



Zagazig University
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Linux Kernel

Project #1 for the course
Operating Systems

To
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Introduction

Linux Kernel is designed by the methodology of Loadable Kernel Modules. This design approach involves that the kernel has a set of core components and can link in additional services via modules. Linux uses loadable kernel modules to support device drivers and file systems. This approach allows an administrator to add functionality only when required. Keeping only what is necessary for kernel memory reduces the kernel's memory footprint and increases its overall performance.

This programming project will introduce dealing with loadable modules. So, in this project, we will be able to develop a kernel module and inject it into the kernel. We will start first by introducing the different steps showed in the project description then showing the actual assignment attaches with some comments.

Part 1: Loading and Removing Kernel Modules

A- Printing the golden ratio prime and the gcd.

Code:

```
#include <linux/init.h>
#include <linux/module.h>
#include <linux/kernel.h>
#include <linux/hash.h>
#include <linux/gcd.h>
/* This function is called when the module is loaded. */
static int simple_init(void)
{
    printk(KERN_INFO "Loading Module\n");
    printk(KERN_INFO "The Golden Prime Ratio: %lu\n", GOLDEN_RATIO_PRIME);

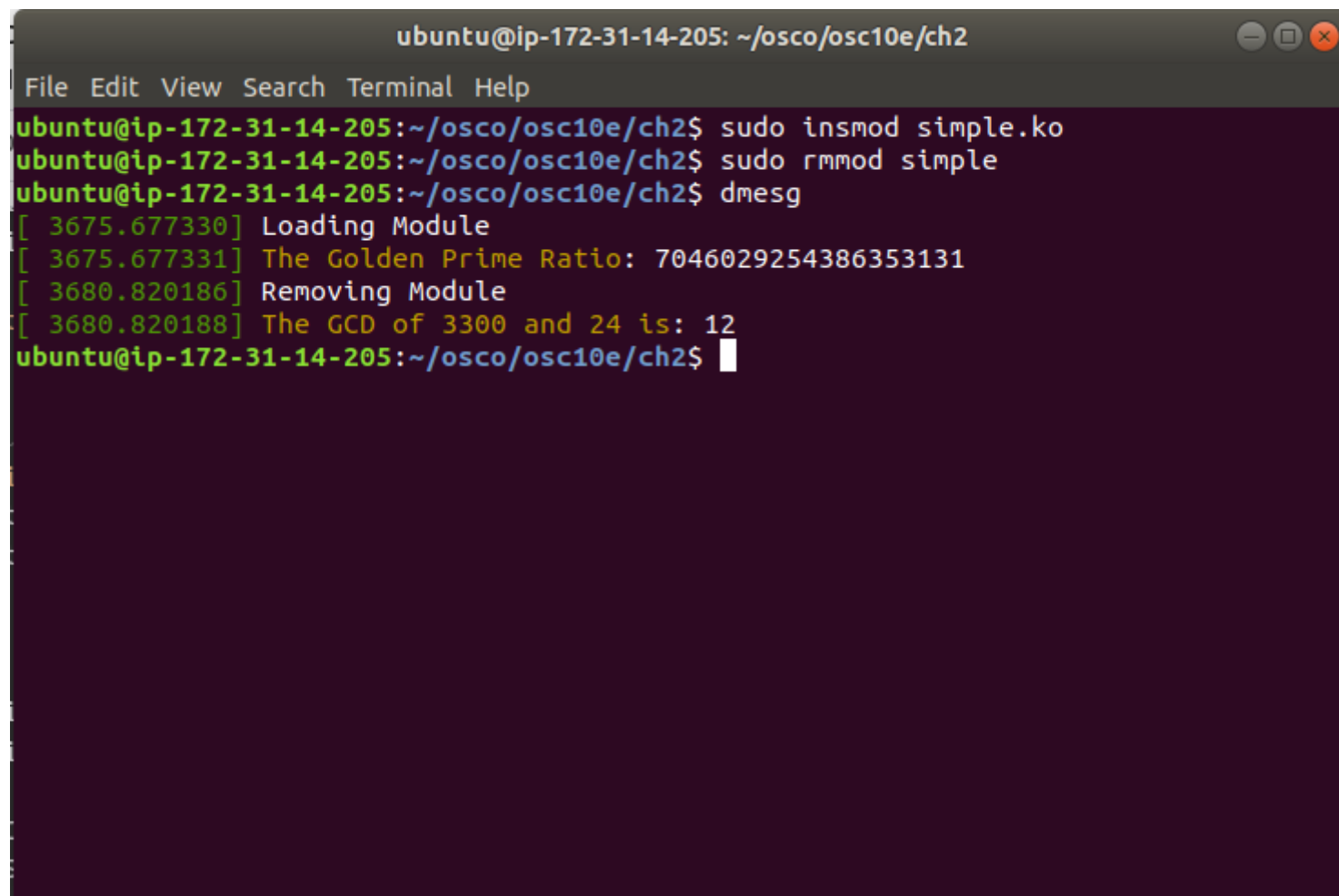
    return 0;
}

/* This function is called when the module is removed. */
static void simple_exit(void) {
    printk(KERN_INFO "Removing Module\n");
    printk(KERN_INFO "The GCD of 3300 and 24 is: %lu\n", gcd(3300, 24));
}

/* Macros for registering module entry and exit points. */
module_init( simple_init );
module_exit( simple_exit );

MODULE_LICENSE("GPL");
MODULE_DESCRIPTION("Simple Module");
MODULE_AUTHOR("Ahmed Moustafa");
```

