

Hands-on Session

- ◀ Create a Linux device driver

Exercise 8: Creating a Linux Device Driver

- ◀ We will use the red LEDs and pushbuttons
- ◀ The program increments the value displayed on the LEDs when a pushbutton is pressed

Kernel Module - Initialization

```
void * lwbridgebase;

static int __init initialize_pushbutton_handler(void)
{
    // get the virtual addr that maps to 0xff200000
    lwbridgebase = ioremap_nocache(0xff200000, 0x200000);
    // Set LEDs to 0x200 (the leftmost LED will turn on)
    iowrite32(0x200, lwbridgebase);
    // Clear the PIO edgecapture register (clear any pending interrupt)
    iowrite32(0xf, lwbridgebase+0x5c);
    // Enable IRQ generation for the 4 buttons
    iowrite32(0xf, lwbridgebase+0x58);

    // Register the interrupt handler.
    return request_irq(73, (irq_handler_t)irq_handler,
        IRQF_SHARED, "pushbutton_irq_handler",
        (void *)(irq_handler));
}

module_init(initialize_pushbutton_handler);
```

Kernel Module – Interrupt Handler

```
irq_handler_t irq_handler(int irq, void *dev_id, struct pt_regs *regs)
{
    // Increment the value on the LEDs
    iowrite32(ioread32(lwbridgebase)+1,lwbridgebase);
    // Clear the edgecapture register (clears current interrupt)
    iowrite32(0xf,lwbridgebase+0x5c);

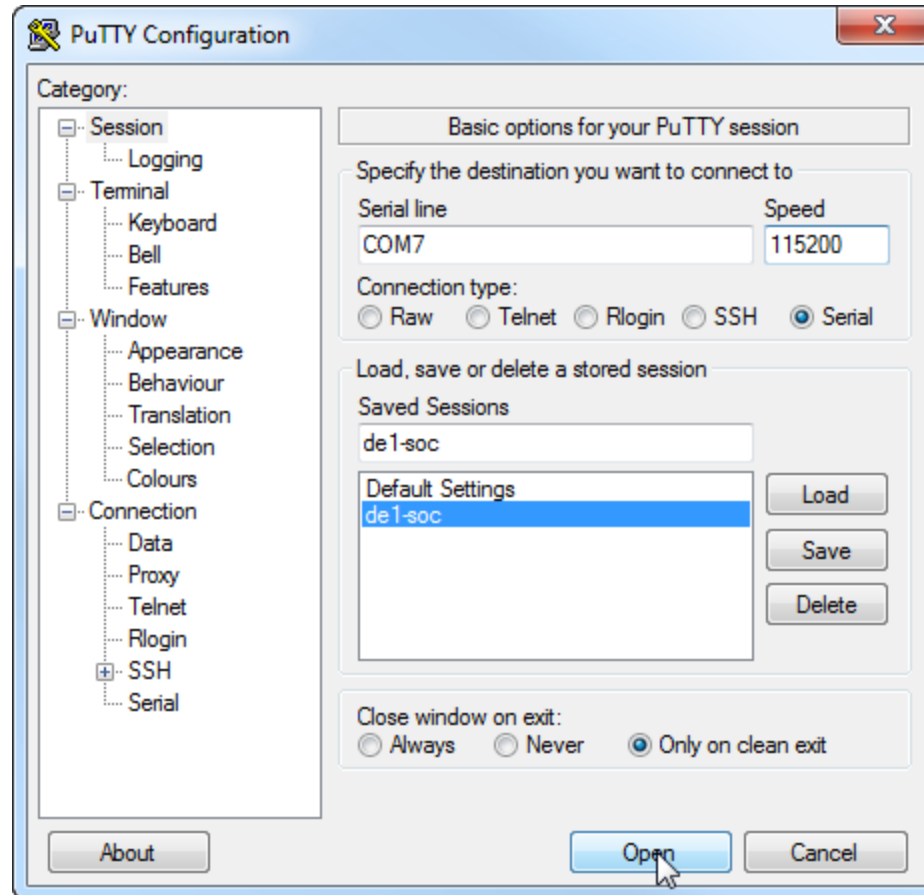
    return (irq_handler_t) IRQ_HANDLED;
}
```

Kernel Module – Exit Routine

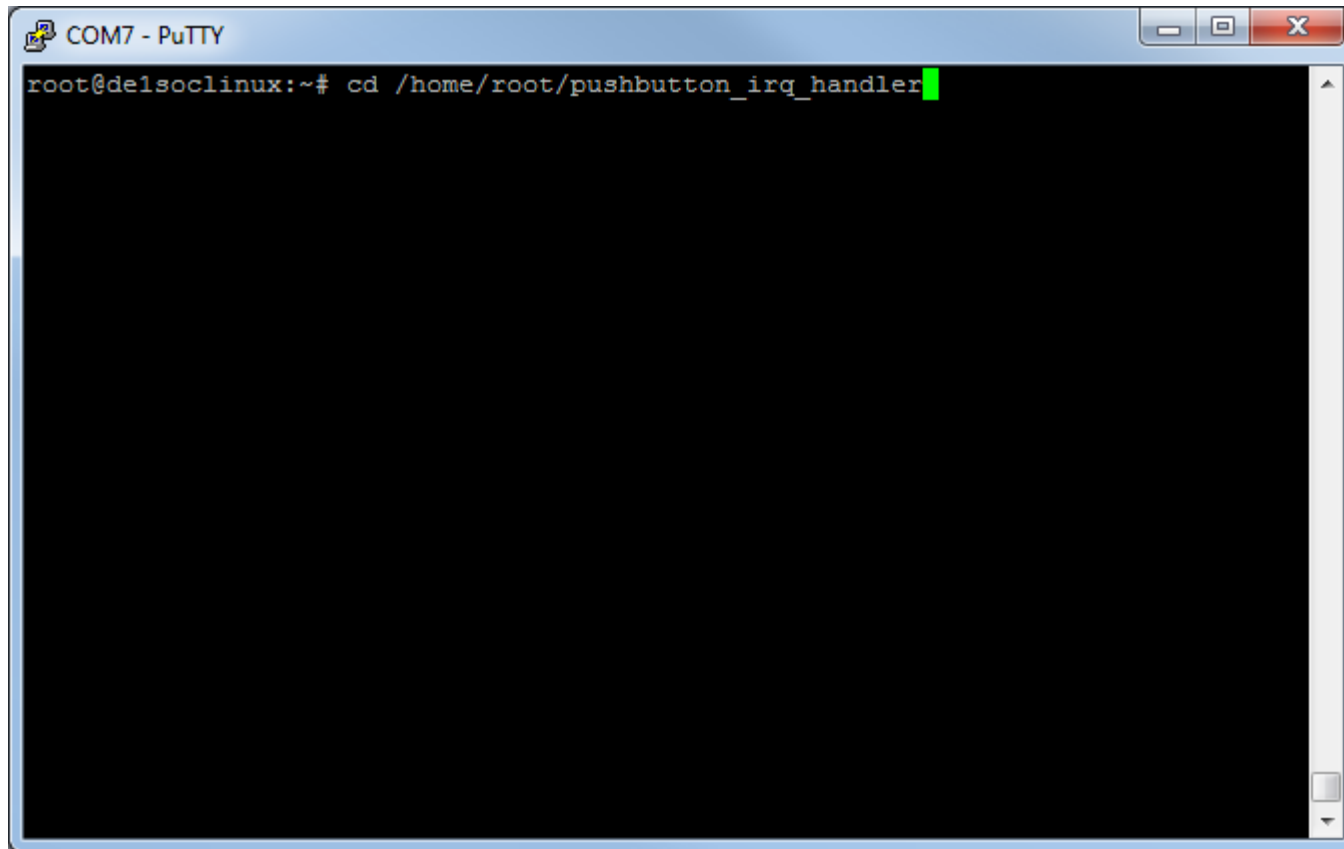
```
static void __exit cleanup_pushbutton_handler(void)
{
    // Turn off LEDs and de-register irq handler
    iowrite32(0x0, lwbridgebase);
    free_irq(73, (void*) irq_handler);
}

module_exit(cleanup_pushbutton_handler);
```

