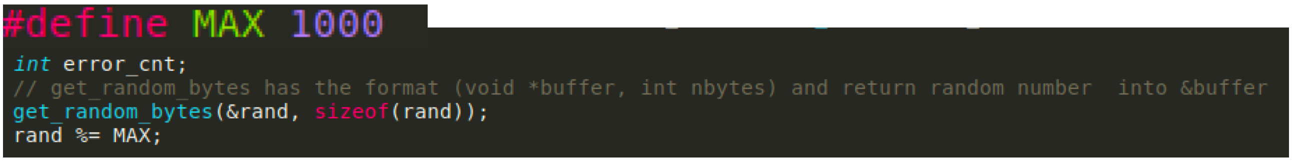
Kernel Module:
To generate random number, we use *get_random_bytes* function from <linux/random.h> library. Moreover, we limit random number which less than MAX by getting remainder of this number and MAX



```
#define MAX 1000
int error_cnt;
// get_random_bytes has the format (void *buffer, int nbytes) and return random number  into &buffer
get_random_bytes(&rand, sizeof(rand));
rand %= MAX;
```

Functions	**Mean**
static int __init RandomNumber_Init(void	**__int** means that is for a built-driver and function is only used at initialization time and it will be discard when memory will be freed
static void __exit RandomNumber_Exit(void)	**__exit:** this function will be run when process is killed
static int device_open(struct inode *inodep, struct file *filep)	This function will be run every time when our device is opened by user process
static int device_release(struct inode *inodep, struct file *filep)	This function will be run every time when our device is closed by user process
static ssize_t device_read(struct file *filep, char* usr_space, size_t len, loff_t* offset)	This function will be run when user process want to read from our device This function will generate a random integer number which less than MAX (I define MAX in top kernel program) and then copy this number to the buffer of user-space by *copy_to_user* function
unsigned long copy_to_user (void user* user_space_buffer, const void* kernel_space_buffer, unsigned long numBytes)	This function run in **device_read** function. It will copy data from *kernel_sapce_buffer* to *user_space_buffer* and return 0 when it success

User Program:

Functions	**Mean**
open("/dev/RandomNumberDevice", O_RDONLY)	This function is used for open operation of the device driver We open device with read-only access
read(fd, &randNum, sizeof(randNum))	This function invokes read operation of the device driver and the user-space will read random number generated by the device and copy it to user buffer.

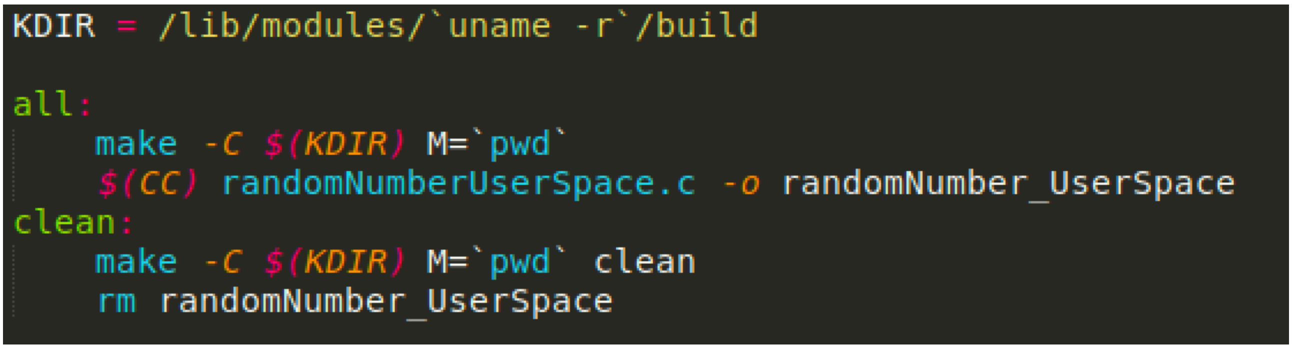
How to build:

+ Run the *make* command: **make**
+ Load new module from *randomNumberModule.ko* by command:
  sudo insmod randomNumberModule.ko
+ If you want to unload the module *randomNumberModule.ko,* run the command:
  sudo rmmod randomNumberModule.ko

How to run from user-space: You need to run *randomNumber_UserSpace* file and your result will be displayed in your terminal: **sudo ./randomNumber_UserSpace**

Screenshots:

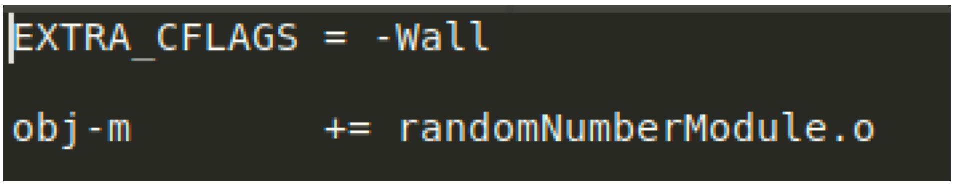
+ Makefile:



```
KDIR = /lib/modules/`uname -r`/build

all:
    make -C $(KDIR) M=`pwd`
    $(CC) randomNumberUserSpace.c -o randomNumber_UserSpace
clean:
    make -C $(KDIR) M=`pwd` clean
    rm randomNumber_UserSpace
```