Preview:

A terminal window titled 'ubuntu@ip-172-31-14-205: ~/osco/osc10e/ch2'. The terminal shows the following commands and output:

```
File Edit View Search Terminal Help
ubuntu@ip-172-31-14-205:~/osco/osc10e/ch2$ sudo insmod simple.ko
ubuntu@ip-172-31-14-205:~/osco/osc10e/ch2$ sudo rmmod simple
ubuntu@ip-172-31-14-205:~/osco/osc10e/ch2$ dmesg
[ 3675.677330] Loading Module
[ 3675.677331] The Golden Prime Ratio: 7046029254386353131
[ 3680.820186] Removing Module
[ 3680.820188] The GCD of 3300 and 24 is: 12
ubuntu@ip-172-31-14-205:~/osco/osc10e/ch2$
```

Comment:

In this section, we have started playing with the kernel module by adding one then removing it. This kernel module has two roles only. The first one is to print the `GOLDEN_PRIME_RATIO` which is found in the "linux/hash.h", the second role is to print the greatest common divisor of 3300 and 24 using the function `gcd` found in "linux/gcd.h". The former is done in the initialization of the module and the second one at the exit. The last picture also provides information about the commands to add and remove modules from the kernel using `insmod` and `rmmod`. `dmesg` is used to show the kernel log.

B- Printing the values of jiffies and HZ.

