

OS Assignment #1

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This is the first Operating System Assignment of Spring 2023. Roll Number = K213309, Name = Mohammad Yehya Hayati.

The main command to perform this is:

- **sudo apt install gcc flex bison dwarves libelf-dev build-essential libncurses5-dev libssl-dev**

Here is a screenshot (I performed this prior to any research, and was just blindly following the incomplete/incorrect manual, therefore my work is all over the place):

```
mohammadyehya@K213309: ~$ sudo apt-get install libncurses-dev
Reading package lists... Done
Building dependency tree... Done
Reading state information... Done

The following packages were automatically installed and are no longer required:
chromium-codecs-ffmpeg-extra gstreamer1.0-vadriver intel-media-va-driver libascan libavcodec58 libbluray2 libbz2-1.0 libcdparanoia0 libcodec2-1.0 libdvdnav4 libdvdread2 libebml5 libepoxy0 libfontconfig1 libfreetype6 libgdk-pixbuf2.0 libglvnd0 libgnutls30 libgsm1 libidn2-0 libltdl7 liblua5.1-0 libmariadbclient18 libmp3lame0 libmpeg2encpp libmpeg2-shared libmjpegutils-1.9.0 libnss-systemd libopenal1 libopenexr7 libopenjp2-2 libopenmpt0 libopus0 liborc-0.4-0 librtmp1 librubio2 libserd-0.10-0 libshairt-0.10-0 libslang2 libsndfile1 libsox-filters libsox-libmad libsox-lsb libsox-plugins-a libsox-plugins-base libsox-plugins-es libsox-plugins-gst libsox-plugins-isaac libsox-plugins-jack libsox-plugins-mp3 libsox-plugins-nas libsox-plugins-null libsox-plugins-out libsox-plugins-sdl libsox-plugins-stk libsox-plugins-voicemorph libsox-plugins-xmms libsox-plugins-xml libsox-plugins-zvbi libsox-plugins-zyx libsox-plugins-zyx2 libsox-plugins-zyx3 libsox-plugins-zyx4 libsox-plugins-zyx5 libsox-plugins-zyx6 libsox-plugins-zyx7 libsox-plugins-zyx8 libsox-plugins-zyx9 libsox-plugins-zyx10 libsox-plugins-zyx11 libsox-plugins-zyx12 libsox-plugins-zyx13 libsox-plugins-zyx14 libsox-plugins-zyx15 libsox-plugins-zyx16 libsox-plugins-zyx17 libsox-plugins-zyx18 libsox-plugins-zyx19 libsox-plugins-zyx20 libsox-plugins-zyx21 libsox-plugins-zyx22 libsox-plugins-zyx23 libsox-plugins-zyx24 libsox-plugins-zyx25 libsox-plugins-zyx26 libsox-plugins-zyx27 libsox-plugins-zyx28 libsox-plugins-zyx29 libsox-plugins-zyx30 libsox-plugins-zyx31 libsox-plugins-zyx32 libsox-plugins-zyx33 libsox-plugins-zyx34 libsox-plugins-zyx35 libsox-plugins-zyx36 libsox-plugins-zyx37 libsox-plugins-zyx38 libsox-plugins-zyx39 libsox-plugins-zyx40 libsox-plugins-zyx41 libsox-plugins-zyx42 libsox-plugins-zyx43 libsox-plugins-zyx44 libsox-plugins-zyx45 libsox-plugins-zyx46 libsox-plugins-zyx47 libsox-plugins-zyx48 libsox-plugins-zyx49 libsox-plugins-zyx50 libsox-plugins-zyx51 libsox-plugins-zyx52 libsox-plugins-zyx53 libsox-plugins-zyx54 libsox-plugins-zyx55 libsox-plugins-zyx56 libsox-plugins-zyx57 libsox-plugins-zyx58 libsox-plugins-zyx59 libsox-plugins-zyx60 libsox-plugins-zyx61 libsox-plugins-zyx62 libsox-plugins-zyx63 libsox-plugins-zyx64 libsox-plugins-zyx65 libsox-plugins-zyx66 libsox-plugins-zyx67 libsox-plugins-zyx68 libsox-plugins-zyx69 libsox-plugins-zyx70 libsox-plugins-zyx71 libsox-plugins-zyx72 libsox-plugins-zyx73 libsox-plugins-zyx74 libsox-plugins-zyx75 libsox-plugins-zyx76 libsox-plugins-zyx77 libsox-plugins-zyx78 libsox-plugins-zyx79 libsox-plugins-zyx80 libsox-plugins-zyx81 libsox-plugins-zyx82 libsox-plugins-zyx83 libsox-plugins-zyx84 libsox-plugins-zyx85 libsox-plugins-zyx86 libsox-plugins-zyx87 libsox-plugins-zyx88 libsox-plugins-zyx89 libsox-plugins-zyx90 libsox-plugins-zyx91 libsox-plugins-zyx92 libsox-plugins-zyx93 libsox-plugins-zyx94 libsox-plugins-zyx95 libsox-plugins-zyx96 libsox-plugins-zyx97 libsox-plugins-zyx98 libsox-plugins-zyx99 libsox-plugins-zyx100 libsox-plugins-zyx101 libsox-plugins-zyx102 libsox-plugins-zyx103 libsox-plugins-zyx104 libsox-plugins-zyx105 libsox-plugins-zyx106 libsox-plugins-zyx107 libsox-plugins-zyx108 libsox-plugins-zyx109 libsox-plugins-zyx110 libsox-plugins-zyx111 libsox-plugins-zyx112 libsox-plugins-zyx113 libsox-plugins-zyx114 libsox-plugins-zyx115 libsox-plugins-zyx116 libsox-plugins-zyx117 libsox-plugins-zyx118 libsox-plugins-zyx119 libsox-plugins-zyx120 libsox-plugins-zyx121 libsox-plugins-zyx122 libsox-plugins-zyx123 libsox-plugins-zyx124 libsox-plugins-zyx125 libsox-plugins-zyx126 libsox-plugins-zyx127 libsox-plugins-zyx128 libsox-plugins-zyx129 libsox-plugins-zyx130 libsox-plugins-zyx131 libsox-plugins-zyx132 libsox-plugins-zyx133 libsox-plugins-zyx134 libsox-plugins-zyx135 libsox-plugins-zyx136 libsox-plugins-zyx137 libsox-plugins-zyx138 libsox-plugins-zyx139 libsox-plugins-zyx140 libsox-plugins-zyx141 libsox-plugins-zyx142 libsox-plugins-zyx143 libsox-plugins-zyx144 libsox-plugins-zyx145 libsox-plugins-zyx146 libsox-plugins-zyx147 libsox-plugins-zyx148 libsox-plugins-zyx149 libsox-plugins-zyx150 libsox-plugins-zyx151 libsox-plugins-zyx152 libsox-plugins-zyx153 libsox-plugins-zyx154 libsox-plugins-zyx155 libsox-plugins-zyx156 libsox-plugins-zyx157 libsox-plugins-zyx158 libsox-plugins-zyx159 libsox-plugins-zyx160 libsox-plugins-zyx161 libsox-plugins-zyx162 libsox-plugins-zyx163 libsox-plugins-zyx164 libsox-plugins-zyx165 libsox-plugins-zyx166 libsox-plugins-zyx167 libsox-plugins-zyx168 libsox-plugins-zyx169 libsox-plugins-zyx170 libsox-plugins-zyx171 libsox-plugins-zyx172 libsox-plugins-zyx173 libsox-plugins-zyx174 libsox-plugins-zyx175 libsox-plugins-zyx176 libsox-plugins-zyx177 libsox-plugins-zyx178 libsox-plugins-zyx179 libsox-plugins-zyx180 libsox-plugins-zyx181 libsox-plugins-zyx182 libsox-plugins-zyx183 libsox-plugins-zyx184 libsox-plugins-zyx185 libsox-plugins-zyx186 libsox-plugins-zyx187 libsox-plugins-zyx188 libsox-plugins-zyx189 libsox-plugins-zyx190 libsox-plugins-zyx191 libsox-plugins-zyx192 libsox-plugins-zyx193 libsox-plugins-zyx194 libsox-plugins-zyx195 libsox-plugins-zyx196 libsox-plugins-zyx197 libsox-plugins-zyx198 libsox-plugins-zyx199 libsox-plugins-zyx200 libsox-plugins-zyx201 libsox-plugins-zyx202 libsox-plugins-zyx203 libsox-plugins-zyx204 libsox-plugins-zyx205 libsox-plugins-zyx206 libsox-plugins-zyx207 libsox-plugins-zyx208 libsox-plugins-zyx209 libsox-plugins-zyx210 libsox-plugins-zyx211 libsox-plugins-zyx212 libsox-plugins-zyx213 libsox-plugins-zyx214 libsox-plugins-zyx215 libsox-plugins-zyx216 