 dfl dfl)
[    0.175268] ACPI: INT_SRC_OVR (bus 0 bus_irq 9 global_irq 9 low level)
[    0.175273] ACPI: Using ACPI (MADT) for SMP configuration information
[    0.175298] smpboot: Allowing 4 CPUs, 0 hotplug CPUs
[    0.175384] PM: hibernation: Registered nosave memory: [mem 0x00000000-0x00000fff]
[    0.175386] PM: hibernation: Registered nosave memory: [mem 0x0009f000-0x0009ffff]
[    0.175387] PM: hibernation: Registered nosave memory: [mem 0x000a0000-0x000effff]
[    0.175388] PM: hibernation: Registered nosave memory: [mem 0x000f0000-0x000fffff]
[    0.175389] PM: hibernation: Registered nosave memory: [mem 0xdfff0000-0xdfffffff]
[    0.175390] PM: hibernation: Registered nosave memory: [mem 0xe0000000-0xfebfffff]
[    0.175391] PM: hibernation: Registered nosave memory: [mem 0xfec00000-0xfec00fff]
[    0.175392] PM: hibernation: Registered nosave memory: [mem 0xfec01000-0xfedfffff]
[    0.175392] PM: hibernation: Registered nosave memory: [mem 0xfee00000-0xfee00fff]
[    0.175393] PM: hibernation: Registered nosave memory: [mem 0xfee01000-0xfffbffff]
[    0.175394] PM: hibernation: Registered nosave memory: [mem 0xfffc0000-0xffffffff]
[    0.175395] [mem 0xe0000000-0xfebfffff] available for PCI devices
[    0.175396] Booting paravirtualized kernel on KVM
[    0.175399] clocksource: refined-jiffies: mask: 0xffffffff max_cycles: 0xffffffff, max_idle_ns: 7645519600211!
[    0.175408] setup_percpu: NR_CPUS:8192 nr_cpumask_bits:4 nr_cpu_ids:4 nr_node_ids:1
[    0.180809] percpu: Embedded 61 pages/cpu s212992 r8192 d28672 u524288
```

```
[    0.180910] PV qspinlock hash table entries: 256 (order: 0, 4096 bytes, linear)
[    0.180920] Fallback order for Node 0: 0
[    0.180923] Built 1 zonelists, mobility grouping on.  Total pages: 1009744
[    0.180924] Policy zone: Normal
[    0.180925] Kernel command line: BOOT_IMAGE=/boot/vmlinuz-5.19.0-38-generic root=UUID=08c18884-2377-43c9-aef0-
ro quiet splash
[    0.180975] Unknown kernel command line parameters "splash BOOT_IMAGE=/boot/vmlinuz-5.19.0-38-generic", will b
ser space.
[    0.191526] Dentry cache hash table entries: 524288 (order: 10, 4194304 bytes, linear)
[    0.197318] Inode-cache hash table entries: 262144 (order: 9, 2097152 bytes, linear)
[    0.197415] mem auto-init: stack:off, heap alloc:on, heap free:off
[    0.301574] Memory: 3847216K/4103736K available (18440K kernel code, 4050K rwdata, 11292K rodata, 3168K init,
6260K reserved, 0K cma-reserved)
[    0.303371] SLUB: HWalign=64, Order=0-3, MinObjects=0, CPUs=4, Nodes=1
[    0.303465] ftrace: allocating 52179 entries in 204 pages
[    0.312932] ftrace: allocated 204 pages with 4 groups
[    0.314490] Dynamic Preempt: voluntary
[    0.314652] rcu: Preemptible hierarchical RCU implementation.
[    0.314653] rcu:     RCU restricting CPUs from NR_CPUS=8192 to nr_cpu_ids=4.
[    0.314655]   Trampoline variant of Tasks RCU enabled.
[    0.314655]   Rude variant of Tasks RCU enabled.
[    0.314655]   Tracing variant of Tasks RCU enabled.
[    0.314656] rcu: RCU calculated value of scheduler-enlistment delay is 25 jiffies.
[    0.314657] rcu: Adjusting geometry for rcu_fanout_leaf=16, nr_cpu_ids=4
[    0.320089] NR_IRQS: 524544, nr_irqs: 456, preallocated irqs: 16
[    0.320450] rcu: srcu_init: Setting srcu_struct sizes based on contention.
[    0.320704] random: crng init done
[    0.358829] Console: colour VGA+ 80x25
[    0.358847] printk: console [tty0] enabled
[    0.358938] ACPI: Core revision 20220331
[    0.360294] APIC: Switch to symmetric I/O mode setup
[    0.372468] ..TIMER: vector=0x30 apic1=0 pin1=2 apic2=-1 pin2=-1
[    0.372645] clocksource: tsc-early: mask: 0xffffffffffffffff max_cycles: 0x22df0f35937, max_idle_ns: 44079526!