Step 1: Open the Connection to the DE1-SoC using Putty

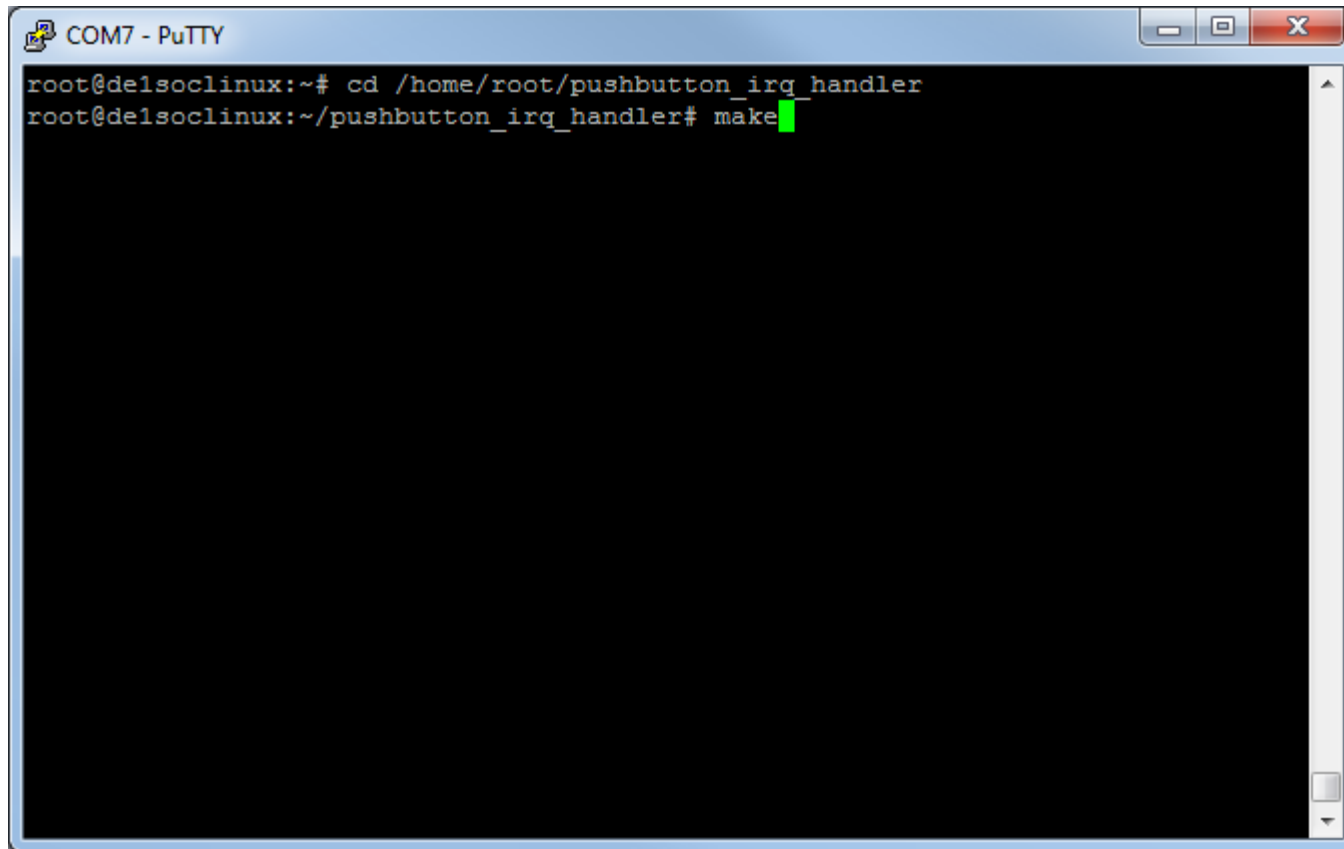


Step 2: Change to the Example Directory



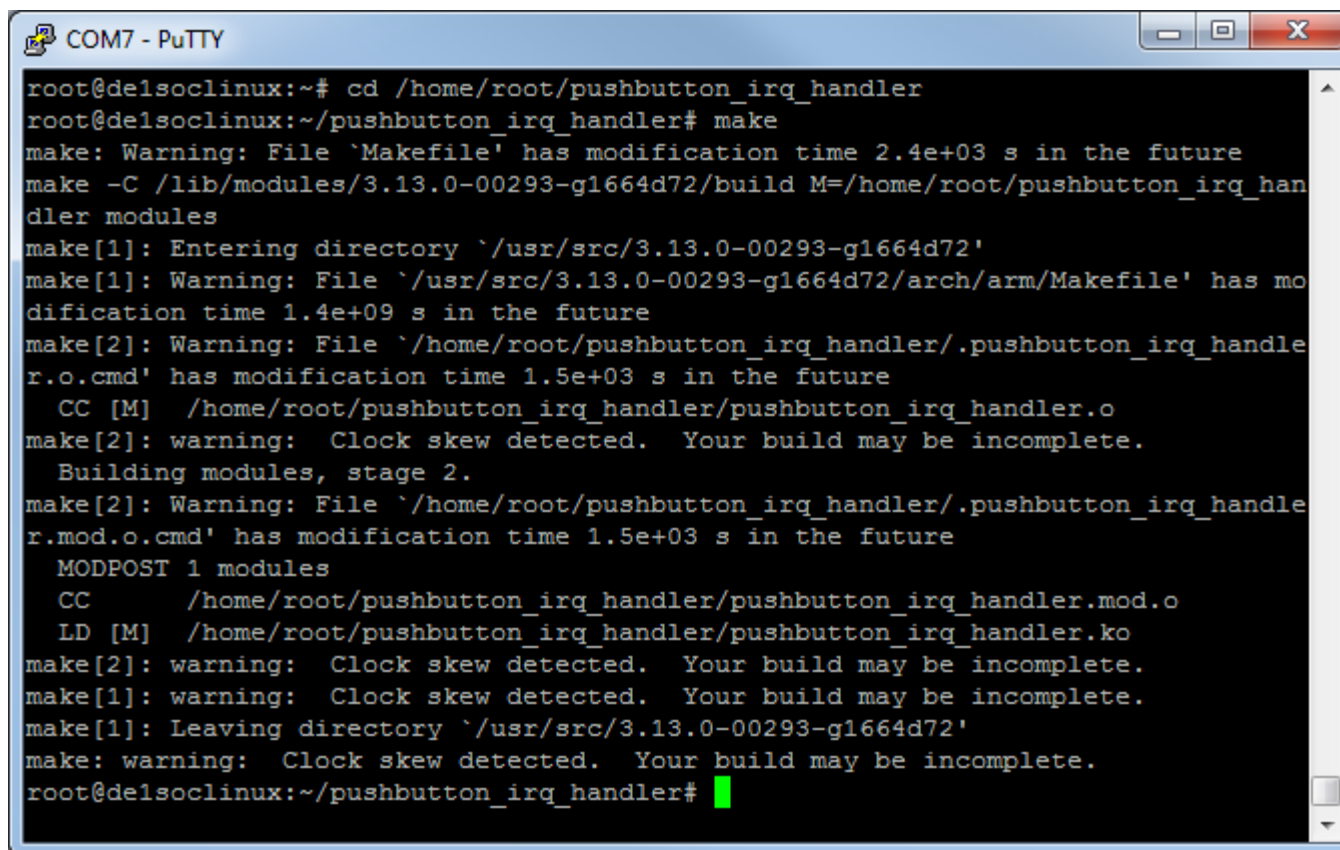
```
COM7 - PuTTY
root@delsoclinux:~# cd /home/root/pushbutton_irq_handler
```