libsox-plugins-zyx217 libsox-plugins-zyx218 libsox-plugins-zyx219 libsox-plugins-zyx220 libsox-plugins-zyx221 libsox-plugins-zyx222 libsox-plugins-zyx223 libsox-plugins-zyx224 libsox-plugins-zyx225 libsox-plugins-zyx226 libsox-plugins-zyx227 libsox-plugins-zyx228 libsox-plugins-zyx229 libsox-plugins-zyx230 libsox-plugins-zyx231 libsox-plugins-zyx232 libsox-plugins-zyx233 libsox-plugins-zyx234 libsox-plugins-zyx235 libsox-plugins-zyx236 libsox-plugins-zyx237 libsox-plugins-zyx238 libsox-plugins-zyx239 libsox-plugins-zyx240 libsox-plugins-zyx241 libsox-plugins-zyx242 libsox-plugins-zyx243 libsox-plugins-zyx244 libsox-plugins-zyx245 libsox-plugins-zyx246 libsox-plugins-zyx247 libsox-plugins-zyx248 libsox-plugins-zyx249 libsox-plugins-zyx250 libsox-plugins-zyx251 libsox-plugins-zyx252 libsox-plugins-zyx253 libsox-plugins-zyx254 libsox-plugins-zyx255 libsox-plugins-zyx256 libsox-plugins-zyx257 libsox-plugins-zyx258 libsox-plugins-zyx259 libsox-plugins-zyx260 libsox-plugins-zyx261 libsox-plugins-zyx262 libsox-plugins-zyx263 libsox-plugins-zyx264 libsox-plugins-zyx265 libsox-plugins-zyx266 libsox-plugins-zyx267 libsox-plugins-zyx268 libsox-plugins-zyx269 libsox-plugins-zyx270 libsox-plugins-zyx271 libsox-plugins-zyx272 libsox-plugins-zyx273 libsox-plugins-zyx274 libsox-plugins-zyx275 libsox-plugins-zyx276 libsox-plugins-zyx277 libsox-plugins-zyx278 libsox-plugins-zyx279 libsox-plugins-zyx280 libsox-plugins-zyx281 libsox-plugins-zyx282 libsox-plugins-zyx283 libsox-plugins-zyx284 libsox-plugins-zyx285 libsox-plugins-zyx286 libsox-plugins-zyx287 libsox-plugins-zyx288 libsox-plugins-zyx289 libsox-plugins-zyx290 libsox-plugins-zyx291 libsox-plugins-zyx292 libsox-plugins-zyx293 libsox-plugins-zyx294 libsox-plugins-zyx295 libsox-plugins-zyx296 libsox-plugins-zyx297 libsox-plugins-zyx298 libsox-plugins-zyx299 libsox-plugins-zyx300 libsox-plugins-zyx301 libsox-plugins-zyx302 libsox-plugins-zyx303 libsox-plugins-zyx304 libsox-plugins-zyx305 libsox-plugins-zyx306 libsox-plugins-zyx307 libsox-plugins-zyx308 libsox-plugins-zyx309 libsox-plugins-zyx310 libsox-plugins-zyx311 libsox-plugins-zyx312 libsox-plugins-zyx313 libsox-plugins-zyx314 libsox-plugins-zyx315 libsox-plugins-zyx316 libsox-plugins-zyx317 libsox-plugins-zyx318 libsox-plugins-zyx319 libsox-plugins-zyx320 libsox-plugins-zyx321 libsox-plugins-zyx322 libsox-plugins-zyx323 libsox-plugins-zyx324 libsox-plugins-zyx325 libsox-plugins-zyx326 libsox-plugins-zyx327 libsox-plugins-zyx328 libsox-plugins-zyx329 libsox-plugins-zyx330 libsox-plugins-zyx331 libsox-plugins-zyx332 libsox-plugins-zyx333 libsox-plugins-zyx334 libsox-plugins-zyx335 libsox-plugins-zyx336 libsox-plugins-zyx337 libsox-plugins-zyx338 libsox-plugins-zyx339 libsox-plugins-zyx340 libsox-plugins-zyx341 libsox-plugins-zyx342 libsox-plugins-zyx343 libsox-plugins-zyx344 libsox-plugins-zyx345 libsox-plugins-zyx346 libsox-plugins-zyx347 libsox-plugins-zyx348 libsox-plugins-zyx349 libsox-plugins-zyx350 libsox-plugins-zyx351 libsox-plugins-zyx352 libsox-plugins-zyx353 libsox-plugins-zyx354 libsox-plugins-zyx355 libsox-plugins-zyx356 libsox-plugins-zyx357 libsox-plugins-zyx358 libsox-plugins-zyx359 libsox-plugins-zyx360 libsox-plugins-zyx361 libsox-plugins-zyx362 libsox-plugins-zyx363 libsox-plugins-zyx364 libsox-plugins-zyx365 libsox-plugins-zyx366 libsox-plugins-zyx367 libsox-plugins-zyx368 libsox-plugins-zyx369 libsox-plugins-zyx370 libsox-plugins-zyx371 libsox-plugins-zyx372 libsox-plugins-zyx373 libsox-plugins-zyx374 libsox-plugins-zyx375 libsox-plugins-zyx376 libsox-plugins-zyx377 libsox-plugins-zyx378 libsox-plugins-zyx379 libsox-plugins-zyx380 libsox-plugins-zyx3
```

```

root@ubuntu:/# apt install libelf-dev
Reading package lists... Done
Building dependency tree... Done
Reading state information... Done
The following packages were automatically installed and are no longer required:
chromium-codecs-ffmpeg-extra gstreamer1.0-vapori i965-va-driver intel-media-va-driver libasound2 libatk-1.0 libatspi2c-2 libavcodec58 libavformat58 libavutil56 libbdplus1 libbluetooth1 libbluray2 libbz2-1.0
libchromaprint1 libcdec2-1.6 libdvdnav1 libflite1 libgsm1 libgnutls-sysutils-plugins-bad1.6-0 libhogweed2 libidn2-1.6 libltdl7 libmariadb1 libmpc3 libmpfr6 libnetcdf5 libopenal1 libopenexr1 libopenjp2-2 liborc-0.4-2
libpcrecpp1 libprotobuf1 librtmp1 librubio1 libseccomp2 libserf-1-0 libsigc++2.10 libslang2 libsnappy1v5 libsox-filters1.4-gnutls libssh-crypt-4 libswresample1 libtesseract1 libtheora1.1 libudfread1 libvidstab1-drm2
libva-wayland1 libva-x11-2 libx264 libx265 libxdo1 libxft2 libxml2 libxslt1.1 libzstd1
systemd-hwdb va-driver-all vdpau-driver-all
Use 'sudo apt autoremove' to remove them.
The following additional packages will be installed:
  zlib1g-zlib-dev
The following NEW packages will be installed:
  libelf-dev
The following packages will be upgraded:
  libelf-dev
The following packages will be upgraded:
  libelf-dev
1 upgraded, 2 newly installed, 0 to remove and 272 not upgraded.
Need to get 228 kB/287 kB of archives.
After this operation, 979 kB of additional disk space will be used.
Do you want to continue? [Y/n] y
Get:1 http://pk.archive.ubuntu.com/ubuntu [army-updates/main amd64 zlib1g-dev amd64 1:1.2.11.dfsg-2ubuntu9.2 [164 kB]
Get:2 http://pk.archive.ubuntu.com/ubuntu [army/main amd64 libelf-dev amd64 0.180-3build1 [64.4 kB]
Fetched 228 kB in 4s (64.6 kB/s)
(Reading database ... 203190 files and directories currently installed.)
Preparing to unpack .../zlib1g_1.2.11.dfsg-2ubuntu9.2_amd64.deb ...
Unpacking zlib1g:amd64 (1:1.2.11.dfsg-2ubuntu9.2) over (1:1.2.11.dfsg-2ubuntu9.2) ...
Setting up zlib1g:amd64 (1:1.2.11.dfsg-2ubuntu9.2) ...
Selecting previously unselected package zlib-dev:amd64.
(Reading database ... 203190 files and directories currently installed.)
Preparing to unpack .../zlib-dev_1.2.11.dfsg-2ubuntu9.2_amd64.deb ...
Unpacking zlib-dev:amd64 (1:1.2.11.dfsg-2ubuntu9.2) ...
Selecting previously unselected package libelf-dev:amd64.
Preparing to unpack .../libelf-dev_0.180-3build1_amd64.deb ...
Unpacking libelf-dev:amd64 (0.180-3build1) ...
Setting up zlib-dev:amd64 (1:1.2.11.dfsg-2ubuntu9.2) ...
Setting up libelf-dev:amd64 (0.180-3build1) ...
Processing triggers for man-db (2.10.2-1) ...
Processing triggers for libc-bin (2.35-0ubuntu1) ...