[    0.372655] Calibrating delay loop (skipped) preset value.. 4838.39 BogoMIPS (lpj=9676792)
[    0.372657] pid_max: default: 32768 minimum: 301
[    0.372694] LSM: Security Framework initializing
[    0.372704] landlock: Up and running.
[    0.372704] Yama: becoming mindful.
[    0.372815] AppArmor: AppArmor initialized
[    0.373016] Mount-cache hash table entries: 8192 (order: 4, 65536 bytes, linear)
[    0.373180] Mountpoint-cache hash table entries: 8192 (order: 4, 65536 bytes, linear)
[    0.381489] Last level iTLB entries: 4KB 0, 2MB 0, 4MB 0
[    0.381492] Last level dTLB entries: 4KB 0, 2MB 0, 4MB 0, 1GB 0
[    0.381498] Spectre V1 : Mitigation: usercopy/swapgs barriers and __user pointer sanitization
[    0.381501] Spectre V2 : Mitigation: Enhanced IBRS
[    0.381501] Spectre V2 : Spectre v2 / SpectreRSB mitigation: Filling RSB on context switch
[    0.381502] Spectre V2 : Spectre v2 / PBRSB-eIBRS: Retire a single CALL on VMEXIT
```

```
[    0.381501] Spectre V2 : Spectre v2 / SpectreRSB mitigation: Filling RSB on context switch
[    0.381502] Spectre V2 : Spectre v2 / PBRSB-eIBRS: Retire a single CALL on VMEXIT
[    0.381503] RETBleed: Mitigation: Enhanced IBRS
[    0.381504] Speculative Store Bypass: Vulnerable
[    0.416868] Freeing SMP alternatives memory: 44K
[    0.548651] APIC calibration not consistent with PM-Timer: 115ms instead of 100ms
[    0.548656] APIC delta adjusted to PM-Timer: 6250366 (7250414)
[    0.548946] smpboot: CPU0: 11th Gen Intel(R) Core(TM) i5-1135G7 @ 2.40GHz (family: 0x6, model: 0x8c, stepping:
[    0.549531] cblist_init_generic: Setting adjustable number of callback queues.
[    0.549534] cblist_init_generic: Setting shift to 2 and lim to 1.
[    0.549668] cblist_init_generic: Setting shift to 2 and lim to 1.
[    0.549719] cblist_init_generic: Setting shift to 2 and lim to 1.
[    0.549770] Performance Events: unsupported p6 CPU model 140 no PMU driver, software events only.
[    0.549841] rcu: Hierarchical SRCU implementation.
[    0.549842] rcu:     Max phase no-delay instances is 1000.
[    0.550647] NMI watchdog: Perf NMI watchdog permanently disabled
[    0.551056] smp: Bringing up secondary CPUs ...
[    0.551567] x86: Booting SMP configuration:
[    0.551569] .... node  #0, CPUs:       #1
[    0.555926] TSC synchronization [CPU#0 -> CPU#1]:
[    0.555929] Measured 38237 cycles TSC warp between CPUs, turning off TSC clock.
[    0.555930] tsc: Marking TSC unstable due to check_tsc_sync_source failed
[    0.564659]  #2 #3
[    0.592965] smp: Brought up 1 node, 4 CPUs
[    0.592972] smpboot: Max logical packages: 1
[    0.592974] smpboot: Total of 4 processors activated (19353.58 BogoMIPS)
[    0.596811] devtmpfs: initialized
[    0.596811] x86/mm: Memory block size: 128MB
[    0.604754] clocksource: jiffies: mask: 0xffffffff max_cycles: 0xffffffff, max_idle_ns: 7645041785100000 ns
[    0.604937] futex hash table entries: 1024 (order: 4, 65536 bytes, linear)
[    0.604998] pinctrl core: initialized pinctrl subsystem
[    0.605437] PM: RTC time: 14:21:04, date: 2023-04-13
[    0.621154] NET: Registered PF_NETLINK/PF_ROUTE protocol family
[    0.621239] DMA: preallocated 512 KiB GFP_KERNEL pool for atomic allocations