Step 3: Compile the Sample Program



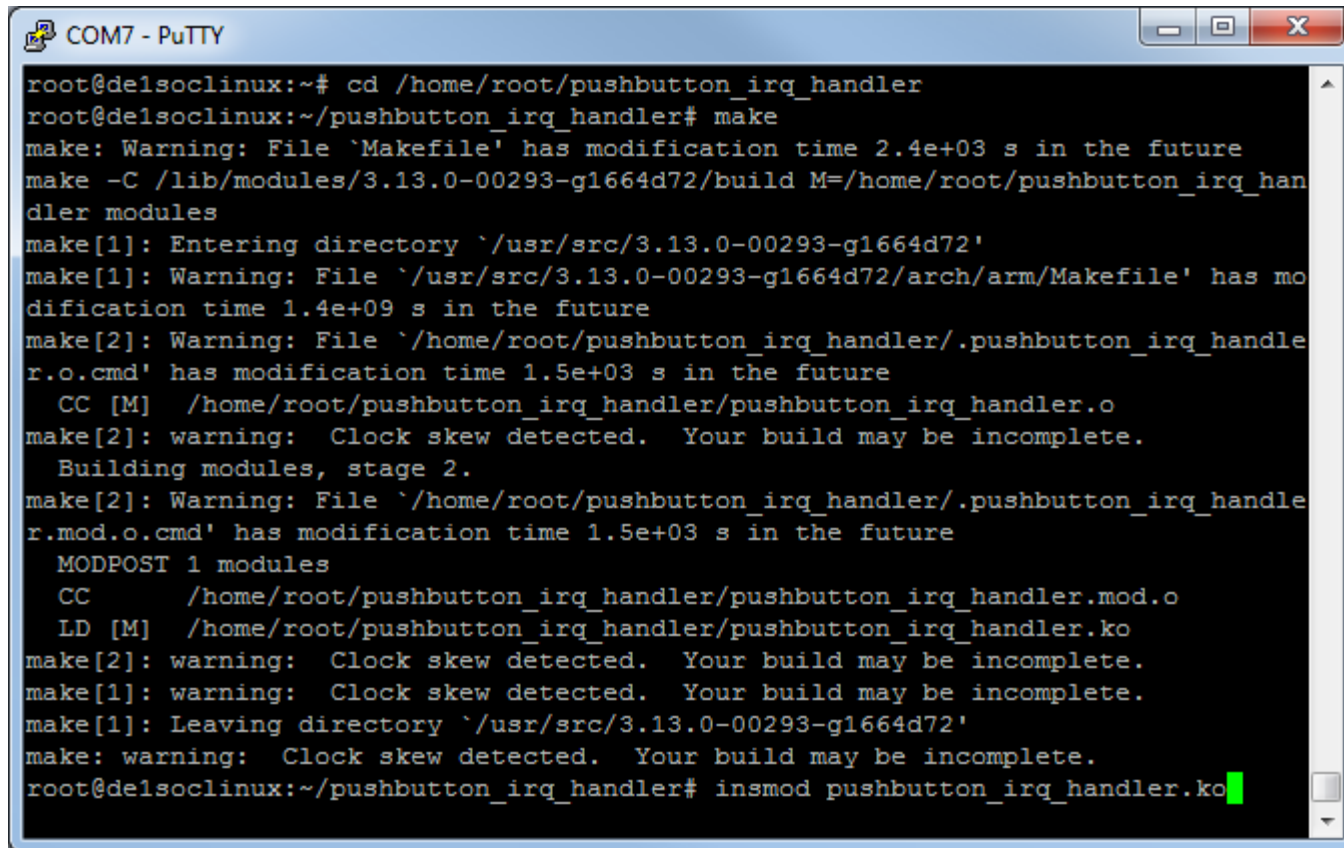
```
COM7 - PuTTY
root@delsoclinux:~# cd /home/root/pushbutton_irq_handler
root@delsoclinux:~/pushbutton_irq_handler# make
```