```

[illegible]

Downloading and Configuring the Kernel

Download and Extract

First we have to download the kernel using this command:

- **wget <https://cdn.kernel.org/pub/linux/kernel/v5.x/linux-5.15.1.tar.xz>**

Then we extract and open the file using these commands:

- **tar xf linux-5.15.1.tar.xz**
- **cd linux-5.15.1**

Configuring

Now that the kernel is downloaded and extracted we need to configure it.

So first we need to copy our current kernel config, and that is done using these commands:

- **ls /boot | grep config**
- **cp /boot/config-X.X.X-generic .config**

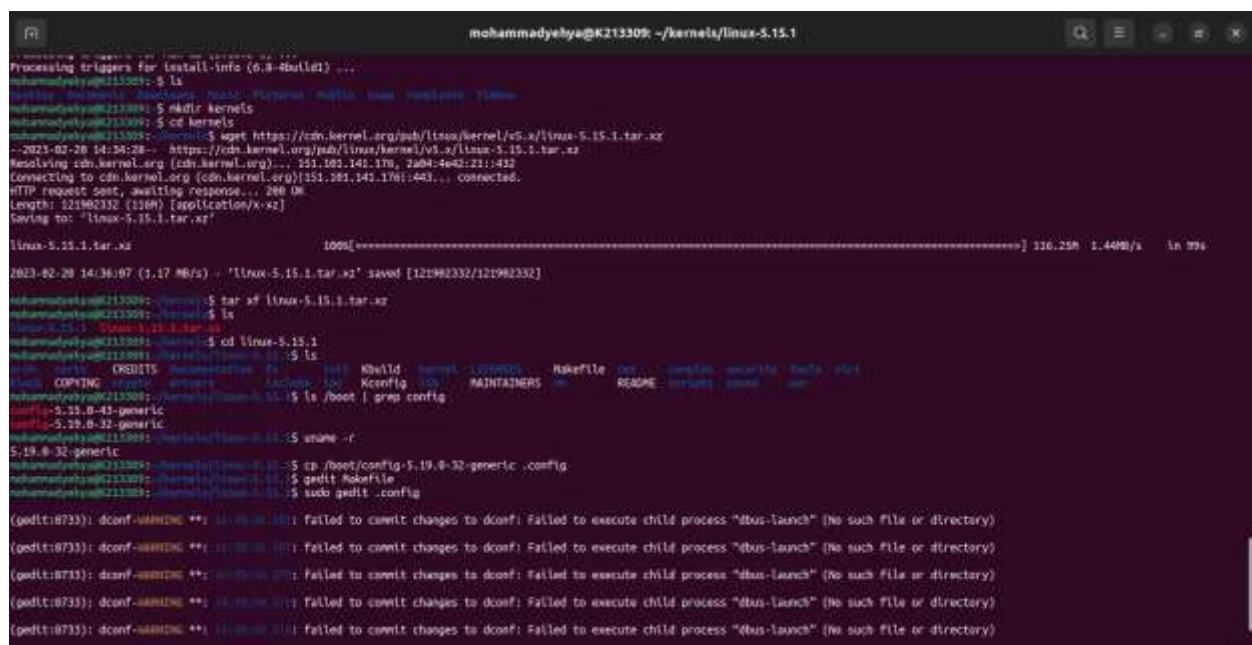
(X.X.X is the version of the current running kernel)

Next we need to open the Makefile and set our roll number with the kernel version (as requested in the assignment).

We open the Makefile using the command:

- **gedit Makefile**

Here are some screenshots:

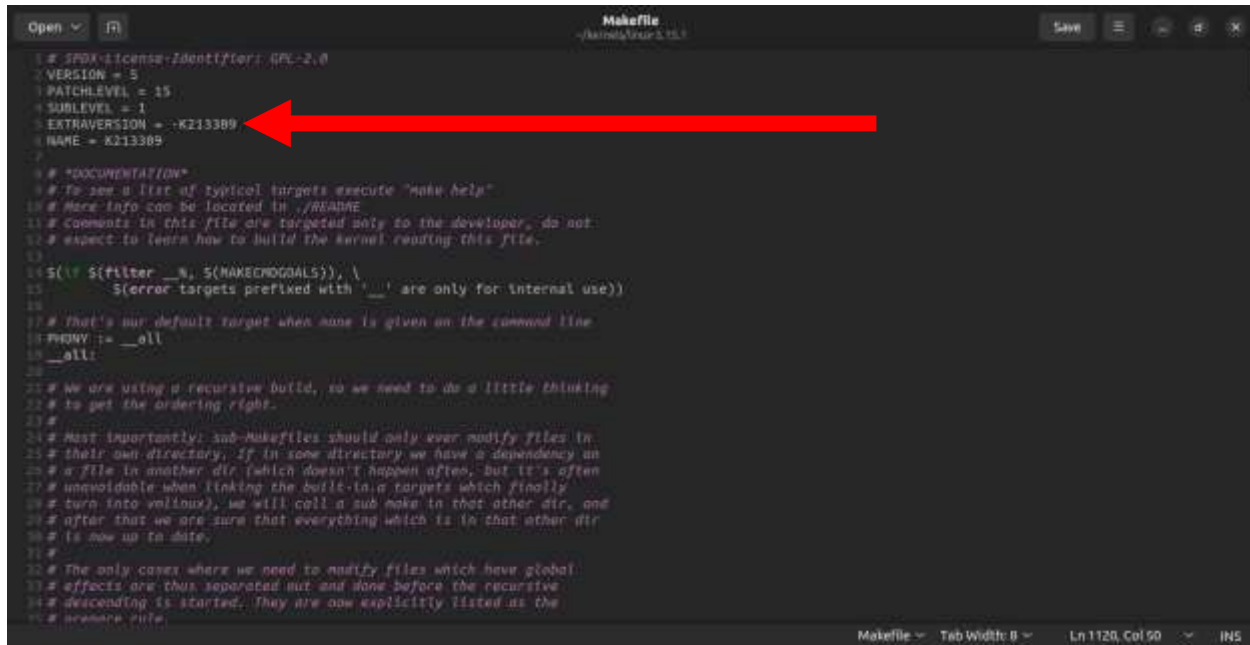


```
mohammadyehya@K213309: ~/kernels/linux-5.15.1
Processing triggers for install-info (6.8-4build1) ...
mohammadyehya@K213309: ~$ ls
Downloads  Desktop  Downloads  Desktop  Downloads  Desktop  Downloads  Desktop  Downloads  Desktop
mohammadyehya@K213309: ~$ mkdir kernels
mohammadyehya@K213309: ~$ cd kernels
mohammadyehya@K213309: ~/kernels$ wget https://cdn.kernel.org/pub/linux/kernel/v5.x/linux-5.15.1.tar.xz
--2023-02-28 14:34:28-- https://cdn.kernel.org/pub/linux/kernel/v5.x/linux-5.15.1.tar.xz
Resolving cdn.kernel.org (cdn.kernel.org)... 151.101.141.170, 2a04:4e42:21::432
Connecting to cdn.kernel.org (cdn.kernel.org)[151.101.141.170]:443... connected.
HTTP request sent, awaiting response... 200 OK
Length: 121962332 (116M) [application/x-xz]
Saving to: 'linux-5.15.1.tar.xz'

linux-5.15.1.tar.xz
100%[=====] 116.25M 1.44MB/s in 89s

2023-02-28 14:36:07 (1.17 MB/s) - 'linux-5.15.1.tar.xz' saved [121962332/121962332]

mohammadyehya@K213309: ~/kernels$ tar xf linux-5.15.1.tar.xz
mohammadyehya@K213309: ~/kernels$ ls
linux-5.15.1  linux-5.15.1.tar.xz
mohammadyehya@K213309: ~/kernels$ cd linux-5.15.1
mohammadyehya@K213309: ~/kernels/linux-5.15.1$ ls
ARCH  boot  CREDITS  Documentation  fs  gcc  kernel  lib  Makefile  net  scripts  security  tools  vmlinux
Makefile  COPYING  README  arch  drivers  fs  gcc  kernel  lib  Kconfig  MAINTAINERS  README  scripts  tools  vmlinux
mohammadyehya@K213309: ~/kernels/linux-5.15.1$ ls /boot | grep config
config-5.19.0-32-generic
mohammadyehya@K213309: ~/kernels/linux-5.15.1$ cp /boot/config-5.19.0-32-generic .config
mohammadyehya@K213309: ~/kernels/linux-5.15.1$ gedit Makefile
mohammadyehya@K213309: ~/kernels/linux-5.15.1$ sudo gedit .config
(gedit:8733): dconf-WARNING **: 14:36:08.101: Failed to commit changes to dconf: Failed to execute child process "dbus-launch" (No such file or directory)
(gedit:8733): dconf-WARNING **: 14:36:08.101: Failed to commit changes to dconf: Failed to execute child process "dbus-launch" (No such file or directory)
(gedit:8733): dconf-WARNING **: 14:36:08.101: Failed to commit changes to dconf: Failed to execute child process "dbus-launch" (No such file or directory)
(gedit:8733): dconf-WARNING **: 14:36:08.101: Failed to commit changes to dconf: Failed to execute child process "dbus-launch" (No such file or directory)
(gedit:8733): dconf-WARNING **: 14:36:08.101: Failed to commit changes to dconf: Failed to execute child process "dbus-launch" (No such file or directory)
```



```
1 # SPDX-License-Identifier: GPL-2.0
2 VERSION = 5
3 PATCHLEVEL = 15
4 SUBLEVEL = 1
5 EXTRAVERSION = -K213309
6 NAME = K213309
7
8 # "DOCUMENTATION"
9 # To see a list of typical targets execute "make help"
10 # More info can be located in ./README
11 # Comments in this file are targeted only to the developer, do not
12 # expect to learn how to build the kernel reading this file.
13
14 $(if $(filter __%, $(MAKECMDGOALS)), \
15     $(error targets prefixed with '__' are only for internal use))
16
17 # That's our default target when none is given on the command line
18 PROMV := __all
19 __all:
20
21 # We are using a recursive build, so we need to do a little thinking
22 # to get the ordering right.
23 #
24 # Most importantly, sub-Makefiles should only ever modify files in
25 # their own directory, if in some directory we have a dependency on
26 # a file in another dir (which doesn't happen often, but it's often
27 # unavoidable when linking the built-in.a targets which finally
28 # turn into vmlinux), we will call a sub make in that other dir, and
29 # after that we are sure that everything which is in that other dir
30 # is now up to date.
31 #
32 # The only cases where we need to modify files which have global
33 # effects are thus separated out and done before the recursive
34 # descending is started. They are now explicitly listed as the
35 # upstream rule.
```