Code:

```
#include <linux/init.h>
#include <linux/module.h>
#include <linux/kernel.h>
#include <linux/jiffies.h>
#include <asm/param.h>
/* This function is called when the module is loaded. */
static int simple_init(void)
{
    printk(KERN_INFO "Loading Module\n");
    printk(KERN_INFO "HZ Value: %lu\n", HZ);
    printk(KERN_INFO "Jiffies Value: %lu\n", jiffies);
}
```

```

return 0;
}

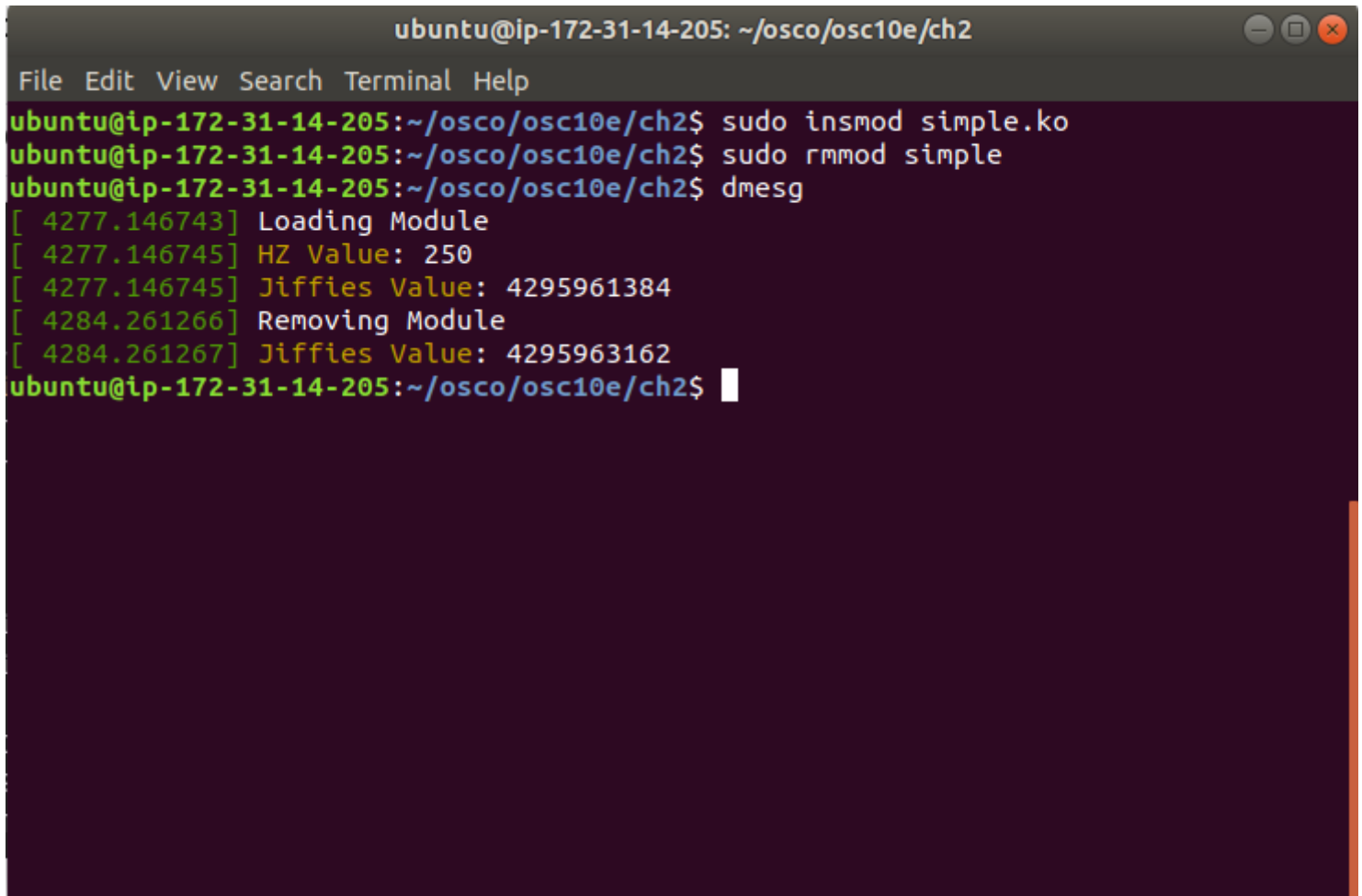
/* This function is called when the module is removed. */
static void simple_exit(void) {
    printk(KERN_INFO "Removing Module\n");
    printk(KERN_INFO "Jiffies Value: %lu\n", jiffies);
}

/* Macros for registering module entry and exit points. */
module_init( simple_init );
module_exit( simple_exit );

MODULE_LICENSE("GPL");
MODULE_DESCRIPTION("Simple Module");
MODULE_AUTHOR("Ahmed Moustafa");