[    0.621296] DMA: preallocated 512 KiB GFP_KERNEL|GFP_DMA pool for atomic allocations
[    0.621332] DMA: preallocated 512 KiB GFP_KERNEL|GFP_DMA32 pool for atomic allocations
[    0.621342] audit: initializing netlink subsys (disabled)
[    0.621467] audit: type=2000 audit(1681399530.067:1): state=initialized audit_enabled=0 res=1
[    0.621467] thermal_sys: Registered thermal governor 'fair_share'
[    0.621467] thermal_sys: Registered thermal governor 'bang_bang'
[    0.621467] thermal_sys: Registered thermal governor 'step_wise'
[    0.621467] thermal_sys: Registered thermal governor 'user_space'
[    0.621467] thermal_sys: Registered thermal governor 'power_allocator'
[    0.621467] EISA bus registered
[    0.621467] cpuidle: using governor ladder
[    0.621467] cpuidle: using governor menu
[    0.621467] acpiphp: ACPI Hot Plug PCI Controller Driver version: 0.5
```

```
[    0.621332] DMA: preallocated 512 KiB GFP_KERNEL|GFP_DMA32 pool for atomic allocations
[    0.621342] audit: initializing netlink subsys (disabled)
[    0.621467] audit: type=2000 audit(1681399530.067:1): state=initialized audit_enabled=0 res=1
[    0.621467] thermal_sys: Registered thermal governor 'fair_share'
[    0.621467] thermal_sys: Registered thermal governor 'bang_bang'
[    0.621467] thermal_sys: Registered thermal governor 'step_wise'
[    0.621467] thermal_sys: Registered thermal governor 'user_space'
[    0.621467] thermal_sys: Registered thermal governor 'power_allocator'
[    0.621467] EISA bus registered
[    0.621467] cpuidle: using governor ladder
[    0.621467] cpuidle: using governor menu
[    0.621467] acpiphp: ACPI Hot Plug PCI Controller Driver version: 0.5
[    0.621467] PCI: Using configuration type 1 for base access
[    0.629731] kprobes: kprobe jump-optimization is enabled. All kprobes are optimized if possible.
[    0.676767] HugeTLB: can optimize 7 vmemmap pages for hugepages-2048kB
[    0.676772] HugeTLB registered 2.00 MiB page size, pre-allocated 0 pages
[    0.688881] ACPI: Added _OSI(Module Device)
[    0.688881] ACPI: Added _OSI(Processor Device)
[    0.688881] ACPI: Added _OSI(3.0 _SCP Extensions)
[    0.688881] ACPI: Added _OSI(Processor Aggregator Device)
[    0.688881] ACPI: Added _OSI(Linux-Dell-Video)
[    0.688881] ACPI: Added _OSI(Linux-Lenovo-NV-HDMI-Audio)
[    0.688881] ACPI: Added _OSI(Linux-HPI-Hybrid-Graphics)
[    0.697331] ACPI: 2 ACPI AML tables successfully acquired and loaded
[    0.704876] ACPI: Interpreter enabled
[    0.704884] ACPI: PM: (supports S0 S5)
[    0.704886] ACPI: Using IOAPIC for interrupt routing
[    0.705211] PCI: Using host bridge windows from ACPI; if necessary, use "pci=nocrs" and report a bug
[    0.705212] PCI: Using E820 reservations for host bridge windows
[    0.705318] ACPI: Enabled 2 GPEs in block 00 to 07
[    0.724993] ACPI: PCI Root Bridge [PCI0] (domain 0000 [bus 00-ff])
[    0.725000] acpi PNP0A03:00: _OSC: OS supports [ASPM ClockPM Segments MSI EDR HPX-Type3]
[    0.725002] acpi PNP0A03:00: _OSC: not requesting OS control; OS requires [ExtendedConfig ASPM ClockPM MSI]
[    0.728698] acpi PNP0A03:00: fail to add MMCONFIG information, can't access extended PCI configuration space u
dge.