Now we have to set the config parameters of our current running kernel to the new one, and to do that we use this command:

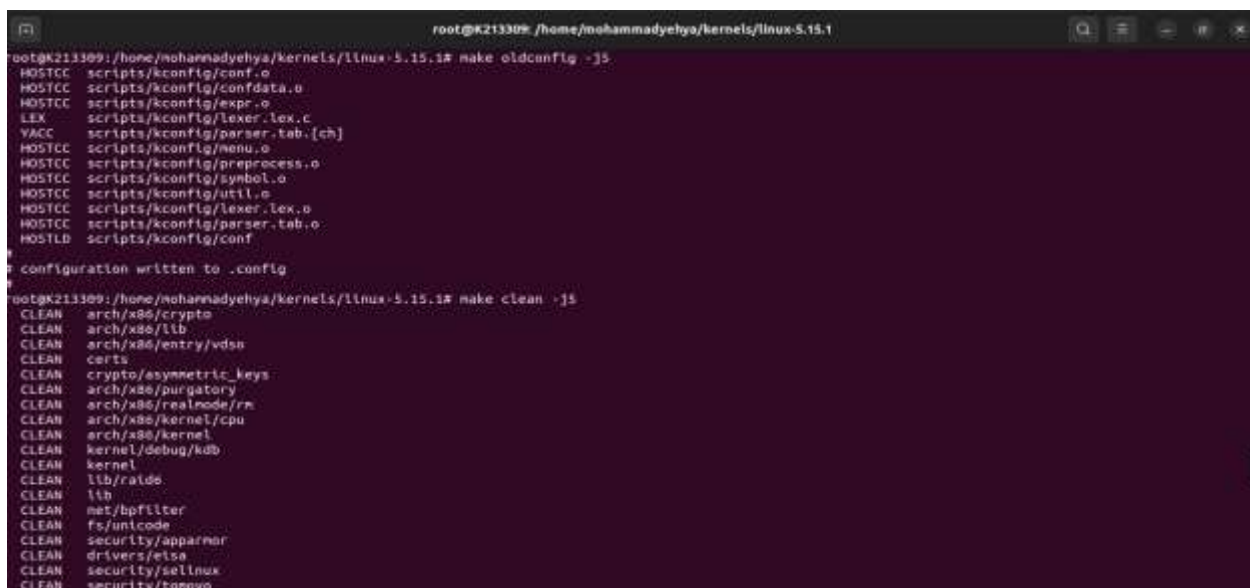
- **yes “ | make oldconfig -j4**

(-jx, where x represents the number of cores available to your pc. To find out how many and available use command nproc)

Extra step is to clean all temp files in the new kernel, to do that we use command:

- **make clean -j4**

Here are some screenshots:



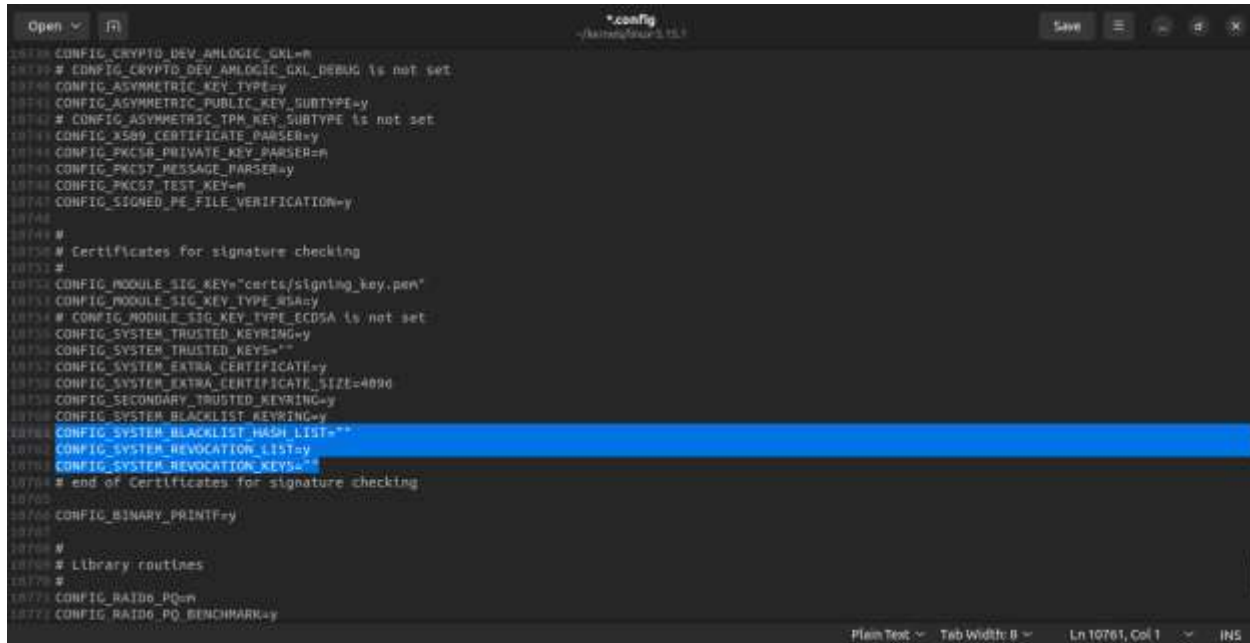
```
root@K213309: /home/mohammadyehya/kernels/linux-5.15.1
root@K213309: /home/mohammadyehya/kernels/linux-5.15.1# make oldconfig -j5
HOSTCC scripts/kconfig/conf.o
HOSTCC scripts/kconfig/confdata.o
HOSTCC scripts/kconfig/expr.o
LEX scripts/kconfig/lexer.lex.c
YACC scripts/kconfig/parser.tab.[ch]
HOSTCC scripts/kconfig/menu.o
HOSTCC scripts/kconfig/preprocess.o
HOSTCC scripts/kconfig/symbol.o
HOSTCC scripts/kconfig/util.o
HOSTCC scripts/kconfig/lexer.lex.o
HOSTCC scripts/kconfig/parser.tab.o
HOSTLD scripts/kconfig/conf
configuration written to .config
root@K213309: /home/mohammadyehya/kernels/linux-5.15.1# make clean -j5
CLEAN arch/x86/crypto
CLEAN arch/x86/lib
CLEAN arch/x86/entry/vdso
CLEAN certs
CLEAN crypto/asymmetric_keys
CLEAN arch/x86/purgatory
CLEAN arch/x86/realmode/rm
CLEAN arch/x86/kernel/cpu
CLEAN arch/x86/kernel
CLEAN kernel/debug/kdb
CLEAN kernel
CLEAN lib/raid6
CLEAN lib
CLEAN net/bpfILTER
CLEAN fs/unicode
CLEAN security/apparmor
CLEAN drivers/fuse
CLEAN security/selinux
CLEAN security/tomoyo
```