Step 4: Compilation Complete



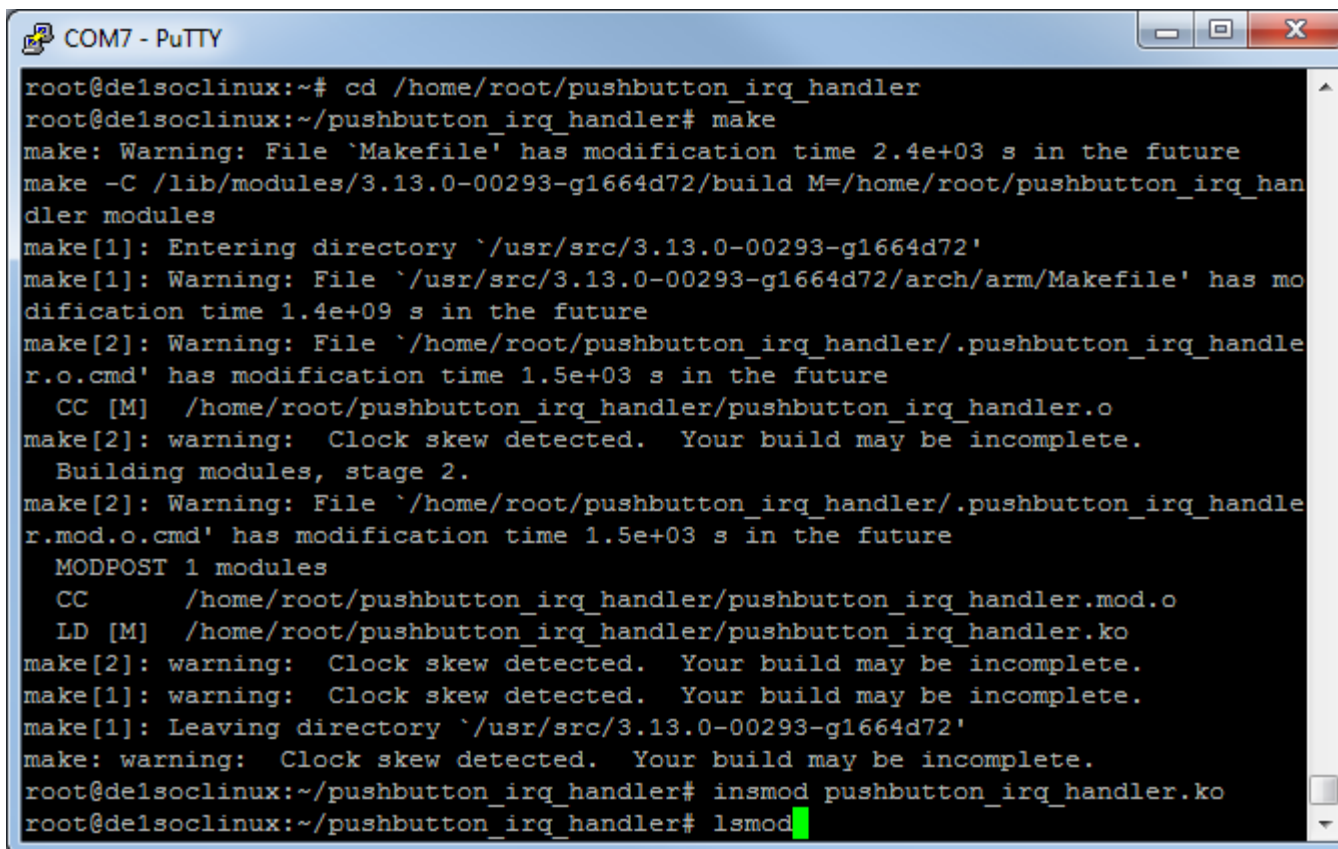
```
COM7 - PuTTY
root@delsoclinux:~# cd /home/root/pushbutton_irq_handler
root@delsoclinux:~/pushbutton_irq_handler# make
make: Warning: File `Makefile' has modification time 2.4e+03 s in the future
make -C /lib/modules/3.13.0-00293-g1664d72/build M=/home/root/pushbutton_irq_handler modules
make[1]: Entering directory `/usr/src/3.13.0-00293-g1664d72'
make[1]: Warning: File `/usr/src/3.13.0-00293-g1664d72/arch/arm/Makefile' has modification time 1.4e+09 s in the future
make[2]: Warning: File `/home/root/pushbutton_irq_handler/.pushbutton_irq_handler.o.cmd' has modification time 1.5e+03 s in the future
  CC [M] /home/root/pushbutton_irq_handler/pushbutton_irq_handler.o
make[2]: warning: Clock skew detected. Your build may be incomplete.
  Building modules, stage 2.
make[2]: Warning: File `/home/root/pushbutton_irq_handler/.pushbutton_irq_handler.mod.o.cmd' has modification time 1.5e+03 s in the future
  MODPOST 1 modules
  CC      /home/root/pushbutton_irq_handler/pushbutton_irq_handler.mod.o
  LD [M] /home/root/pushbutton_irq_handler/pushbutton_irq_handler.ko
make[2]: warning: Clock skew detected. Your build may be incomplete.
make[1]: warning: Clock skew detected. Your build may be incomplete.
make[1]: Leaving directory `/usr/src/3.13.0-00293-g1664d72'
make: warning: Clock skew detected. Your build may be incomplete.
root@delsoclinux:~/pushbutton_irq_handler#
```

Step 5: Insert Newly Compiled Kernel Module into Linux



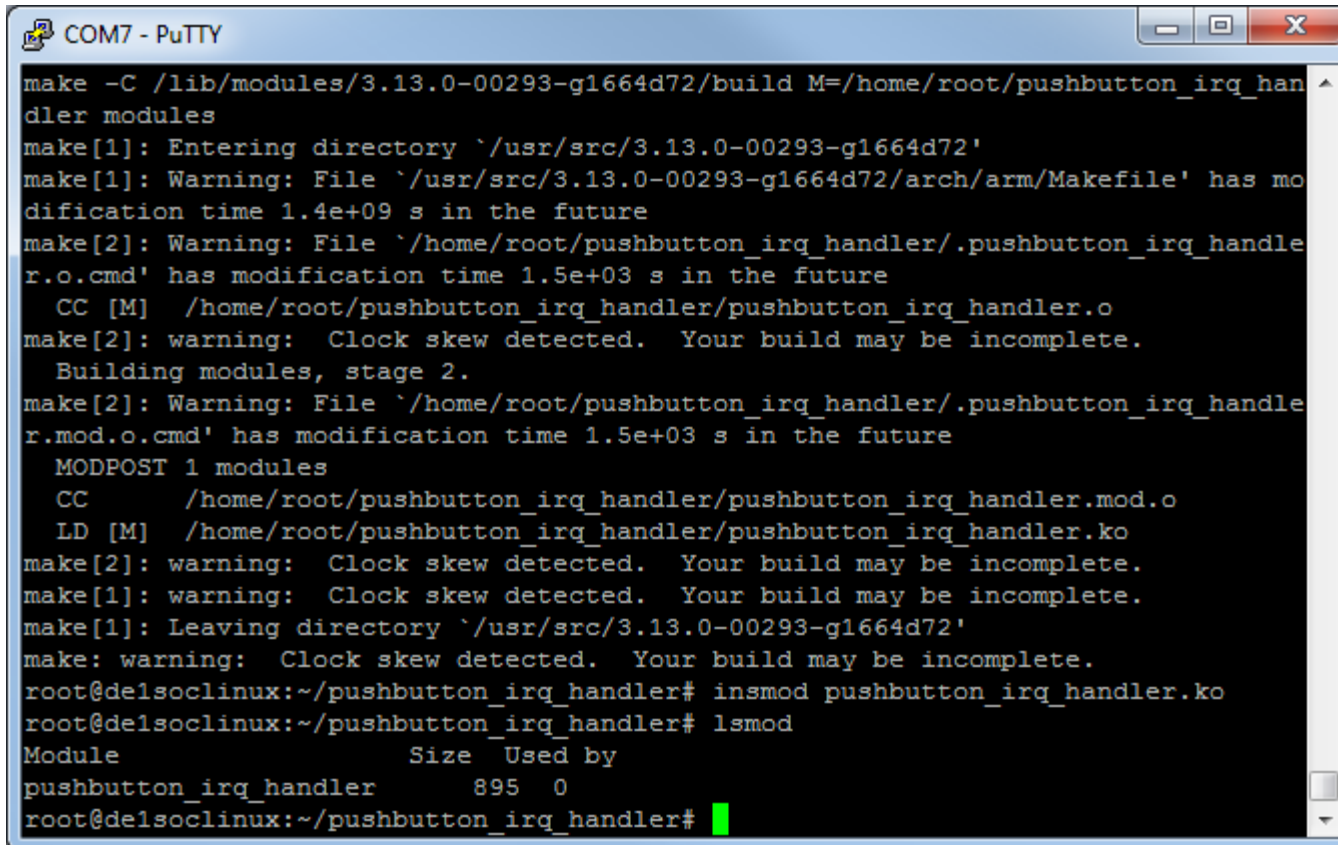
```
root@delsoclinux:~# cd /home/root/pushbutton_irq_handler
root@delsoclinux:~/pushbutton_irq_handler# make
make: Warning: File `Makefile' has modification time 2.4e+03 s in the future
make -C /lib/modules/3.13.0-00293-g1664d72/build M=/home/root/pushbutton_irq_handler modules
make[1]: Entering directory `/usr/src/3.13.0-00293-g1664d72'
make[1]: Warning: File `/usr/src/3.13.0-00293-g1664d72/arch/arm/Makefile' has modification time 1.4e+09 s in the future
make[2]: Warning: File `/home/root/pushbutton_irq_handler/.pushbutton_irq_handler.o.cmd' has modification time 1.5e+03 s in the future
  CC [M] /home/root/pushbutton_irq_handler/pushbutton_irq_handler.o
make[2]: warning: Clock skew detected. Your build may be incomplete.
  Building modules, stage 2.
make[2]: Warning: File `/home/root/pushbutton_irq_handler/.pushbutton_irq_handler.mod.o.cmd' has modification time 1.5e+03 s in the future
  MODPOST 1 modules
  CC      /home/root/pushbutton_irq_handler/pushbutton_irq_handler.mod.o
  LD [M] /home/root/pushbutton_irq_handler/pushbutton_irq_handler.ko
make[2]: warning: Clock skew detected. Your build may be incomplete.
make[1]: warning: Clock skew detected. Your build may be incomplete.
make[1]: Leaving directory `/usr/src/3.13.0-00293-g1664d72'
make: warning: Clock skew detected. Your build may be incomplete.
root@delsoclinux:~/pushbutton_irq_handler# insmod pushbutton_irq_handler.ko
```