[    0.729245] PCI host bridge to bus 0000:00
[    0.729247] pci_bus 0000:00: root bus resource [io  0x0000-0x0cf7 window]
[    0.729249] pci_bus 0000:00: root bus resource [io  0x0d00-0xffff window]
[    0.729250] pci_bus 0000:00: root bus resource [mem 0x000a0000-0x000bffff window]
[    0.729251] pci_bus 0000:00: root bus resource [mem 0xe0000000-0xfdffffff window]
[    0.729252] pci_bus 0000:00: root bus resource [bus 00-ff]
[    0.729574] pci 0000:00:00.0: [8086:1237] type 00 class 0x060000
[    0.732907] pci 0000:00:01.0: [8086:7000] type 00 class 0x060100
[    0.734415] pci 0000:00:01.1: [8086:7111] type 00 class 0x01018a
[    0.736871] pci 0000:00:01.1: reg 0x20: [io  0xd000-0xd00f]
[    0.737240] pci 0000:00:01.1: legacy IDE quirk: reg 0x10: [io  0x01f0-0x01f7]
[    0.737242] pci 0000:00:01.1: legacy IDE quirk: reg 0x14: [io  0x03f6]
```

```
[    0.741691] pci 0000:00:02.0: reg 0x10: [io  0xd010-0xd01f]
[    0.744653] pci 0000:00:02.0: reg 0x14: [mem 0xe0000000-0xe0ffffff pref]
[    0.748652] pci 0000:00:02.0: reg 0x18: [mem 0xf0000000-0xf01fffff]
[    0.757143] pci 0000:00:02.0: Video device with shadowed ROM at [mem 0x000c0000-0x000dffff]
[    0.757625] pci 0000:00:03.0: [8086:100e] type 00 class 0x020000
[    0.760652] pci 0000:00:03.0: reg 0x10: [mem 0xf0200000-0xf021ffff]
[    0.761015] pci 0000:00:03.0: reg 0x18: [io  0xd020-0xd027]
[    0.765200] pci 0000:00:04.0: [80ee:cafe] type 00 class 0x088000
[    0.768652] pci 0000:00:04.0: reg 0x10: [io  0xd040-0xd05f]
[    0.769056] pci 0000:00:04.0: reg 0x14: [mem 0xf0400000-0xf07fffff]
[    0.769493] pci 0000:00:04.0: reg 0x18: [mem 0xf0800000-0xf0803fff pref]
[    0.774014] pci 0000:00:05.0: [8086:2415] type 00 class 0x040100
[    0.774311] pci 0000:00:05.0: reg 0x10: [io  0xd100-0xd1ff]
[    0.776738] pci 0000:00:05.0: reg 0x14: [io  0xd200-0xd23f]
[    0.777901] pci 0000:00:06.0: [106b:003f] type 00 class 0x0c0310
[    0.778227] pci 0000:00:06.0: reg 0x10: [mem 0xf0804000-0xf0804fff]
[    0.782072] pci 0000:00:07.0: [8086:7113] type 00 class 0x068000
[    0.785310] pci 0000:00:07.0: quirk: [io  0x4000-0x403f] claimed by PIIX4 ACPI
[    0.785334] pci 0000:00:07.0: quirk: [io  0x4100-0x410f] claimed by PIIX4 SMB
[    0.812936] pci 0000:00:0b.0: [8086:265c] type 00 class 0x0c0320
[    0.813275] pci 0000:00:0b.0: reg 0x10: [mem 0xf0805000-0xf0805fff]
[    0.824652] pci 0000:00:0d.0: [8086:2829] type 00 class 0x010601
[    0.824972] pci 0000:00:0d.0: reg 0x10: [io  0xd240-0xd247]
[    0.825150] pci 0000:00:0d.0: reg 0x14: [io  0xd248-0xd24b]
[    0.825337] pci 0000:00:0d.0: reg 0x18: [io  0xd250-0xd257]
[    0.825513] pci 0000:00:0d.0: reg 0x1c: [io  0xd258-0xd25b]
[    0.825688] pci 0000:00:0d.0: reg 0x20: [io  0xd260-0xd26f]
[    0.825862] pci 0000:00:0d.0: reg 0x24: [mem 0xf0806000-0xf0807fff]
[    0.977095] ACPI: PCI: Interrupt link LNKA configured for IRQ 11
[    0.977555] ACPI: PCI: Interrupt link LNKB configured for IRQ 10
[    0.980674] ACPI: PCI: Interrupt link LNKC configured for IRQ 9
[    0.980846] ACPI: PCI: Interrupt link LNKD configured for IRQ 11
[    0.981111] iommu: Default domain type: Translated
[    0.981111] iommu: DMA domain TLB invalidation policy: lazy mode
[    0.981111] SCSI subsystem initialized
[    0.984768] libata version 3.00 loaded.