Before building the kernel we need to make sure we perform one more step.

We need to open the .config file and change 2 strings to empty strings.

These strings are set to CONFIG_SYSTEM-BLACKLIST_HASH_LIST and CONFIG_SYSTEM_REVOCATION_KEYS.

Here is a screenshot:



```
10730 CONFIG_CRYPTO_DEV_ARMLOGIC_GXL=m
10731 # CONFIG_CRYPTO_DEV_ARMLOGIC_GXL_DEBUG is not set
10732 CONFIG_CRYPTO_ASYMMETRIC_KEY_TYPE=y
10733 CONFIG_CRYPTO_ASYMMETRIC_PUBLIC_KEY_SUBTYPE=y
10734 # CONFIG_CRYPTO_ASYMMETRIC_TPM_KEY_SUBTYPE is not set
10735 CONFIG_X509_CERTIFICATE_PARSER=y
10736 CONFIG_PKCS8_PRIVATE_KEY_PARSER=m
10737 CONFIG_PKCS7_MESSAGE_PARSER=y
10738 CONFIG_PKCS7_TEST_KEY=m
10739 CONFIG_SIGNED_PE_FILE_VERIFICATION=y
10740
10741 #
10742 # Certificates for signature checking
10743 #
10744 CONFIG_MODULE_SIG_KEY="certs/signing_key.pem"
10745 CONFIG_MODULE_SIG_KEY_TYPE_RSA=y
10746 # CONFIG_MODULE_SIG_KEY_TYPE_ECDSA is not set
10747 CONFIG_SYSTEM_TRUSTED_KEYRING=y
10748 CONFIG_SYSTEM_TRUSTED_KEYS=""
10749 CONFIG_SYSTEM_EXTRA_CERTIFICATE=y
10750 CONFIG_SYSTEM_EXTRA_CERTIFICATE_SIZE=4096
10751 CONFIG_SECONDARY_TRUSTED_KEYRING=y
10752 CONFIG_SYSTEM_BLACKLIST_KEYRING=y
10753 CONFIG_SYSTEM_BLACKLIST_HASH_LIST=""
10754 CONFIG_SYSTEM_REVOCATION_LIST=y
10755 CONFIG_SYSTEM_REVOCATION_KEYS=""
10756 # end of Certificates for signature checking
10757
10758 CONFIG_BINARY_PRINTF=y
10759
10760 #
10761 # Library routines
10762 #
10763 CONFIG_RAID6_PQ=m
10764 CONFIG_RAID6_PQ_BENCHMARK=y
```

Adding Hello World System Call

First of all we will make a directory in the kernel directory having the name helloworld, this is done using the command :

- **mkdir helloworld**

Next we will make a C file which actually defines what the system call will do:

- **gedit helloworld.c**

Here is a screenshot:



```
helloworld.c [Read-Only]
~/kernel/src-5.15.1/helloworld

#include <linux/kernel.h>
#include <linux/syscalls.h>

SYSCALL_DEFINE0(helloworld)
{
    printk("Hello World\n");
    return 0;
}
```

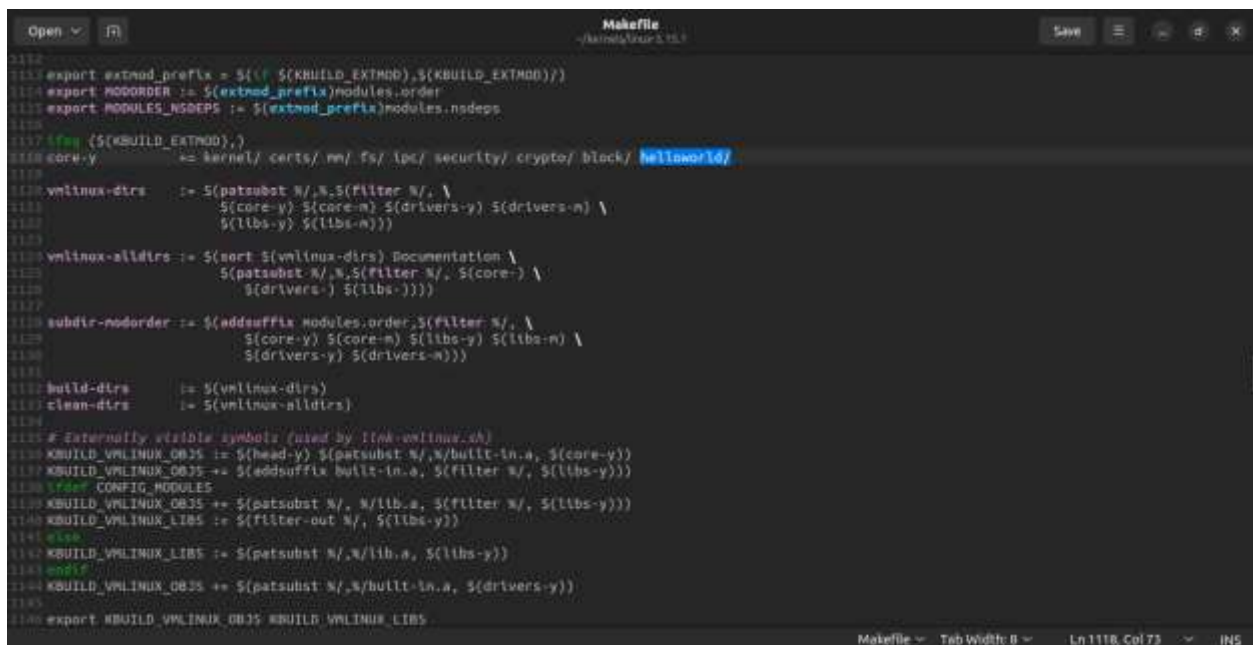
Then we make a Makefile (gedit Makefile) and do the following:



```
Makefile [Read-Only]
~/kernel/src-5.15.1/helloworld

obj-y += helloworld.o
```