```

Preview:



```

ubuntu@ip-172-31-14-205: ~/osco/osc10e/ch2
File Edit View Search Terminal Help
ubuntu@ip-172-31-14-205:~/osco/osc10e/ch2$ sudo insmod simple.ko
ubuntu@ip-172-31-14-205:~/osco/osc10e/ch2$ sudo rmmod simple
ubuntu@ip-172-31-14-205:~/osco/osc10e/ch2$ dmesg
[ 4277.146743] Loading Module
[ 4277.146745] HZ Value: 250
[ 4277.146745] Jiffies Value: 4295961384
[ 4284.261266] Removing Module
[ 4284.261267] Jiffies Value: 4295963162
ubuntu@ip-172-31-14-205:~/osco/osc10e/ch2$

```

Comment:

Here we have used two libraries for the linux kernel in order to get the values of the timer interrupt frequency (HZ) and the number of interrupts (jiffies). In order to calculate the number of seconds elapsed since the kernel module was loaded, we should subtract both values of jiffies at init and exit then divide the result by HZ.

Part 2: Assignment

A- Design a kernel module that creates a /proc file named /proc/jiffies that reports the current value of jiffies.

Code:

```
#include <linux/init.h>
#include <linux/module.h>
#include <linux/kernel.h>
#include <linux/proc_fs.h>
#include <asm/uaccess.h>
#include <linux/jiffies.h>

#define BUFFER_SIZE 128

#define PROC_NAME "jiffies"

/**
 * Function prototypes
 */
static ssize_t proc_read(struct file *file, char *buf, size_t count, loff_t *pos);

static struct file_operations proc_ops = {
    .owner = THIS_MODULE,
    .read = proc_read,
};

/* This function is called when the module is loaded. */
static int proc_init(void)
{
    // creates the /proc/jiffies entry
    // the following function call is a wrapper for
    // proc_create_data() passing NULL as the last argument
    proc_create(PROC_NAME, 0, NULL, &proc_ops);

    printk(KERN_INFO "/proc/%s created\n", PROC_NAME);

    return 0;
}

/* This function is called when the module is removed. */
static void proc_exit(void) {
    // removes the /proc/jiffies entry
    remove_proc_entry(PROC_NAME, NULL);

    printk( KERN_INFO "/proc/%s removed\n", PROC_NAME);
}
```

```

/**
 * This function is called each time the /proc/jiffies is read.
 *
 * This function is called repeatedly until it returns 0, so
 * there must be logic that ensures it ultimately returns 0
 * once it has collected the data that is to go into the
 * corresponding /proc file.
 *
 * params:
 *
 * file:
 * buf: buffer in user space
 * count:
 * pos:
 */
static ssize_t proc_read(struct file *file, char __user *usr_buf, size_t count,
loff_t *pos)
{
    int rv = 0;
    char buffer[BUFFER_SIZE];
    static int completed = 0;

    if (completed) {
        completed = 0;
        return 0;
    }

    completed = 1;

    rv = sprintf(buffer, "Value of Jiffies: %lu", jiffies);

    // copies the contents of buffer to userspace usr_buf
    raw_copy_to_user(usr_buf, buffer, rv);

    return rv;
}

/* Macros for registering module entry and exit points. */
module_init( proc_init );
module_exit( proc_exit );

MODULE_LICENSE("GPL");
MODULE_DESCRIPTION("Jiffies Module");
MODULE_AUTHOR("Ahmed Moustafa");

```

Preview:

```
ubuntu@ip-172-31-14-205: ~/osco/osc10e/ch2
File Edit View Search Terminal Help
ubuntu@ip-172-31-14-205:~/osco/osc10e/ch2$ sudo insmod jiffies.ko
ubuntu@ip-172-31-14-205:~/osco/osc10e/ch2$ cat /proc/jiffies
Value of Jiffies: 4296607489
ubuntu@ip-172-31-14-205:~/osco/osc10e/ch2$ sudo rmmod jiffies
ubuntu@ip-172-31-14-205:~/osco/osc10e/ch2$ dmesg
[ 6854.610602] /proc/jiffies created
[ 6876.220013] /proc/jiffies removed
ubuntu@ip-172-31-14-205:~/osco/osc10e/ch2$
```

Comment:

Using the already designed code in the textbook, we have added to it the jiffies printing functionality which has been introduced before.