Step 6: Run 'lsmod' to See All Loaded Kernel Modules



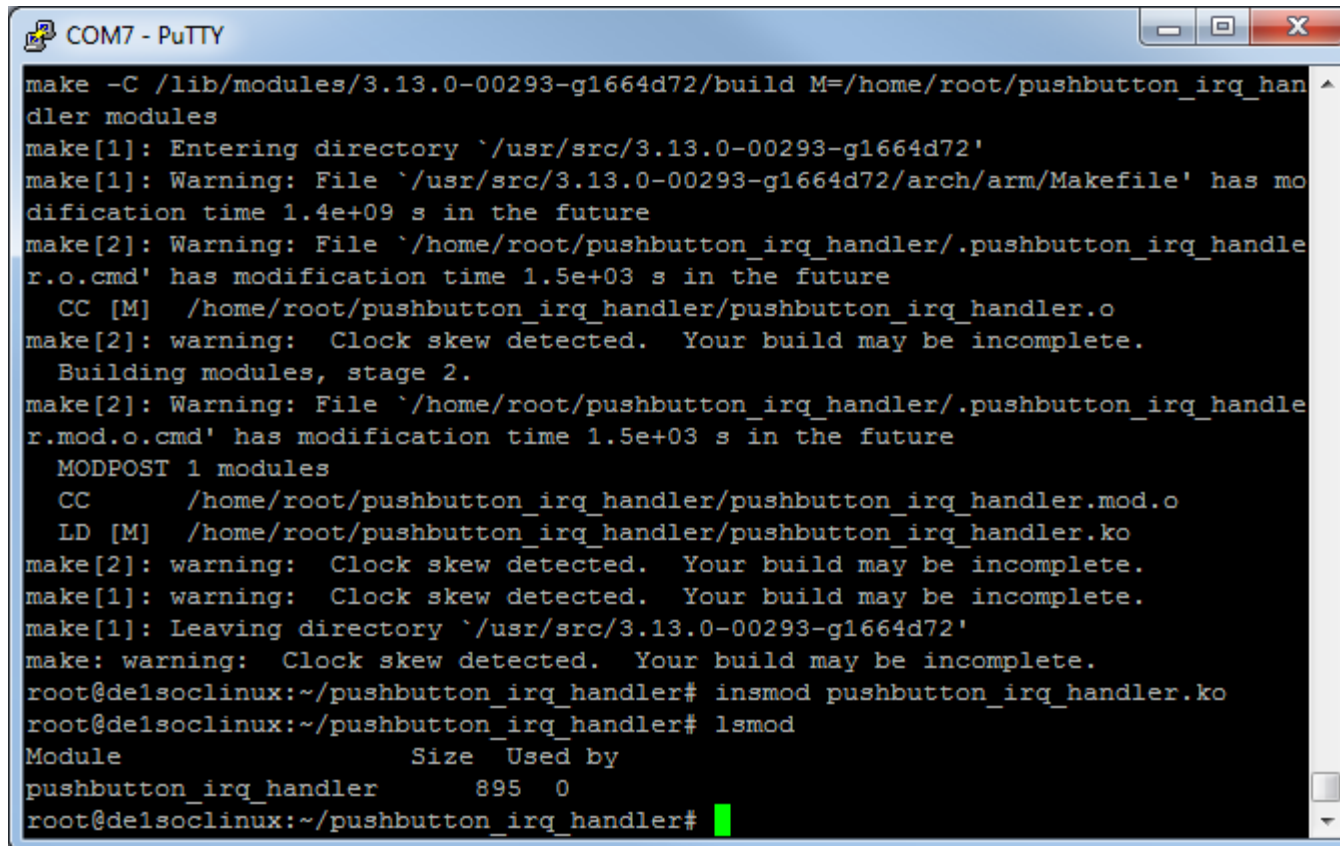
```
root@delsoclinux:~# cd /home/root/pushbutton_irq_handler
root@delsoclinux:~/pushbutton_irq_handler# make
make: Warning: File `Makefile' has modification time 2.4e+03 s in the future
make -C /lib/modules/3.13.0-00293-g1664d72/build M=/home/root/pushbutton_irq_handler modules
make[1]: Entering directory `/usr/src/3.13.0-00293-g1664d72'
make[1]: Warning: File `/usr/src/3.13.0-00293-g1664d72/arch/arm/Makefile' has modification time 1.4e+09 s in the future
make[2]: Warning: File `/home/root/pushbutton_irq_handler/.pushbutton_irq_handler.o.cmd' has modification time 1.5e+03 s in the future
  CC [M] /home/root/pushbutton_irq_handler/pushbutton_irq_handler.o
make[2]: warning: Clock skew detected. Your build may be incomplete.
  Building modules, stage 2.
make[2]: Warning: File `/home/root/pushbutton_irq_handler/.pushbutton_irq_handler.mod.o.cmd' has modification time 1.5e+03 s in the future
  MODPOST 1 modules
  CC /home/root/pushbutton_irq_handler/pushbutton_irq_handler.mod.o
  LD [M] /home/root/pushbutton_irq_handler/pushbutton_irq_handler.ko
make[2]: warning: Clock skew detected. Your build may be incomplete.
make[1]: warning: Clock skew detected. Your build may be incomplete.
make[1]: Leaving directory `/usr/src/3.13.0-00293-g1664d72'
make: warning: Clock skew detected. Your build may be incomplete.
root@delsoclinux:~/pushbutton_irq_handler# insmod pushbutton_irq_handler.ko
root@delsoclinux:~/pushbutton_irq_handler# lsmod
```