Then we go back to the kernel directory and open the Makefile again, this time we need to add our C file into the list as follows:



```
Makefile
~/kernel/src-5.15.1

1112 export extmod_prefix = ${if ${KBUILD_EXTMOD},${KBUILD_EXTMOD}}
1113 export MODORDER := $(extmod_prefix)modules.order
1114 export MODULES_NSDEPS := $(extmod_prefix)modules.nsdeps
1115
1116 ifeq (${KBUILD_EXTMOD},)
1117     core-y      += kernel/ certs/ mm/ fs/ ipc/ security/ crypto/ block/ helloworld/
1118
1119 vmlinux-dirs   := $(patsubst %/,%,$(filter %/, \
1120     $(core-y) $(core-m) $(drivers-y) $(drivers-m) \
1121     $(libs-y) $(libs-m)))
1122
1123 vmlinux-all-dirs := $(sort $(vmlinux-dirs) Documentation \
1124     $(patsubst %/,%,$(filter %/, $(core-y) \
1125     $(drivers-y) $(libs-y)))
1126
1127 subdir-objorder := $(addsuffix modules.order,$(filter %/, \
1128     $(core-y) $(core-m) $(libs-y) $(libs-m) \
1129     $(drivers-y) $(drivers-m)))
1130
1131 build-dirs     := $(vmlinux-dirs)
1132 clean-dirs     := $(vmlinux-all-dirs)
1133
1134 # Externally visible symbols (used by link-vmlinux.sh)
1135 KBUILD_VMLINUX_OBJS := $(head-y) $(patsubst %/,%,$(built-in.a) $(core-y))
1136 KBUILD_VMLINUX_OBJS += $(addsuffix built-in.a,$(filter %/, $(libs-y)))
1137 KBUILD_VMLINUX_OBJS += $(addsuffix built-in.a,$(filter %/, $(libs-y)))
1138 KBUILD_VMLINUX_OBJS += $(patsubst %/, %/lib.a,$(filter %/, $(libs-y)))
1139 KBUILD_VMLINUX_OBJS += $(filter-out %/, $(libs-y))
1140 KBUILD_VMLINUX_OBJS += $(patsubst %/, %/built-in.a,$(drivers-y))
1141 KBUILD_VMLINUX_OBJS += $(patsubst %/, %/lib.a,$(libs-y))
1142 KBUILD_VMLINUX_OBJS += $(patsubst %/, %/built-in.a,$(drivers-y))
1143 KBUILD_VMLINUX_OBJS += $(patsubst %/, %/lib.a,$(libs-y))
1144 KBUILD_VMLINUX_OBJS += $(patsubst %/, %/built-in.a,$(drivers-y))
1145 KBUILD_VMLINUX_OBJS += $(patsubst %/, %/lib.a,$(libs-y))
1146 export KBUILD_VMLINUX_OBJS KBUILD_VMLINUX_OBJS
```

Now we have to update the system call library to include our helloworld.c, so we need to open the file as follows:

- **gedit include/linux/syscalls.h**

And add the following line:

```

1232         set_personality(personality);
1233     }
1234     return old;
1235 }
1236
1237 /* for __ARCH_WANT_SYS_ZAC */
1238 long ksys_senctidop(int senid, struct senbuf __user *tsops,
1239                    unsigned int nsops,
1240                    const struct __kernel_timespec __user *timeout);
1241 long ksys_senget(key_t key, int nsent, int senflg);
1242 long ksys_old_sencti(int senid, int sennum, int end, unsigned long arg);
1243 long ksys_msgget(key_t key, int msgflg);
1244 long ksys_old_msgctl(int msqid, int cmd, struct msqid_ds __user *buf);
1245 long ksys_msgrcv(int msqid, struct msgbuf __user *msgp, size_t msgsz,
1246                 long msgtyp, int msgflg);
1247 long ksys_msgsnd(int msqid, struct msgbuf __user *msgp, size_t msgsz,
1248                 int msgflg);
1249 long ksys_shmget(key_t key, size_t size, int shmflg);
1250 long ksys_shmctl(char __user *shmaddr);
1251 long ksys_old_shmctl(int shmid, int cmd, struct shmid_ds __user *buf);
1252 long compat_ksys_senctidop(int senid, struct senbuf __user *tsops,
1253                            unsigned int nsops,
1254                            const struct old_timespec32 __user *timeout);
1255 long __do_senctidop(int senid, struct senbuf *tsops, unsigned int nsops,
1256                    const struct timespec64 *timeout,
1257                    struct ipc_namespace *ns);
1258
1259 int __sys_getsockopt(int fd, int level, int optname, char __user *optval,
1260                     int __user *optlen);
1261 int __sys_setsockopt(int fd, int level, int optname, char __user *optval,
1262                     int optlen);
1263
1264 #endif

```

The last step is to add the system call to the kernel's system call table like so

- **gedit arch/x86/entry/syscalls/syscall_64.tbl:**

And do as follows

```

393 429 common move_mount sys_move_mount
394 430 common fsopen sys_fsopen
395 431 common fsconfig sys_fsconfig
396 432 common fsmount sys_fsmount
397 433 common fspick sys_fspick
398 434 common pidfd_open sys_pidfd_open
399 435 common clone3 sys_clone3
400 436 common close_range sys_close_range
401 437 common openat2 sys_openat2
402 438 common pidfd_getfd sys_pidfd_getfd
403 439 common faccessat2 sys_faccessat2
404 440 common process_madvise sys_process_madvise
405 441 common epoll_pwait2 sys_epoll_pwait2
406 442 common mount_setattr sys_mount_setattr
407 443 common quotactl_fd sys_quotactl_fd
408 444 common landlock_create_ruleset sys_landlock_create_ruleset
409 445 common landlock_add_rule sys_landlock_add_rule
410 446 common landlock_restrict_self sys_landlock_restrict_self
411 447 common memfd_secret sys_memfd_secret
412 448 common process_mrelease sys_process_mrelease
413 449 common helloworld sys_helloworld
414 #
415 # Due to a historical design error, certain syscalls are numbered differently
416 # in x32 as compared to native x86_64. These syscalls have numbers 512-547.
417 # Do not add new syscalls to this range. Numbers 548 and above are available
418 # for non-x32 use.
419 #
420 512 x32 rt_sigaction compat_sys_rt_sigaction
421 513 x32 rt_sigreturn compat_sys_x32_rt_sigreturn
422 514 x32 loctl compat_sys_loctl
423 515 x32 readv sys_readv
424 516 x32 writev sys_writev
425 517 x32 recvmmsg compat_sys_recvmmsg
426 518 x32 sendmsg compat_sys_sendmsg
427 519 x32 recvmmsg compat_sys_recvmmsg

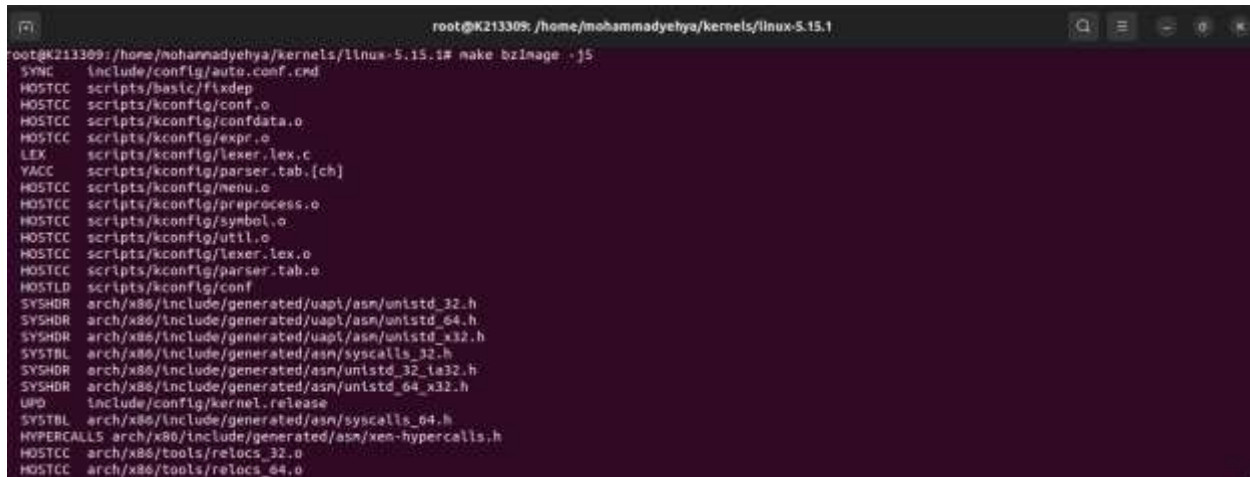
```


And remember to put it above the x32 system calls, as well as to keep the number of the system call in mind.