B- Design a kernel module that creates a proc file named /proc/seconds that reports the number of elapsed seconds since the kernel module was loaded.

Code:

```
#include <linux/init.h>
#include <linux/module.h>
#include <linux/kernel.h>
#include <linux/proc_fs.h>
#include <asm/uaccess.h>
#include <linux/jiffies.h>
#include <asm/param.h>

#define BUFFER_SIZE 128

#define PROC_NAME "elapsed-seconds"

unsigned long current_jiffies = 0;
/**
 * Function prototypes
 */
```

```

static ssize_t proc_read(struct file *file, char *buf, size_t count, loff_t *pos);

static struct file_operations proc_ops = {
    .owner = THIS_MODULE,
    .read = proc_read,
};

/* This function is called when the module is loaded. */
static int proc_init(void)
{
    // creates the /proc/elapsed-seconds entry
    // the following function call is a wrapper for
    // proc_create_data() passing NULL as the last argument
    proc_create(PROC_NAME, 0, NULL, &proc_ops);
    current_jiffies = jiffies;
    printk(KERN_INFO "/proc/%s created\n", PROC_NAME);

    return 0;
}

/* This function is called when the module is removed. */
static void proc_exit(void) {
    // removes the /proc/elapsed-seconds entry
    remove_proc_entry(PROC_NAME, NULL);
    printk( KERN_INFO "/proc/%s removed\n", PROC_NAME);
}

/**
 * This function is called each time the /proc/elapsed-seconds is read.
 *
 * This function is called repeatedly until it returns 0, so
 * there must be logic that ensures it ultimately returns 0
 * once it has collected the data that is to go into the
 * corresponding /proc file.
 *
 * params:
 *
 * file:
 * buf: buffer in user space
 * count:
 * pos:
 */
static ssize_t proc_read(struct file *file, char __user *usr_buf, size_t count,
loff_t *pos)
{
    int rv = 0;