[    0.984806] ACPI: bus type USB registered
[    0.984822] usbcore: registered new interface driver usbfs
[    0.984826] usbcore: registered new interface driver hub
[    0.984831] usbcore: registered new device driver usb
[    0.984846] pps_core: LinuxPPS API ver. 1 registered
[    0.984847] pps_core: Software ver. 5.3.6 - Copyright 2005-2007 Rodolfo Giometti <giometti@linux.it>
[    0.984849] PTP clock support registered
[    0.988910] EDAC MC: Ver: 3.0.0
[    0.992894] NetLabel: Initializing
[    0.992894] NetLabel:  domain hash size = 128
[    0.992894] NetLabel:  protocols = UNLABELED CIPSOv4 CALIPSO
```

```
[    0.997116] pci 0000:00:02.0: vgaarb: setting as boot VGA device
[    0.997116] pci 0000:00:02.0: vgaarb: bridge control possible
[    0.997116] pci 0000:00:02.0: vgaarb: VGA device added: decodes=io+mem,owns=io+mem,locks=none
[    0.997116] vgaarb: loaded
[    1.005712] clocksource: Switched to clocksource kvm-clock
[    1.043726] VFS: Disk quotas dquot_6.6.0
[    1.043867] VFS: Dquot-cache hash table entries: 512 (order 0, 4096 bytes)
[    1.044134] AppArmor: AppArmor Filesystem Enabled
[    1.044156] pnp: PnP ACPI init
[    1.045568] pnp: PnP ACPI: found 2 devices
[    1.052398] clocksource: acpi_pm: mask: 0xffffff max_cycles: 0xffffff, max_idle_ns: 2085701024 ns
[    1.052540] NET: Registered PF_INET protocol family
[    1.054197] IP idents hash table entries: 65536 (order: 7, 524288 bytes, linear)
[    1.058610] tcp_listen_portaddr_hash hash table entries: 2048 (order: 3, 32768 bytes, linear)
[    1.059292] Table-perturb hash table entries: 65536 (order: 6, 262144 bytes, linear)
[    1.059981] TCP established hash table entries: 32768 (order: 6, 262144 bytes, linear)
[    1.061381] TCP bind hash table entries: 32768 (order: 7, 524288 bytes, linear)
[    1.061405] TCP: Hash tables configured (established 32768 bind 32768)
[    1.061589] MPTCP token hash table entries: 4096 (order: 4, 98304 bytes, linear)
[    1.061589] UDP hash table entries: 2048 (order: 4, 65536 bytes, linear)
[    1.061589] UDP-Lite hash table entries: 2048 (order: 4, 65536 bytes, linear)
[    1.061589] NET: Registered PF_UNIX/PF_LOCAL protocol family
[    1.061589] NET: Registered PF_XDP protocol family
[    1.061589] pci_bus 0000:00: resource 4 [io  0x0000-0x0cf7 window]
[    1.061589] pci_bus 0000:00: resource 5 [io  0x0d00-0xffff window]
[    1.061589] pci_bus 0000:00: resource 6 [mem 0x000a0000-0x000bffff window]
[    1.061589] pci_bus 0000:00: resource 7 [mem 0xe0000000-0xfdffffff window]
[    1.061589] pci 0000:00:00.0: Limiting direct PCI/PCI transfers
[    1.061589] pci 0000:00:01.0: Activating ISA DMA hang workarounds
[    1.061589] PCI: CLS 0 bytes, default 64
[    1.061589] PCI-DMA: Using software bounce buffering for IO (SWIOTLB)
[    1.061589] software IO TLB: mapped [mem 0x00000000dbff0000-0x00000000dfff0000] (64MB)
[    1.061589] platform rtc_cmos: registered platform RTC device (no PNP device found)
[    1.069961] Trying to unpack rootfs image as initramfs...
[    1.071178] Initialise system trusted keyrings
[    1.071197] Key type blacklist registered
[    1.071721] workingset: timestamp_bits=36 max_order=20 bucket_order=0
[    1.074797] zbud: loaded
[    1.075455] squashfs: version 4.0 (2009/01/31) Phillip Lougher
[    1.076545] fuse: init (API version 7.36)
[    1.078317] integrity: Platform Keyring initialized
[    1.078320] integrity: Machine keyring initialized
[    1.086134] Key type asymmetric registered
[    1.086139] Asymmetric key parser 'x509' registered
[    2.038301] Freeing initrd memory: 71308K
[    2.047648] alg: self-tests for CTR-KDF (hmac(sha256)) passed
[    2.047769] Block layer SCSI generic (bsg) driver version 0.4 loaded (major 243)
```

```
[    2.068920] scsi host1: ata_piix
[    2.068998] ata1: PATA max UDMA/33 cmd 0x1f0 ctl 0x3f6 bmdma 0xd000 irq 14
[    2.069000] ata2: PATA max UDMA/33 cmd 0x170 ctl 0x376 bmdma 0xd008 irq 15
[    2.069400] tun: Universal TUN/TAP device driver, 1.6
[    2.069431] PPP generic driver version 2.4.2
[    2.069504] VFIO - User Level meta-driver version: 0.3
[    2.070094] ehci_hcd: USB 2.0 'Enhanced' Host Controller (EHCI) Driver