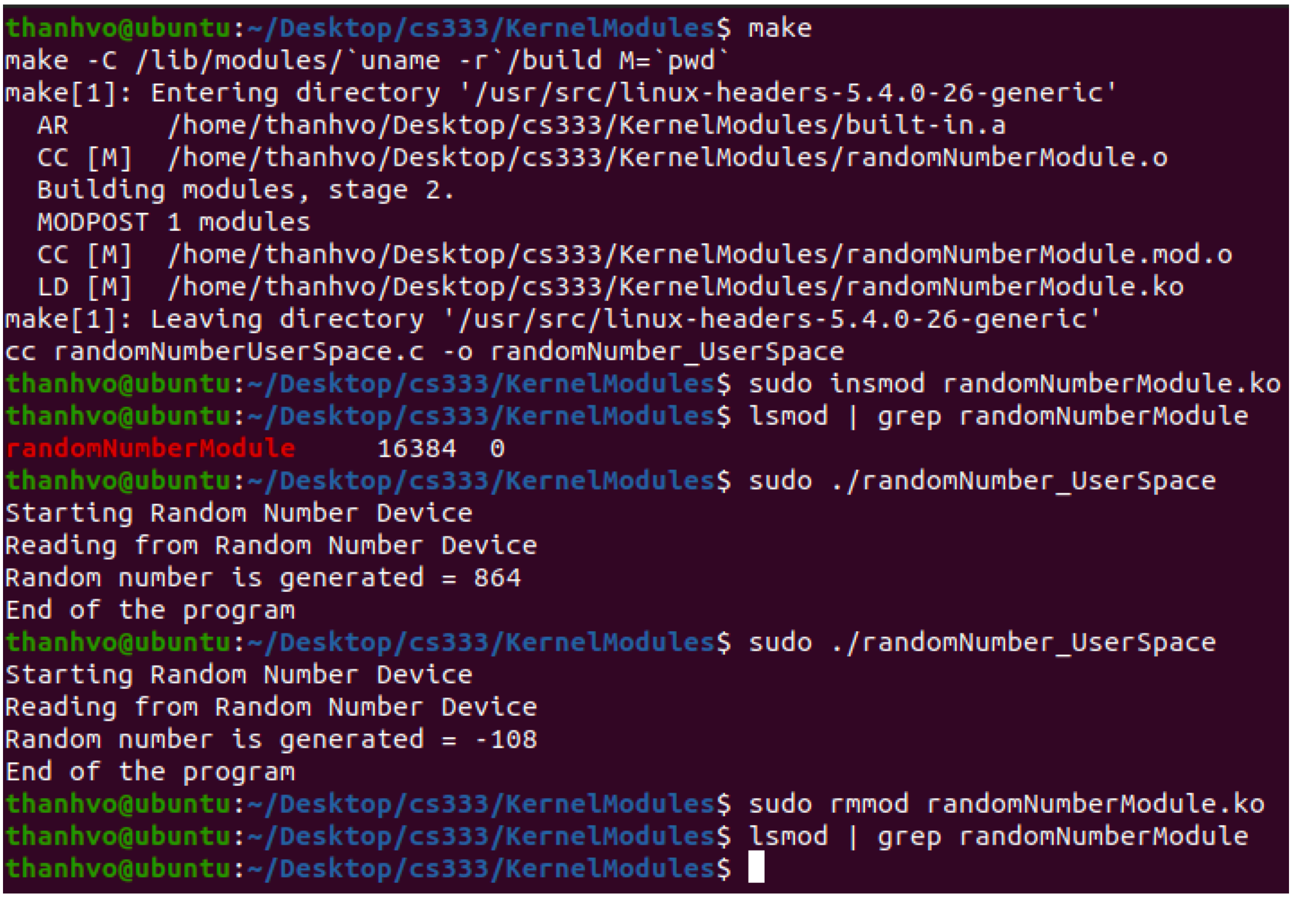
+ Kbuild:



```
EXTRA_CFLAGS = -Wall

obj-m        += randomNumberModule.o
```

+ Run code on terminal to execute code and display **random number**:



```
thanhvo@ubuntu:~/Desktop/cs333/KernelModules$ make
make -C /lib/modules/`uname -r`/build M=`pwd`
make[1]: Entering directory '/usr/src/linux-headers-5.4.0-26-generic'
  AR      /home/thanhvo/Desktop/cs333/KernelModules/built-in.a
  CC [M]  /home/thanhvo/Desktop/cs333/KernelModules/randomNumberModule.o
  Building modules, stage 2.
  MODPOST 1 modules
  CC [M]  /home/thanhvo/Desktop/cs333/KernelModules/randomNumberModule.mod.o
  LD [M]  /home/thanhvo/Desktop/cs333/KernelModules/randomNumberModule.ko
make[1]: Leaving directory '/usr/src/linux-headers-5.4.0-26-generic'
cc randomNumberUserSpace.c -o randomNumber_UserSpace
thanhvo@ubuntu:~/Desktop/cs333/KernelModules$ sudo insmod randomNumberModule.ko
thanhvo@ubuntu:~/Desktop/cs333/KernelModules$ lsmod | grep randomNumberModule
randomNumberModule     16384  0
thanhvo@ubuntu:~/Desktop/cs333/KernelModules$ sudo ./randomNumber_UserSpace
Starting Random Number Device
Reading from Random Number Device
Random number is generated = 864
End of the program
thanhvo@ubuntu:~/Desktop/cs333/KernelModules$ sudo ./randomNumber_UserSpace
Starting Random Number Device
Reading from Random Number Device
Random number is generated = -108
End of the program
thanhvo@ubuntu:~/Desktop/cs333/KernelModules$ sudo rmmod randomNumberModule.ko
thanhvo@ubuntu:~/Desktop/cs333/KernelModules$ lsmod | grep randomNumberModule
thanhvo@ubuntu:~/Desktop/cs333/KernelModules$ 
```