Building the Kernel

Now we have to build the kernel into an installable image file which we can do using the command:

- **Sudo make bzImage -j4**



```
root@K213309: /home/mohammadyehya/kernels/linux-5.15.1# make bzImage -j4
SYMC      include/config/auto.conf.cmd
HOSTCC    scripts/basic/fixdep
HOSTCC    scripts/kconfig/conf.o
HOSTCC    scripts/kconfig/confdata.o
HOSTCC    scripts/kconfig/expr.o
LEX        scripts/kconfig/lexer.lex.c
YACC       scripts/kconfig/parser.tab.[ch]
HOSTCC    scripts/kconfig/menu.o
HOSTCC    scripts/kconfig/preprocess.o
HOSTCC    scripts/kconfig/symbol.o
HOSTCC    scripts/kconfig/util.o
HOSTCC    scripts/kconfig/lexer.lex.o
HOSTCC    scripts/kconfig/parser.tab.o
HOSTLD    scripts/kconfig/conf
SYSHDR    arch/x86/include/generated/uapi/asm/unistd_32.h
SYSHDR    arch/x86/include/generated/uapi/asm/unistd_64.h
SYSHDR    arch/x86/include/generated/uapi/asm/unistd_x32.h
SYSTBL    arch/x86/include/generated/asm/syscalls_32.h
SYSHDR    arch/x86/include/generated/asm/unistd_32_x32.h
SYSHDR    arch/x86/include/generated/asm/unistd_64_x32.h
UPD        include/config/kernel.release
SYSTBL    arch/x86/include/generated/asm/syscalls_64.h
HYPERCALLS arch/x86/include/generated/asm/xen-hypercalls.h
HOSTCC    arch/x86/tools/relocs_32.o
HOSTCC    arch/x86/tools/relocs_64.o
```

Now we need to make and install the modules, and this process takes an extremely long amount of time since the Linux kernel has a huge number of line of codes (around 3 hours for my pc but can vary from pc to pc);

- **make module -j4**
- **make modules_install -j4**
- **make install -j4**

Here is a screenshot:

```
mohammadyehya@K213309: ~/kernel/linux-5.15.1
LD [M] sound/usb/6fire/snd-usb-6fire.ko
LD [M] sound/usb/bcd2000/snd-bcd2000.ko
LD [M] sound/usb/caiaq/snd-usb-caiaq.ko
LD [M] sound/usb/hiface/snd-usb-hiface.ko
BTf [M] sound/usb/bcd2000/snd-bcd2000.ko
BTf [M] sound/usb/hiface/snd-usb-hiface.ko
BTf [M] sound/usb/caiaq/snd-usb-caiaq.ko
BTf [M] sound/usb/6fire/snd-usb-6fire.ko
LD [M] sound/usb/line6/snd-usb-line6.ko
LD [M] sound/usb/line6/snd-usb-pod.ko
LD [M] sound/usb/line6/snd-usb-podhd.ko
LD [M] sound/usb/line6/snd-usb-toneport.ko
BTf [M] sound/usb/line6/snd-usb-pod.ko
BTf [M] sound/usb/line6/snd-usb-toneport.ko
BTf [M] sound/usb/line6/snd-usb-podhd.ko
BTf [M] sound/usb/line6/snd-usb-line6.ko
LD [M] sound/usb/line6/snd-usb-variax.ko
LD [M] sound/usb/misc/snd-ua101.ko
LD [M] sound/usb/snd-usb-audio.ko
LD [M] sound/usb/snd-usb-usbmidi1.ko
BTf [M] sound/usb/misc/snd-ua101.ko
BTf [M] sound/usb/line6/snd-usb-variax.ko
BTf [M] sound/usb/snd-usb-usbmidi1.ko
LD [M] sound/usb/usx2y/snd-usb-usx2y.ko
LD [M] sound/usb/usx2y/snd-usb-usx2y.ko
LD [M] sound/virtio/virtio_snd.ko
BTf [M] sound/usb/snd-usb-audio.ko
BTf [M] sound/usb/usx2y/snd-usb-usx2y.ko
BTf [M] sound/usb/usx2y/snd-usb-usx2y.ko
BTf [M] sound/virtio/virtio_snd.ko
LD [M] sound/x86/snd-hdmi-lpe-audio.ko
BTf [M] sound/x86/snd-hdmi-lpe-audio.ko
LD [M] sound/xen/snd_xen_front.ko
BTf [M] sound/xen/snd_xen_front.ko
mohammadyehya@K213309: ~/kernel/linux-5.15.1 $ sudo make modules -j4 is now done
mohammadyehya@K213309: ~/kernel/linux-5.15.1 $
```

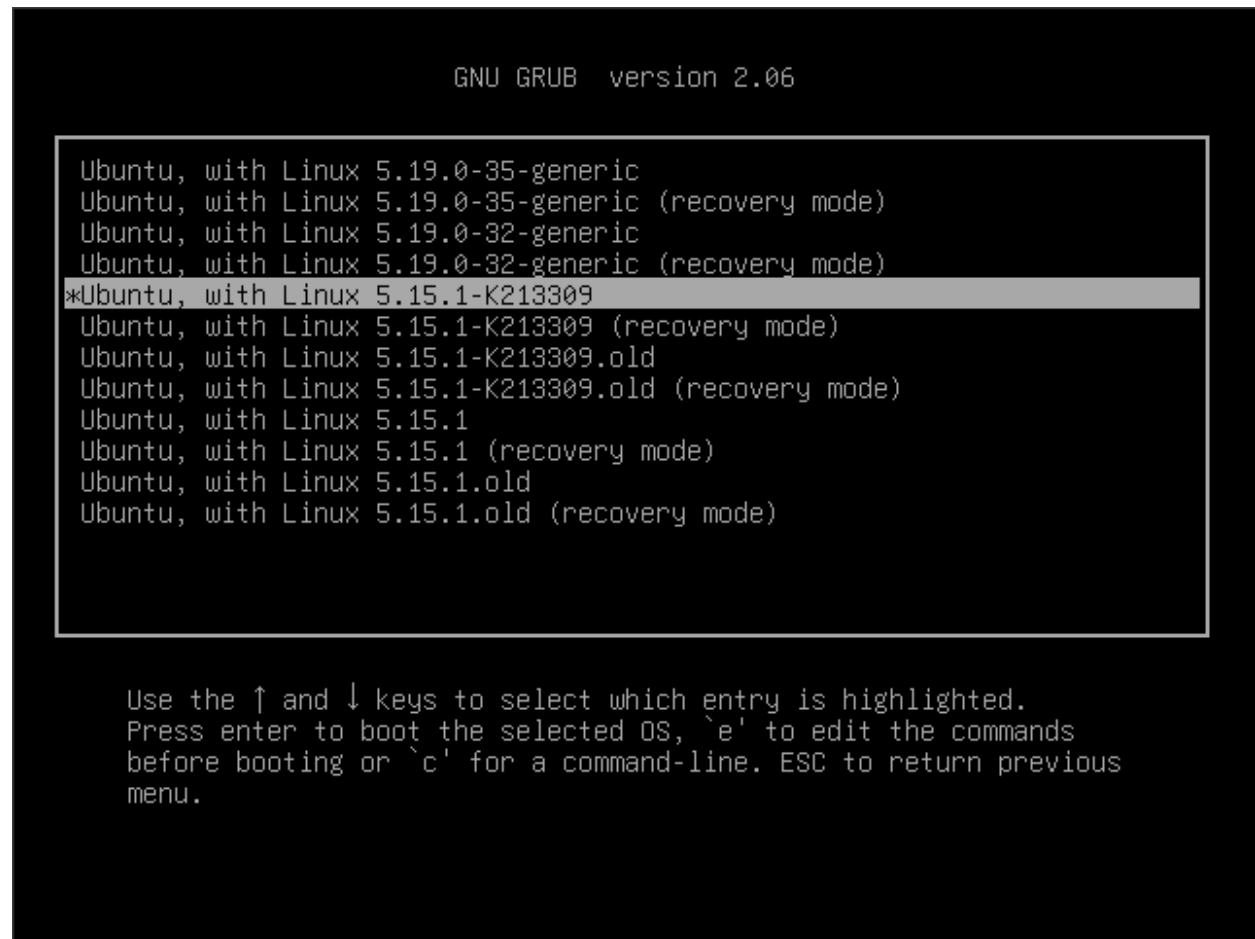
Since the process took a long time to finish, I forgot to take screenshots of the other commands (module_install and install).