[    2.070098] ehci-pci: EHCI PCI platform driver
[    2.071078] ehci-pci 0000:00:0b.0: EHCI Host Controller
[    2.071083] ehci-pci 0000:00:0b.0: new USB bus registered, assigned bus number 1
[    2.071989] ehci-pci 0000:00:0b.0: irq 19, io mem 0xf0805000
[    2.085361] ehci-pci 0000:00:0b.0: USB 2.0 started, EHCI 1.00
[    2.085482] usb usb1: New USB device found, idVendor=1d6b, idProduct=0002, bcdDevice= 5.19
[    2.085484] usb usb1: New USB device strings: Mfr=3, Product=2, SerialNumber=1
[    2.085485] usb usb1: Product: EHCI Host Controller
[    2.085486] usb usb1: Manufacturer: Linux 5.19.0-38-generic ehci_hcd
[    2.085487] usb usb1: SerialNumber: 0000:00:0b.0
[    2.085608] hub 1-0:1.0: USB hub found
[    2.085613] hub 1-0:1.0: 12 ports detected
[    2.086225] ehci-platform: EHCI generic platform driver
[    2.086237] ohci_hcd: USB 1.1 'Open' Host Controller (OHCI) Driver
[    2.086241] ohci-pci: OHCI PCI platform driver
[    2.087164] ohci-pci 0000:00:06.0: OHCI PCI host controller
[    2.087168] ohci-pci 0000:00:06.0: new USB bus registered, assigned bus number 2
[    2.087519] ohci-pci 0000:00:06.0: irq 22, io mem 0xf0804000
[    2.147469] usb usb2: New USB device found, idVendor=1d6b, idProduct=0001, bcdDevice= 5.19
[    2.147476] usb usb2: New USB device strings: Mfr=3, Product=2, SerialNumber=1
[    2.147478] usb usb2: Product: OHCI PCI host controller
[    2.147479] usb usb2: Manufacturer: Linux 5.19.0-38-generic ohci_hcd
[    2.147481] usb usb2: SerialNumber: 0000:00:06.0
[    2.147653] hub 2-0:1.0: USB hub found
[    2.147717] hub 2-0:1.0: 12 ports detected
[    2.149263] ohci-platform: OHCI generic platform driver
[    2.149278] uhci_hcd: USB Universal Host Controller Interface driver
[    2.149403] i8042: PNP: PS/2 Controller [PNP0303:PS2K,PNP0f03:PS2M] at 0x60,0x64 irq 1,12
[    2.152106] serio: i8042 KBD port at 0x60,0x64 irq 1
[    2.152113] serio: i8042 AUX port at 0x60,0x64 irq 12
[    2.152268] mousedev: PS/2 mouse device common for all mice
[    2.158034] rtc_cmos rtc_cmos: registered as rtc0
[    2.158401] input: AT Translated Set 2 keyboard as /devices/platform/i8042/serio0/input/input2
[    2.158564] rtc_cmos rtc_cmos: setting system clock to 2023-04-13T14:21:05 UTC (1681395665)
[    2.158598] rtc_cmos rtc_cmos: alarms up to one day, 114 bytes nvram
[    2.158609] i2c_dev: i2c /dev entries driver
[    2.158649] device-mapper: core: CONFIG_IMA_DISABLE_HTABLE is disabled. Duplicate IMA measurements will not be
the IMA log.
[    2.158696] device-mapper: uevent: version 1.0.3
[    2.159034] device-mapper: ioctl: 4.47.0-ioctl (2022-07-28) initialised: dm-devel@redhat.com
```

nagavenigowda@ubuntu-1: ~/OS

```
[  694.578647] PID: 2063, Name: gsd-color
[  694.578648] PID: 2065, Name: ibus-daemon
[  694.578649] PID: 2067, Name: gsd-datetime
[  694.578650] PID: 2069, Name: gsd-housekeepin
[  694.578651] PID: 2071, Name: gsd-keyboard
[  694.578652] PID: 2073, Name: gsd-media-keys
[  694.578654] PID: 2082, Name: gsd-power
[  694.578655] PID: 2086, Name: gsd-print-notif
[  694.578656] PID: 2089, Name: gsd-rfkill
[  694.578657] PID: 2100, Name: gnome-software
[  694.578658] PID: 2103, Name: gsd-screensaver
[  694.578659] PID: 2123, Name: gsd-sharing
[  694.578660] PID: 2124, Name: gsd-smartcard
[  694.578661] PID: 2129, Name: gsd-disk-utilit
[  694.578662] PID: 2135, Name: gsd-sound
[  694.578663] PID: 2137, Name: gsd-wacom
[  694.578664] PID: 2139, Name: VBoxClient
[  694.578665] PID: 2140, Name: VBoxClient
[  694.578666] PID: 2156, Name: ibus-dconf
[  694.578667] PID: 2159, Name: ibus-extension-
[  694.578669] PID: 2175, Name: ibus-portal
[  694.578670] PID: 2177, Name: evolution-alarm
[  694.578671] PID: 2204, Name: gsd-printer
[  694.578672] PID: 2214, Name: Xwayland
[  694.578673] PID: 2252, Name: ibus-engine-sim
[  694.578674] PID: 2257, Name: gsd-xsettings
[  694.578675] PID: 2278, Name: gjs
[  694.578677] PID: 2305, Name: fwupd
[  694.578678] PID: 2339, Name: xdg-desktop-por
[  694.578679] PID: 2347, Name: ibus-x11
[  694.578680] PID: 2365, Name: VBoxClient
[  694.578681] PID: 2367, Name: VBoxClient