Step 6: The Pushbutton IRQ Handler was Loaded



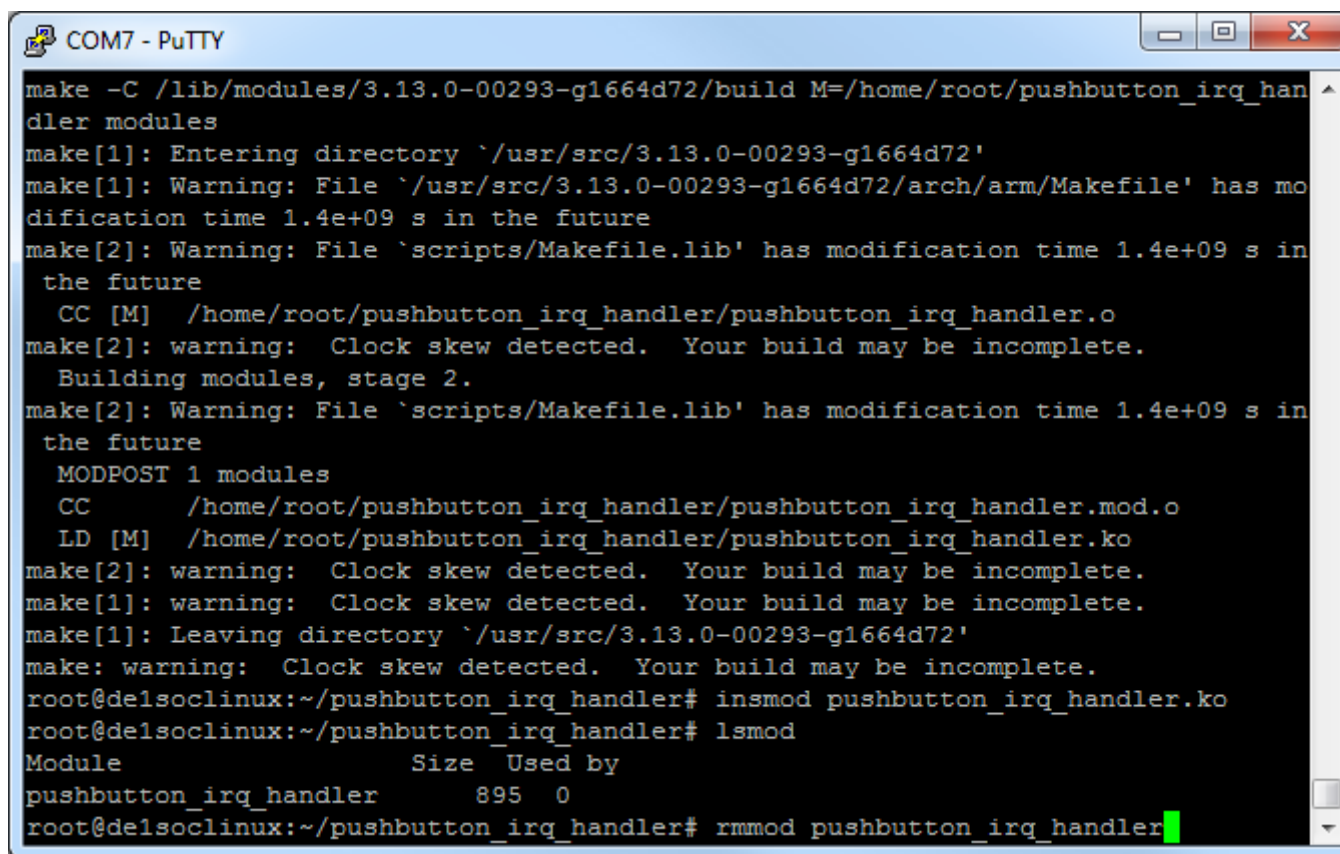
```
make -C /lib/modules/3.13.0-00293-g1664d72/build M=/home/root/pushbutton_irq_handler modules
make[1]: Entering directory `/usr/src/3.13.0-00293-g1664d72'
make[1]: Warning: File `/usr/src/3.13.0-00293-g1664d72/arch/arm/Makefile' has modification time 1.4e+09 s in the future
make[2]: Warning: File `/home/root/pushbutton_irq_handler/.pushbutton_irq_handler.o.cmd' has modification time 1.5e+03 s in the future
  CC [M] /home/root/pushbutton_irq_handler/pushbutton_irq_handler.o
make[2]: warning: Clock skew detected. Your build may be incomplete.
  Building modules, stage 2.
make[2]: Warning: File `/home/root/pushbutton_irq_handler/.pushbutton_irq_handler.mod.o.cmd' has modification time 1.5e+03 s in the future
  MODPOST 1 modules
  CC      /home/root/pushbutton_irq_handler/pushbutton_irq_handler.mod.o
  LD [M] /home/root/pushbutton_irq_handler/pushbutton_irq_handler.ko
make[2]: warning: Clock skew detected. Your build may be incomplete.
make[1]: warning: Clock skew detected. Your build may be incomplete.
make[1]: Leaving directory `/usr/src/3.13.0-00293-g1664d72'
make: warning: Clock skew detected. Your build may be incomplete.
root@delsoclinux:~/pushbutton_irq_handler# insmod pushbutton_irq_handler.ko
root@delsoclinux:~/pushbutton_irq_handler# lsmod
Module                  Size Used by
pushbutton_irq_handler    895  0
root@delsoclinux:~/pushbutton_irq_handler#
```

