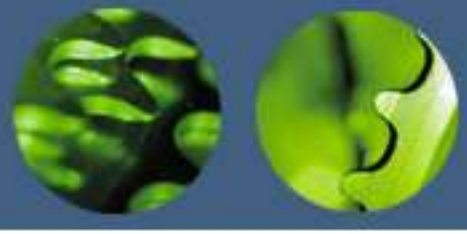
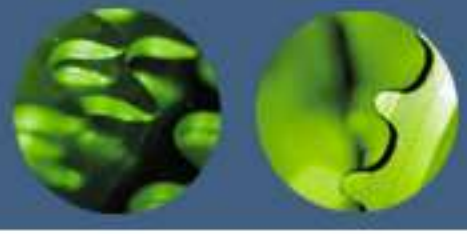
Linux Device Drivers



Project 3 Preview

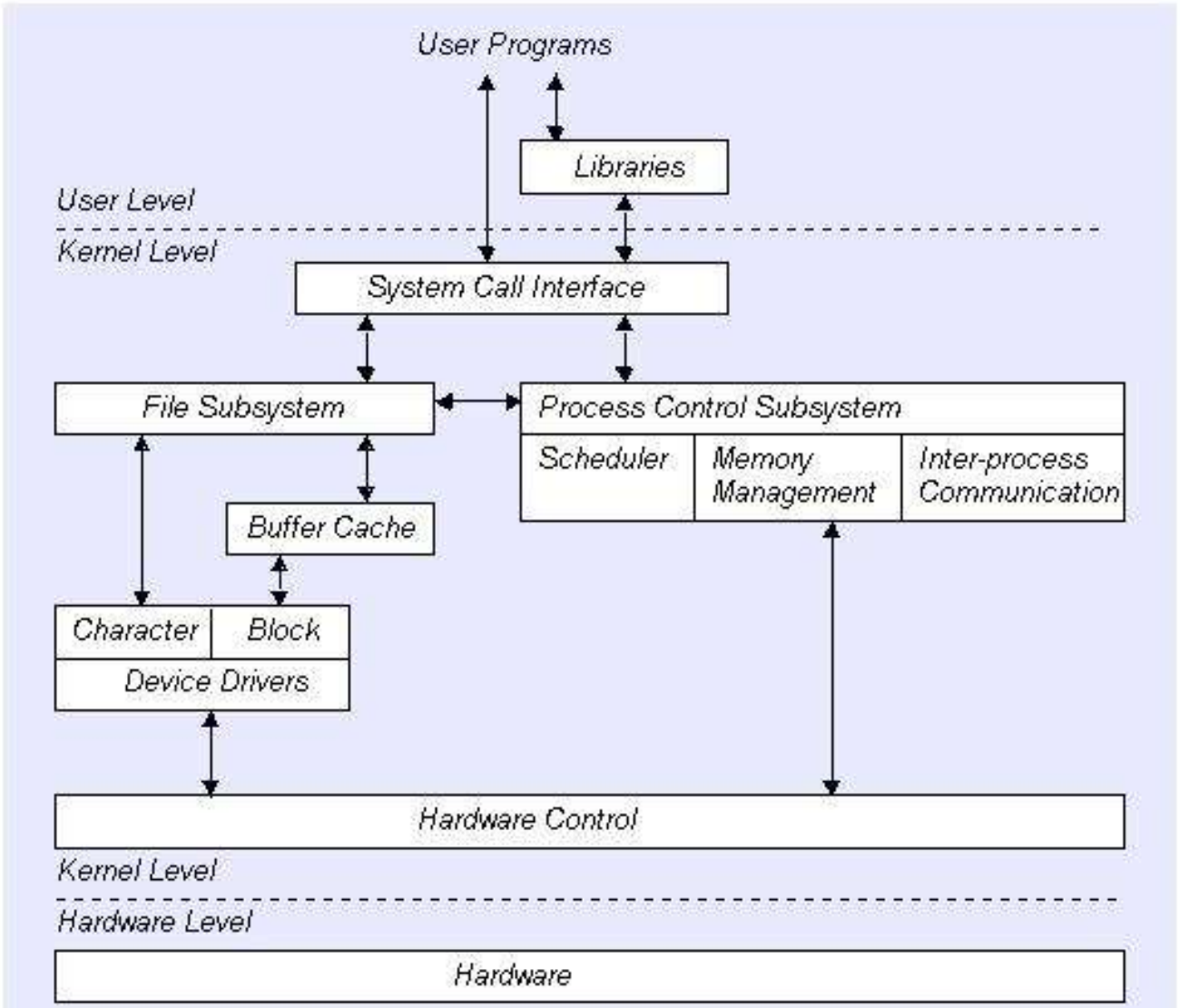
- Write a device driver for a pseudo stack device
- Idea from http://www.cs.swarthmore.edu/~newhall/cs45/f01/proj5.html
- Linux character device type supports the following operations
  - Open: only one is allowed.
  - Write: writes an char string to top of the device stack. Error if stack is empty
  - Read: reads an item from top of the device stack. Error if stack is empty
  - Release: release the device
- Install with LKM.