The last step is to update the GRUB menu (BIOS) simply using the command:

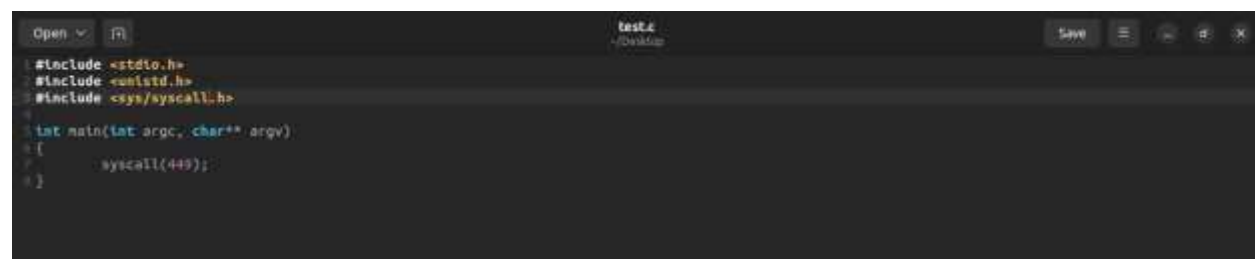
- **sudo update-grub**

Selecting the Kernel and Checking

During the reboot phase we have to pick our kernel version, as follows:



Once we have picked the kernel version, all we need to do is make an example C file and run the helloworld system call in it.



Now that we have created a C file, it is time to execute it.

Here are the screenshots:

```
mohammadyehya@K213309: ~/Desktop
mohammadyehya@K213309:~$ uname -r
5.15.1-K213309
mohammadyehya@K213309:~$ uname -s
K213309
mohammadyehya@K213309:~$ ls
Desktop  Downloads  how_php7.4-tidy  Kernels  Music  Public  Templates  'udo apt install php7.4-tidy'
Documents  how_php7.4-tidy  Maildir  Pictures  Snap  test_message  Videos
mohammadyehya@K213309:~$ cd Desktop
bash: cd: Desktop: No such file or directory
mohammadyehya@K213309:~$ cd Desktop
mohammadyehya@K213309:~/Desktop$ gedit test.c
mohammadyehya@K213309:~/Desktop$ gcc -o test test.c
./test.c:10: Fatal error: sys/syscalls.h: No such file or directory
3 | #include <sys/syscalls.h>
    |
compilation terminated.
mohammadyehya@K213309:~/Desktop$ gedit test.c
mohammadyehya@K213309:~/Desktop$ gcc -o test test.c
mohammadyehya@K213309:~/Desktop$ ./test
mohammadyehya@K213309:~/Desktop$ dmesg
dmesg: read kernel buffer failed: Operation not permitted
mohammadyehya@K213309:~/Desktop$ sudo dmesg
[sudo] password for mohammadyehya:
0.000000 Linux version 5.15.1-K213309 (root@K213309) (gcc (Ubuntu 11.3.0-1ubuntu1-22.04) 11.3.0, GNU ld (GNU Binutils for Ubuntu) 2.38) #6 SMP 5
at Mar 4 13:12:34 PKT 2023
0.000000 Command line: BOOT_IMAGE=/boot/vmlinuz-5.15.1-K213309 root=UUID=96a2619a-abab-4e3e-b026-18426d6f8c33 ro quiet splash
0.000000 KERNEL supported cpus:
0.000000 Intel GenuineIntel
0.000000 AMD AuthenticAMD
0.000000 Hygon HygonGenuine
0.000000 Centaur CentaurHauls
0.000000 zhaoxin Shanghai
0.000000 x86/fpu: Supporting XSAVE feature 0x001: 'x87 floating point registers'
0.000000 x86/fpu: Supporting XSAVE feature 0x002: 'SSE registers'
0.000000 x86/fpu: Supporting XSAVE feature 0x004: 'AVX registers'
0.000000 x86/fpu: xstate_offset[2]: 576, xstate_sizes[2]: 256
62.993679 sched: RT throttling activated
63.931850 kauditd_printk_skb: 7 callbacks suppressed
63.931853 audit: type=1400 audit(1677929078.382:00): apparmor="DENIED" operation="capable" profile="/snap/snapd/18357/usr/lib/snapd/snap-confine"
pid=1790 comm="snap-confine" capability=12 capname="net_admin"
63.932874 audit: type=1400 audit(1677929078.382:07): apparmor="DENIED" operation="capable" profile="/snap/snapd/18357/usr/lib/snapd/snap-confine"
pid=1790 comm="snap-confine" capability=38 capname="perfmon"
76.888180 rfxkill: input handler disabled
139.072234 audit: type=1400 audit(1677929153.487:08): apparmor="DENIED" operation="capable" profile="/snap/snapd/18357/usr/lib/snapd/snap-confine"
pid=2385 comm="snap-confine" capability=12 capname="net_admin"
139.072348 audit: type=1400 audit(1677929153.487:09): apparmor="DENIED" operation="capable" profile="/snap/snapd/18357/usr/lib/snapd/snap-confine"
pid=2385 comm="snap-confine" capability=38 capname="perfmon"
139.044048 rfxkill: input handler enabled
140.112048 rfxkill: input handler disabled
140.089850 ISO 9660 Extensions: Microsoft Joliet Level 3
140.099887 ISO 9660 Extensions: RRIP-1991A
152.277699 audit: type=1326 audit(1677929166.080:70): auid=1000 uid=1000 gid=1000 ses=3 subj=snap.snapd-desktop-integration.snapd-desktop-integra
tion (enforce) pid=3108 comm="snapd-desktop-l" exe="/snap/snapd-desktop-integration/49/usr/bin/snapd-desktop-integration" sig=0 arch=c000003e syscall=
314 compat=0 lp=0x7fd4ebd3e73d code=0x50000
153.388872 audit: type=1326 audit(1677929167.791:71): auid=1000 uid=1000 gid=1000 ses=3 subj=snap.snap-store.snap-store (enforce) pid=2873 comm="
snap-store" exe="/snap/snap-store/638/usr/bin/snap-store" sig=0 arch=c000003e syscall=314 compat=0 lp=0x7fd432661f73d code=0x50000
157.734858 audit: type=1400 audit(1677929172.137:72): apparmor="DENIED" operation="open" profile="snap.snap-store.snap-store" name="/etc/PackageKl
t/Vendor.conf" pid=2873 comm="snap-store" requested_mask="r" denied_mask="r" fsuid=1000 ouid=0
158.943051 audit: type=1400 audit(1677929173.344:73): apparmor="DENIED" operation="open" profile="snap.snap-store.snap-store" name="/etc/appstream
.conf" pid=2873 comm="snap-store" requested_mask="r" denied_mask="r" fsuid=1000 ouid=0
182.150642 audit: type=1400 audit(1677929196.467:74): apparmor="DENIED" operation="capable" profile="/snap/snapd/18357/usr/lib/snapd/snap-confine"
pid=3796 comm="snap-confine" capability=12 capname="net_admin"
182.150655 audit: type=1400 audit(1677929196.467:75): apparmor="DENIED" operation="capable" profile="/snap/snapd/18357/usr/lib/snapd/snap-confine"
pid=3796 comm="snap-confine" capability=38 capname="perfmon"
182.398117 audit: type=1400 audit(1677929196.614:76): apparmor="DENIED" operation="open" profile="snap-update-ns.firefox" name="/var/lib/" pid=373
3 comm="5" requested_mask="r" denied_mask="r" fsuid=0 ouid=0
182.322581 audit: type=1400 audit(1677929196.638:77): apparmor="DENIED" operation="open" profile="snap-update-ns.firefox" name="/var/lib/" pid=373
3 comm="5" requested_mask="r" denied_mask="r" fsuid=0 ouid=0
183.084797 audit: type=1326 audit(1677929207.065:78): auid=1000 uid=1000 gid=1000 ses=3 subj=snap.firefox.firefox (enforce) pid=3796 comm="firefo
x" exe="/snap/firefox/2391/usr/lib/firefox/firefox" sig=0 arch=c000003e syscall=314 compat=0 lp=0x7fd6aeb5b173d code=0x50000
159.487729 Hello World
mohammadyehya@K213309:~/Desktop$
```