Step 7: Try Toggling the Pushbuttons



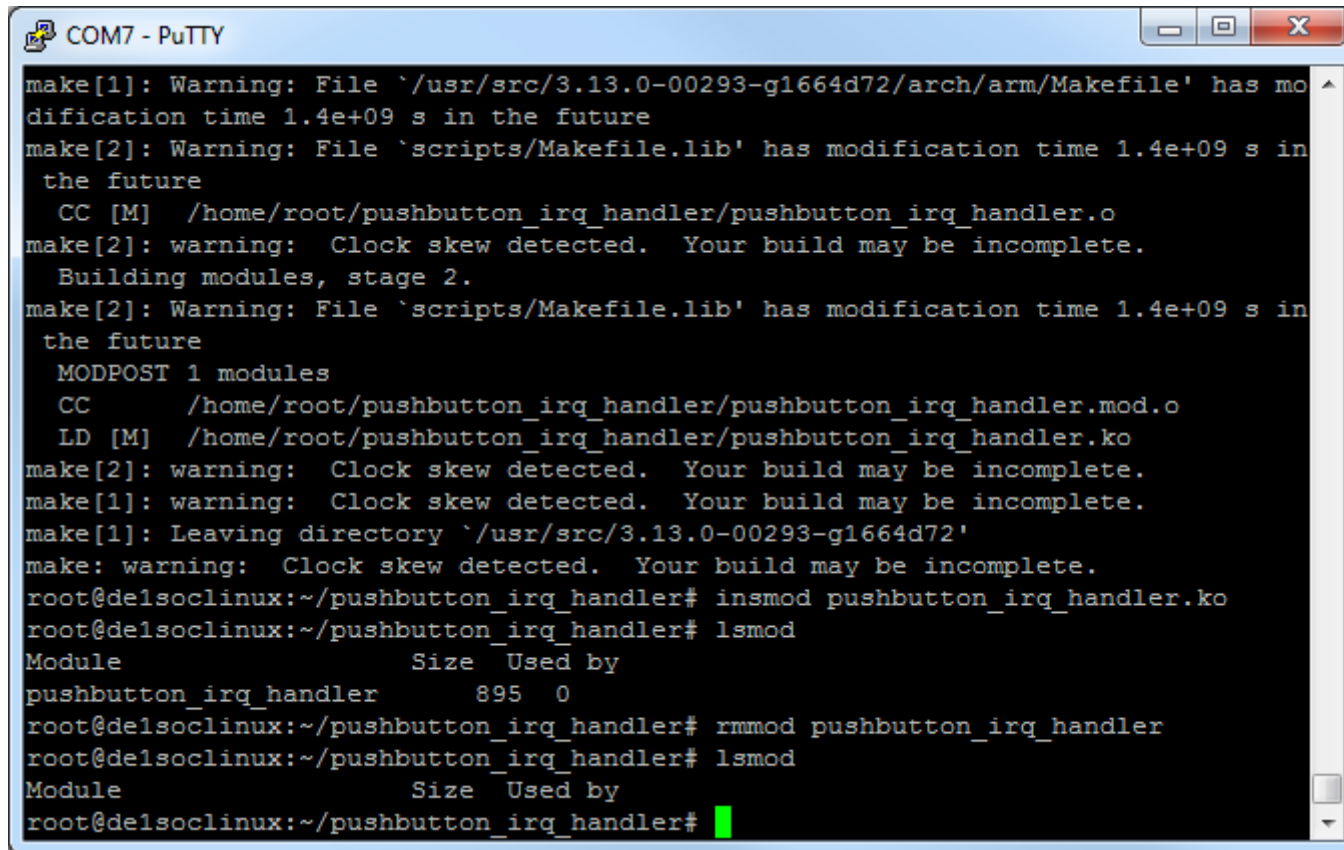
```
COM7 - PuTTY
make -C /lib/modules/3.13.0-00293-g1664d72/build M=/home/root/pushbutton_irq_handler modules
make[1]: Entering directory `/usr/src/3.13.0-00293-g1664d72'
make[1]: Warning: File `/usr/src/3.13.0-00293-g1664d72/arch/arm/Makefile' has modification time 1.4e+09 s in the future
make[2]: Warning: File `/home/root/pushbutton_irq_handler/.pushbutton_irq_handler.o.cmd' has modification time 1.5e+03 s in the future
  CC [M] /home/root/pushbutton_irq_handler/pushbutton_irq_handler.o
make[2]: warning: Clock skew detected. Your build may be incomplete.
  Building modules, stage 2.
make[2]: Warning: File `/home/root/pushbutton_irq_handler/.pushbutton_irq_handler.mod.o.cmd' has modification time 1.5e+03 s in the future
  MODPOST 1 modules
  CC /home/root/pushbutton_irq_handler/pushbutton_irq_handler.mod.o
  LD [M] /home/root/pushbutton_irq_handler/pushbutton_irq_handler.ko
make[2]: warning: Clock skew detected. Your build may be incomplete.
make[1]: warning: Clock skew detected. Your build may be incomplete.
make[1]: Leaving directory `/usr/src/3.13.0-00293-g1664d72'
make: warning: Clock skew detected. Your build may be incomplete.
root@delsoclinux:~/pushbutton_irq_handler# insmod pushbutton_irq_handler.ko
root@delsoclinux:~/pushbutton_irq_handler# lsmod
Module                  Size Used by
pushbutton_irq_handler    895  0
root@delsoclinux:~/pushbutton_irq_handler#
```