```



```

char buffer[BUFFER_SIZE];
static int completed = 0;

if (completed) {
    completed = 0;
    return 0;
}

completed = 1;

rv = sprintf(buffer, "Elapsed Seconds: %lu\n", (jiffies - current_jiffies) /
HZ);

// copies the contents of buffer to userspace usr_buf
raw_copy_to_user(usr_buf, buffer, rv);

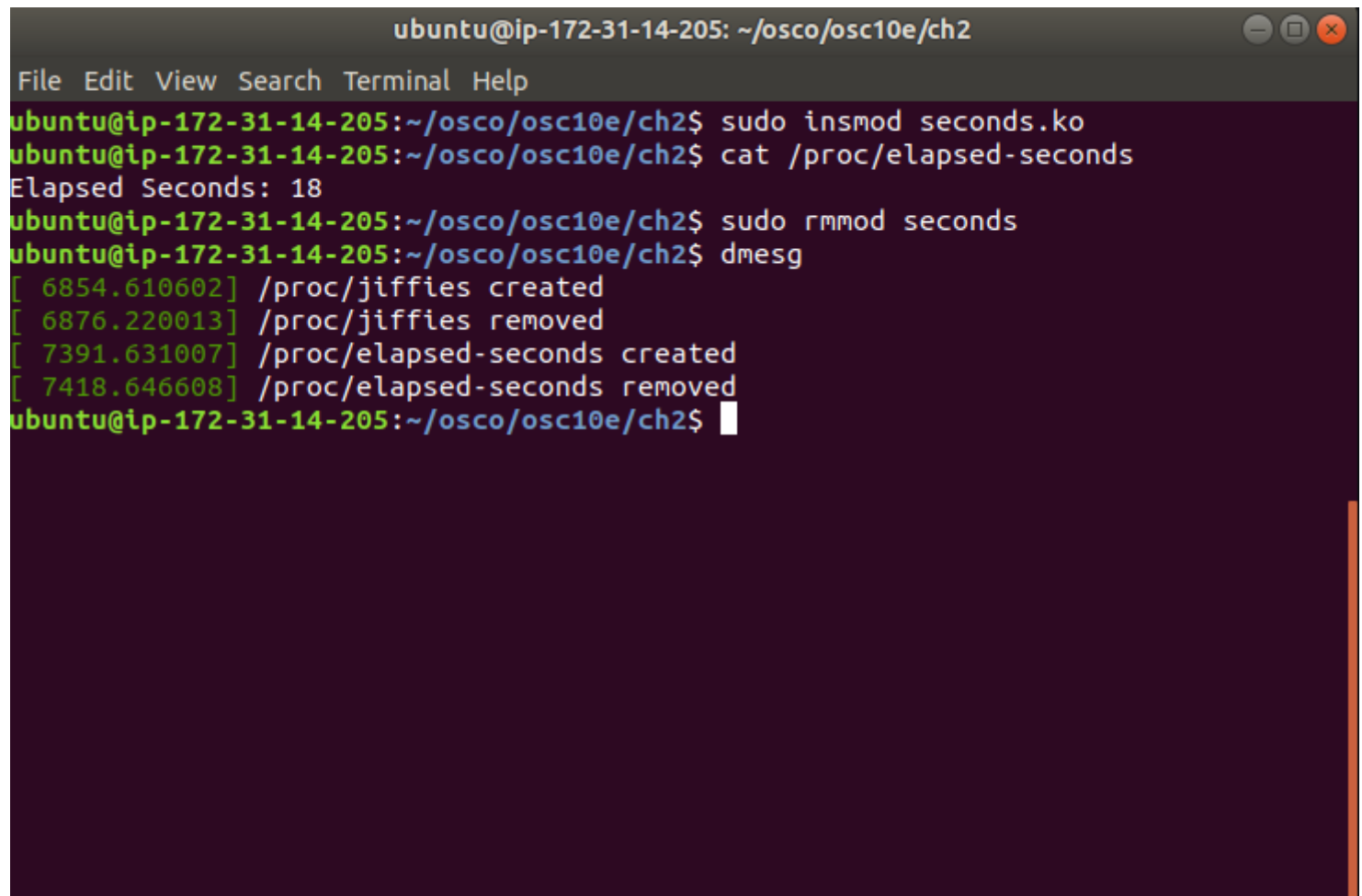
return rv;
}

/* Macros for registering module entry and exit points. */
module_init( proc_init );
module_exit( proc_exit );

MODULE_LICENSE("GPL");
MODULE_DESCRIPTION("elapsed-seconds Module");
MODULE_AUTHOR("Ahmed Moustafa");

```

Preview:

A terminal window titled 'ubuntu@ip-172-31-14-205: ~/osco/osc10e/ch2' with standard window controls. The terminal shows a sequence of commands: 'sudo insmod seconds.ko', 'cat /proc/elapsed-seconds' (output: 'Elapsed Seconds: 18'), 'sudo rmmod seconds', and 'dmesg'. The 'dmesg' output shows four log entries for the creation and removal of '/proc/jiffies' and '/proc/elapsed-seconds' with timestamps in brackets. The prompt returns to the shell after the last command.

```
ubuntu@ip-172-31-14-205: ~/osco/osc10e/ch2
File Edit View Search Terminal Help
ubuntu@ip-172-31-14-205:~/osco/osc10e/ch2$ sudo insmod seconds.ko
ubuntu@ip-172-31-14-205:~/osco/osc10e/ch2$ cat /proc/elapsed-seconds
Elapsed Seconds: 18
ubuntu@ip-172-31-14-205:~/osco/osc10e/ch2$ sudo rmmod seconds
ubuntu@ip-172-31-14-205:~/osco/osc10e/ch2$ dmesg
[ 6854.610602] /proc/jiffies created
[ 6876.220013] /proc/jiffies removed
[ 7391.631007] /proc/elapsed-seconds created
[ 7418.646608] /proc/elapsed-seconds removed
ubuntu@ip-172-31-14-205:~/osco/osc10e/ch2$
```

Comment:

Using the already designed code in the textbook, we have added to it the elapsed time calculation functionality which has been introduced before.