

New York University  
Tandon School of Engineering  
Department of Computer Science and Engineering  
Introduction to Operating Systems  
Fall 2025  
Assignment 3

**Kernel Version:** Linux 6.14.0-32-generic

```
ayushs2k1@ayushs2k1:~/Documents/lab3$ sudo apt-get update
[sudo] password for ayushs2k1:
Hit:1 http://ports.ubuntu.com/ubuntu-ports plucky InRelease
Get:2 http://ports.ubuntu.com/ubuntu-ports plucky-updates InRelease [126 kB]
Get:3 http://ports.ubuntu.com/ubuntu-ports plucky-backports InRelease [126 kB]
Get:4 http://ports.ubuntu.com/ubuntu-ports plucky-security InRelease [126 kB]
Get:5 http://ports.ubuntu.com/ubuntu-ports plucky-updates/main arm64 Packages [394 kB]
Get:6 http://ports.ubuntu.com/ubuntu-ports plucky-updates/main Translation-en [95.1 kB]
Get:7 http://ports.ubuntu.com/ubuntu-ports plucky-updates/main arm64 Components [55.4 kB]
Get:8 http://ports.ubuntu.com/ubuntu-ports plucky-updates/main Icons (48x48) [24.7 kB]
Get:9 http://ports.ubuntu.com/ubuntu-ports plucky-updates/main Icons (64x64) [36.4 kB]
Get:10 http://ports.ubuntu.com/ubuntu-ports plucky-updates/main arm64 c-n-f Metadata [7,720 B]
Get:11 http://ports.ubuntu.com/ubuntu-ports plucky-updates/restricted arm64 Packages [418 kB]
Get:12 http://ports.ubuntu.com/ubuntu-ports plucky-updates/restricted Translation-en [60.1 kB]
Get:13 http://ports.ubuntu.com/ubuntu-ports plucky-updates/restricted arm64 Components [212 B]
Get:14 http://ports.ubuntu.com/ubuntu-ports plucky-updates/universe arm64 Packages [220 kB]
Get:15 http://ports.ubuntu.com/ubuntu-ports plucky-updates/universe Translation-en [70.6 kB]
Get:16 http://ports.ubuntu.com/ubuntu-ports plucky-updates/universe arm64 Components [25.6 kB]
Get:17 http://ports.ubuntu.com/ubuntu-ports plucky-updates/universe arm64 c-n-f Metadata [5,612 B]
Get:18 http://ports.ubuntu.com/ubuntu-ports plucky-updates/multiverse arm64 Components [212 B]
Get:19 http://ports.ubuntu.com/ubuntu-ports plucky-backports/main arm64 Components [212 B]
Get:20 http://ports.ubuntu.com/ubuntu-ports plucky-backports/restricted arm64 Components [216 B]
Get:21 http://ports.ubuntu.com/ubuntu-ports plucky-backports/universe arm64 Packages [3,488 B]
Get:22 http://ports.ubuntu.com/ubuntu-ports plucky-backports/universe Translation-en [1,212 B]
Get:23 http://ports.ubuntu.com/ubuntu-ports plucky-backports/universe arm64 Components [3,120 B]
Get:24 http://ports.ubuntu.com/ubuntu-ports plucky-backports/universe Icons (48x48) [1,865 B]
Get:25 http://ports.ubuntu.com/ubuntu-ports plucky-backports/universe Icons (64x64) [1,829 B]
Get:26 http://ports.ubuntu.com/ubuntu-ports plucky-backports/universe arm64 c-n-f Metadata [176 B]
Get:27 http://ports.ubuntu.com/ubuntu-ports plucky-backports/multiverse arm64 Components [216 B]
Get:28 http://ports.ubuntu.com/ubuntu-ports plucky-security/main arm64 Packages [274 kB]
Get:29 http://ports.ubuntu.com/ubuntu-ports plucky-security/main Translation-en [61.8 kB]
Get:30 http://ports.ubuntu.com/ubuntu-ports plucky-security/main arm64 Components [16.5 kB]
Get:31 http://ports.ubuntu.com/ubuntu-ports plucky-security/main arm64 c-n-f Metadata [4,828 B]
Get:32 http://ports.ubuntu.com/ubuntu-ports plucky-security/restricted arm64 Packages [397 kB]
Get:33 http://ports.ubuntu.com/ubuntu-ports plucky-security/restricted Translation-en [55.4 kB]
Get:34 http://ports.ubuntu.com/ubuntu-ports plucky-security/restricted arm64 Components [212 B]
Get:35 http://ports.ubuntu.com/ubuntu-ports plucky-security/universe arm64 Packages [125 kB]
Get:36 http://ports.ubuntu.com/ubuntu-ports plucky-security/universe Translation-en [44.2 kB]
Get:37 http://ports.ubuntu.com/ubuntu-ports plucky-security/universe arm64 Components [3,680 B]
Get:38 http://ports.ubuntu.com/ubuntu-ports plucky-security/universe arm64 c-n-f Metadata [3,840 B]
Get:39 http://ports.ubuntu.com/ubuntu-ports plucky-security/multiverse arm64 Components [212 B]
Fetched 2,791 kB in 1s (3,632 kB/s)
Reading package lists... Done
ayushs2k1@ayushs2k1:~/Documents/lab3$
```

```
ayushs2k1@ayushs2k1:~/Documents/lab3$ hostnamectl | grep Kernel
Kernel: Linux 6.14.0-33-generic
ayushs2k1@ayushs2k1:~/Documents/lab3$
```