Step 8: Remove the Kernel Module



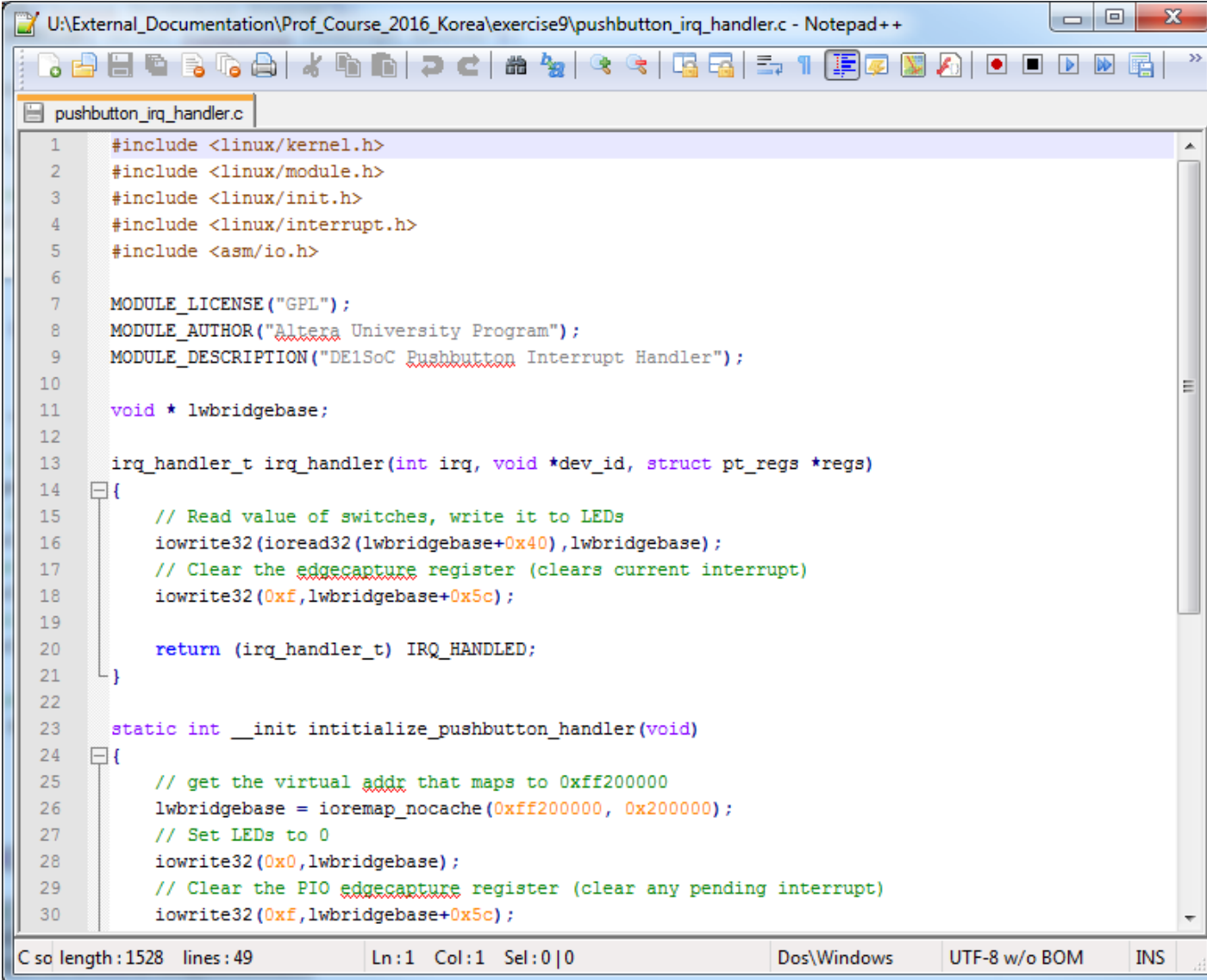
```
make -C /lib/modules/3.13.0-00293-g1664d72/build M=/home/root/pushbutton_irq_handler modules
make[1]: Entering directory `/usr/src/3.13.0-00293-g1664d72'
make[1]: Warning: File `/usr/src/3.13.0-00293-g1664d72/arch/arm/Makefile' has modification time 1.4e+09 s in the future
make[2]: Warning: File `scripts/Makefile.lib' has modification time 1.4e+09 s in the future
  CC [M] /home/root/pushbutton_irq_handler/pushbutton_irq_handler.o
make[2]: warning: Clock skew detected. Your build may be incomplete.
  Building modules, stage 2.
make[2]: Warning: File `scripts/Makefile.lib' has modification time 1.4e+09 s in the future
  MODPOST 1 modules
  CC      /home/root/pushbutton_irq_handler/pushbutton_irq_handler.mod.o
  LD [M] /home/root/pushbutton_irq_handler/pushbutton_irq_handler.ko
make[2]: warning: Clock skew detected. Your build may be incomplete.
make[1]: warning: Clock skew detected. Your build may be incomplete.
make[1]: Leaving directory `/usr/src/3.13.0-00293-g1664d72'
make: warning: Clock skew detected. Your build may be incomplete.
root@delsoclinux:~/pushbutton_irq_handler# insmod pushbutton_irq_handler.ko
root@delsoclinux:~/pushbutton_irq_handler# lsmod
Module                  Size Used by
pushbutton_irq_handler    895  0
root@delsoclinux:~/pushbutton_irq_handler# rmmod pushbutton_irq_handler
```


Step 9: Run 'lsmod' to See All Loaded Kernel Modules



```
COM7 - PuTTY
make[1]: Warning: File `/usr/src/3.13.0-00293-g1664d72/arch/arm/Makefile' has modification time 1.4e+09 s in the future
make[2]: Warning: File `scripts/Makefile.lib' has modification time 1.4e+09 s in the future
  CC [M] /home/root/pushbutton_irq_handler/pushbutton_irq_handler.o
make[2]: warning: Clock skew detected. Your build may be incomplete.
  Building modules, stage 2.
make[2]: Warning: File `scripts/Makefile.lib' has modification time 1.4e+09 s in the future
  MODPOST 1 modules
  CC      /home/root/pushbutton_irq_handler/pushbutton_irq_handler.mod.o
  LD [M] /home/root/pushbutton_irq_handler/pushbutton_irq_handler.ko
make[2]: warning: Clock skew detected. Your build may be incomplete.
make[1]: warning: Clock skew detected. Your build may be incomplete.
make[1]: Leaving directory `/usr/src/3.13.0-00293-g1664d72'
make: warning: Clock skew detected. Your build may be incomplete.
root@delsoclinux:~/pushbutton_irq_handler# insmod pushbutton_irq_handler.ko
root@delsoclinux:~/pushbutton_irq_handler# lsmod
Module                  Size Used by
pushbutton_irq_handler    895  0
root@delsoclinux:~/pushbutton_irq_handler# rmmod pushbutton_irq_handler
root@delsoclinux:~/pushbutton_irq_handler# lsmod
Module                  Size Used by
root@delsoclinux:~/pushbutton_irq_handler#
```

Step 10: Examine the 'pushbutton_irq_handler.c' file



The screenshot shows a Notepad++ window with the file 'pushbutton_irq_handler.c' open. The code is a C program for a Linux kernel module. It includes headers for kernel, module, init, interrupt, and I/O. It defines a module license, author, and description. The main function is 'irq_handler', which reads a switch value, writes it to LEDs, clears the edgecapture register, and returns 'IRQ_HANDLED'. An initialization function '__init initialize_pushbutton_handler' maps a virtual address, sets LEDs to 0, and clears the PIO edgecapture register.

```
1  #include <linux/kernel.h>
2  #include <linux/module.h>
3  #include <linux/init.h>
4  #include <linux/interrupt.h>
5  #include <asm/io.h>
6
7  MODULE_LICENSE("GPL");
8  MODULE_AUTHOR("Altera University Program");
9  MODULE_DESCRIPTION("DE1SoC Pushbutton Interrupt Handler");
10
11 void * lwbridgebase;
12
13 irq_handler_t irq_handler(int irq, void *dev_id, struct pt_regs *regs)
14 {
15     // Read value of switches, write it to LEDs
16     iowrite32(ioread32(lwbridgebase+0x40),lwbridgebase);
17     // Clear the edgecapture register (clears current interrupt)
18     iowrite32(0xf,lwbridgebase+0x5c);
19
20     return (irq_handler_t) IRQ_HANDLED;
21 }
22
23 static int __init initialize_pushbutton_handler(void)
24 {
25     // get the virtual addr that maps to 0xff200000
26     lwbridgebase = ioremap_nocache(0xff200000, 0x200000);
27     // Set LEDs to 0
28     iowrite32(0x0,lwbridgebase);
29     // Clear the PIO edgecapture register (clear any pending interrupt)
30     iowrite32(0xf,lwbridgebase+0x5c);
31 }
```

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