[  694.578695] PID: 2369, Name: VBoxClient
[  694.578696] PID: 2370, Name: VBoxClient
[  694.578709] PID: 2377, Name: VBoxClient
[  694.578710] PID: 2378, Name: VBoxClient
[  694.578711] PID: 2390, Name: gjs
[  694.578712] PID: 2483, Name: gvfsd-burn
[  694.578713] PID: 2769, Name: update-notifier
[  694.578714] PID: 2949, Name: kworker/u8:2
[  694.578716] PID: 2950, Name: kworker/0:0
[  694.578717] PID: 2969, Name: gnome-terminal-
[  694.578718] PID: 2987, Name: bash
[  694.578719] PID: 2999, Name: sudo
[  694.578720] PID: 3000, Name: sudo
[  694.578721] PID: 3001, Name: insmod
nagavenigowda@ubuntu-1:~/OS$
```

lsmod

```
nagavenigowda@ubuntu-1:~/OS$ lsmod
Module                  Size  Used by
my_module              16384  0
4F_pes2ug21cs315       16384  0
vboxvideo              45056  0
binfmt_misc            24576  1
nls_iso8859_1          16384  1
snd_intel8x0           49152  2
snd_ac97_codec        176128  1 snd_intel8x0
ac97_bus               16384  1 snd_ac97_codec
intel_rapl_msr         20480  0
snd_pcm               155648  2 snd_intel8x0,snd_ac97_codec
intel_rapl_common      40960  1 intel_rapl_msr
snd_seq_midi           20480  0
snd_seq_midi_event     16384  1 snd_seq_midi
snd_rawmidi            45056  1 snd_seq_midi
crct10dif_pclmul       16384  1
ghash_clmulni_intel    16384  0
snd_seq                77824  2 snd_seq_midi,snd_seq_midi_event
aesni_intel           376832  0
snd_seq_device         16384  3 snd_seq,snd_seq_midi,snd_rawmidi
snd_timer              40960  2 snd_seq,snd_pcm
joydev                 32768  0
vboxguest             430080  6
crypto_simd            16384  1 aesni_intel
snd                   114688  11 snd_seq,snd_seq_device,snd_intel8x0,snd_timer,snd_ac97_codec,sn
d_pcm,snd_rawmidi
cryptd                 24576  2 crypto_simd,ghash_clmulni_intel
input_leds             16384  0
soundcore              16384  1 snd
serio_raw              20480  0
mac_hid                16384  0
sch_fq_codel           24576  2
vmwgfx                372736  3
drm_ttm_helper         16384  2 vmwgfx,vboxvideo
ttm                    98304  3 vmwgfx,vboxvideo,drm_ttm_helper
drm_kms_helper        200704  2 vmwgfx,vboxvideo
fb_sys_fops            16384  1 drm_kms_helper
syscopyarea            16384  1 drm_kms_helper
sysfillrect            20480  1 drm_kms_helper
sysimgblt              20480  1 drm_kms_helper
msr                    16384  0
parport_pc             53248  0
```

```
snd_timer              40960  2 snd_seq,snd_pcm
joydev                 32768  0
vboxguest             430080  6
crypto_simd            16384  1 aesni_intel
snd                   114688  11 snd_seq,snd_seq_device,snd_intel8x0,snd_timer,snd_ac97_codec,sn
d_pcm,snd_rawmidi
cryptd                 24576  2 crypto_simd,ghash_clmulni_intel
input_leds             16384  0
soundcore              16384  1 snd
serio_raw              20480  0
mac_hid                16384  0
sch_fq_codel           24576  2
vmwgfx                372736  3
drm_ttm_helper         16384  2 vmwgfx,vboxvideo
ttm                    98304  3 vmwgfx,vboxvideo,drm_ttm_helper
drm_kms_helper        200704  2 vmwgfx,vboxvideo
fb_sys_fops            16384  1 drm_kms_helper
syscopyarea            16384  1 drm_kms_helper
sysfillrect            20480  1 drm_kms_helper
sysimgblt              20480  1 drm_kms_helper
msr                    16384  0
parport_pc             53248  0
ppdev                  24576  0
lp                     28672  0
parport                73728  3 parport_pc,lp,ppdev
ramoops                32768  0
pstore_blk             16384  0
reed_solomon           28672  1 ramoops
drm                   581632  8 vmwgfx,drm_kms_helper,vboxvideo,drm_ttm_helper,ttm
pstore_zone            32768  1 pstore_blk
efi_pstore             16384  0
ip_tables              32768  0
x_tables               57344  1 ip_tables
autofs4                45056  2
hid_generic            16384  0
crc32_pclmul           16384  0
psmouse               180224  0
ahci                   49152  2
libahci                49152  1 ahci
usbhid                 65536  0
e1000                 159744  0
i2c_piix4              32768  0
pata_acpi              16384  0