Ensuring we have the necessary kernel headers installed:

```
ayushs2k1@ayushs2k1:~/Documents/lab3$ sudo apt-get install linux-headers-$(uname -r)
[sudo] password for ayushs2k1:
Reading package lists... Done
Building dependency tree... Done
Reading state information... Done
linux-headers-6.14.0-33-generic is already the newest version (6.14.0-33.33).
linux-headers-6.14.0-33-generic set to manually installed.
Solving dependencies... Done
0 upgraded, 0 newly installed, 0 to remove and 2 not upgraded.
ayushs2k1@ayushs2k1:~/Documents/lab3$
```

Current Directory: lab3 and Makefile

```
ayushs2k1@ayushs2k1:~/Documents/lab3$ ls -lrt
total 8
-rw-r--r-- 1 ayushs2k1 ayushs2k1 456 Sep 27 11:13 Makefile
-rw-rw-r-- 1 ayushs2k1 ayushs2k1 2059 Oct  2 19:40 lab3.c
ayushs2k1@ayushs2k1:~/Documents/lab3$
```

Compiling the module using the make command:

```
ayushs2k1@ayushs2k1:~/Documents/lab3$ make
make -C /lib/modules/6.14.0-33-generic/build M=/home/ayushs2k1/Documents/lab3 modules
make[1]: Entering directory '/usr/src/linux-headers-6.14.0-33-generic'
make[2]: Entering directory '/home/ayushs2k1/Documents/lab3'
warning: the compiler differs from the one used to build the kernel
The kernel was built by: aarch64-linux-gnu-gcc-14 (Ubuntu 14.2.0-19ubuntu2) 14.2.0
You are using:          gcc-14 (Ubuntu 14.2.0-19ubuntu2) 14.2.0
CC [M] lab3.o
MODPOST Module.symvers
CC [M] lab3.mod.o
CC [M] .module-common.o
LD [M] lab3.ko
BTF [M] lab3.ko
Skipping BTF generation for lab3.ko due to unavailability of vmlinux
make[2]: Leaving directory '/home/ayushs2k1/Documents/lab3'
make[1]: Leaving directory '/usr/src/linux-headers-6.14.0-33-generic'
```

It compiled with informational warnings, which can be ignored.

After successful compilation, it created files like:

**lab3.o** - The object file compiled from the lab3.c source code.

**lab3.mod** - It lists module information and dependencies.

**lab3.mod.c** - It contains module metadata.

**lab3.mod.o** - The object file compiled from lab3.mod.c. It contains the module metadata in compiled form. It gets linked with lab3.o to create the final lab3.ko file.

**lab3.ko** - This is the kernel object file, which is the final, loadable kernel module.

**modules.order** - Lists the order in which all the modules were built. It is used by the kernel build system for dependency tracking.

**Module.symvers** - It contains symbols used for versioning and resolving dependencies between modules.

```
ayushs2k1@ayushs2k1:~/Documents/lab3$ ls -lrt
total 356
-rw-r--r-- 1 ayushs2k1 ayushs2k1 456 Sep 27 11:13 Makefile
-rw-rw-r-- 1 ayushs2k1 ayushs2k1 2059 Oct 2 19:40 lab3.c
-rw-rw-r-- 1 ayushs2k1 ayushs2k1 20056 Oct 2 19:44 lab3.o
-rw-rw-r-- 1 ayushs2k1 ayushs2k1 9 Oct 2 19:44 lab3.mod
-rw-rw-r-- 1 ayushs2k1 ayushs2k1 7 Oct 2 19:44 modules.order
-rw-rw-r-- 1 ayushs2k1 ayushs2k1 0 Oct 2 19:44 Module.symvers
-rw-rw-r-- 1 ayushs2k1 ayushs2k1 1086 Oct 2 19:44 lab3.mod.c
-rw-rw-r-- 1 ayushs2k1 ayushs2k1 145864 Oct 2 19:44 lab3.mod.o
-rw-rw-r-- 1 ayushs2k1 ayushs2k1 175216 Oct 2 19:44 lab3.ko
ayushs2k1@ayushs2k1:~/Documents/lab3$
```

Clear the kernel logs first, and then load the module. After loading the module using the command `sudo insmod lab3.ko`, waiting, and then unloading the module using the command `sudo rmmod lab3`, we view the output as shown:

```
ayushs2k1@ayushs2k1:~/Documents/lab3$ modinfo lab3.ko
filename:          /home/ayushs2k1/Documents/lab3/lab3.ko
description:       Simple kernel module with timing functionality
author:            Ayush Sharma
license:           Dual BSD/GPL
srcversion:        642A17EB801D4F761F4D221
depends:
name:              lab3
vermagic:          6.14.0-33-generic SMP preempt mod_unload modversions aarch64
ayushs2k1@ayushs2k1:~/Documents/lab3$
```

Net ID: as21108

[illegible]