hid                   159744  2 usbhid,hid_generic
video                  65536  0
```

rmmod

```
nagavenigowda@ubuntu-1:~/OS$ sudo rmmod my_module.ko
nagavenigowda@ubuntu-1:~/OS$ lsmod
Module                    Size  Used by
4F_pes2ug21cs315         16384  0
vboxvideo                45056  0
binfmt_misc              24576  1
nls_iso8859_1            16384  1
snd_intel8x0             49152  2
snd_ac97_codec          176128  1 snd_intel8x0
ac97_bus                 16384  1 snd_ac97_codec
intel_rapl_msr           20480  0
snd_pcm                 155648  2 snd_intel8x0,snd_ac97_codec
intel_rapl_common        40960  1 intel_rapl_msr
snd_seq_midi             20480  0
snd_seq_midi_event       16384  1 snd_seq_midi
snd_rawmidi              45056  1 snd_seq_midi
crct10dif_pclmul         16384  1
ghash_clmulni_intel      16384  0
snd_seq                  77824  2 snd_seq_midi,snd_seq_midi_event
aesni_intel             376832  0
snd_seq_device           16384  3 snd_seq,snd_seq_midi,snd_rawmidi
snd_timer                40960  2 snd_seq,snd_pcm
joydev                   32768  0
vboxguest               430080  6
crypto_simd              16384  1 aesni_intel
snd                     114688  11 snd_seq,snd_seq_device,snd_intel8x0,snd_timer,snd_ac97_codec,sn
d_pcm,snd_rawmidi
cryptd                   24576  2 crypto_simd,ghash_clmulni_intel
input_leds               16384  0
soundcore                16384  1 snd
serio_raw                20480  0
mac_hid                  16384  0
sch_fq_codel             24576  2
vmwgfx                  372736  3
drm_ttm_helper           16384  2 vmwgfx,vboxvideo
ttm                      98304  3 vmwgfx,vboxvideo,drm_ttm_helper
drm_kms_helper          200704  2 vmwgfx,vboxvideo
fb_sys_fops              16384  1 drm_kms_helper
syscopyarea              16384  1 drm_kms_helper
sysfillrect              20480  1 drm_kms_helper
sysimgblt                20480  1 drm_kms_helper
msr                      16384  0
parport_pc               53248  0
ppdev                    24576  0
lp                       28672  0
parport                  73728  3 parport_pc,lp,ppdev
ramoops                  32768  0
```

```
snd_seq_device          16384   3 snd_seq,snd_seq_midi,snd_rawmidi
snd_timer               40960   2 snd_seq,snd_pcm
joydev                  32768   0
vboxguest               430080  6
crypto_simd             16384   1 aesni_intel
snd                     114688  11 snd_seq,snd_seq_device,snd_intel8x0,snd_timer,snd_ac97_codec,sn
d_pcm,snd_rawmidi
cryptd                  24576   2 crypto_simd,ghash_clmulni_intel
input_leds              16384   0
soundcore               16384   1 snd
serio_raw               20480   0
mac_hid                 16384   0
sch_fq_codel            24576   2
vmwgfx                  372736  3
drm_ttm_helper          16384   2 vmwgfx,vboxvideo
ttm                     98304   3 vmwgfx,vboxvideo,drm_ttm_helper
drm_kms_helper          200704  2 vmwgfx,vboxvideo
fb_sys_fops             16384   1 drm_kms_helper
syscopyarea             16384   1 drm_kms_helper
sysfillrect             20480   1 drm_kms_helper
sysimgblt               20480   1 drm_kms_helper
msr                     16384   0
parport_pc              53248   0
ppdev                   24576   0
lp                      28672   0
parport                 73728   3 parport_pc,lp,ppdev
ramoops                 32768   0
pstore_blk              16384   0
reed_solomon            28672   1 ramoops
drm                     581632  8 vmwgfx,drm_kms_helper,vboxvideo,drm_ttm_helper,ttm
pstore_zone             32768   1 pstore_blk
efi_pstore              16384   0
ip_tables               32768   0
x_tables                57344   1 ip_tables
autofs4                 45056   2
hid_generic             16384   0
crc32_pclmul            16384   0
psmouse                 180224  0
ahci                    49152   2
libahci                 49152   1 ahci
usbhid                  65536   0
e1000                   159744  0
i2c_piix4               32768   0
pata_acpi               16384   0
hid                     159744  2 usbhid,hid_generic
video                   65536   0
nagavenigowda@ubuntu-1:~/OS$
```

THANK YOU 👑