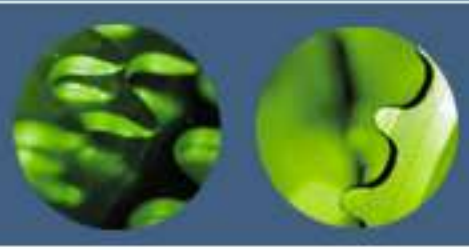
What is a device driver?

- A programming module with interfaces
  - Communication Medium between application/user and hardware
- In Unix,
  - Kernel module
  - device driver interface = file interface
  - What are normal operations?
  - Block vs. character

User program & Kernel interface

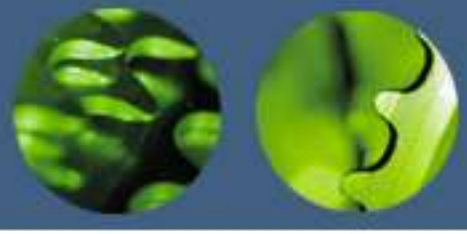


Note: This picture is excerpted from Write a Linux Hardware Device Driver, Andrew O'Shauqhnessy, Unix world



Loadable Kernel Module (LKM)

- A new kernel module can be added on the fly (while OS is still running)
- LKMs are often called “kernel modules”
- They are not user program

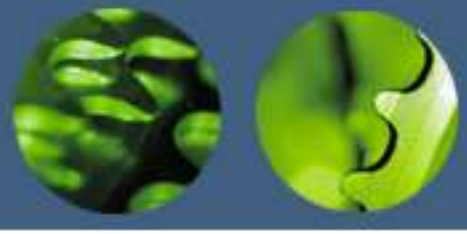


Basic LKM (program)

- Every LKM consist of two basic functions (minimum) :

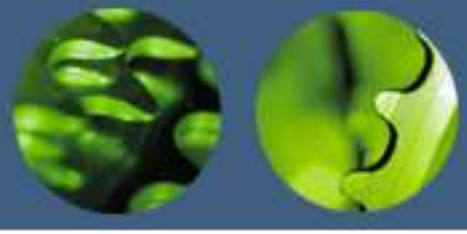
```
int init_module(void) /*used for all initialition stuff*/
{
...
}
void cleanup_module(void) /*used for a clean shutdown*/
{
...
}
```

- Loading a module - normally restricted to root - is managed by issuing the following command: # insmod module.o



LKM Utilities cmd

- insmod
  - Insert an LKM into the kernel.
- rmmod
  - Remove an LKM from the kernel.
- depmod
  - Determine interdependencies between LKMs.
- kerneld
  - Kerneld daemon program
- ksyms
  - Display symbols that are exported by the kernel for use by new LKMs.
- lsmod
  - List currently loaded LKMs.
- modinfo
  - Display contents of .modinfo section in an LKM object file.
- modprobe
  - Insert or remove an LKM or set of LKMs intelligently. For example, if you must load A before loading B, Modprobe will automatically load A when you tell it to load B.



Common LKM util cmd

- Create a special device file

  % mknode /dev/driver c 40 0

- Insert a new module

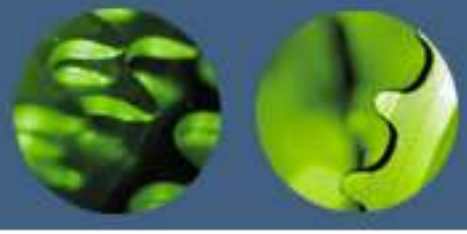
  % insmod modname

- Remove a module
- %rmmod modname
- List module

  % lsmod

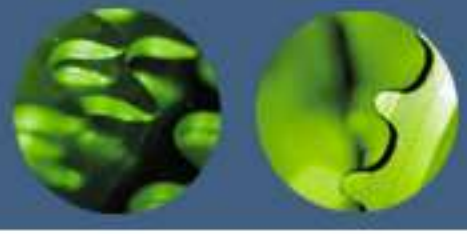
  Or % more /proc/modules

```
audio                37840   0
cmpci                24544   0
soundcore             4208   4 [audio cmpci]
nfsd                 70464   8 (autoclean)
```



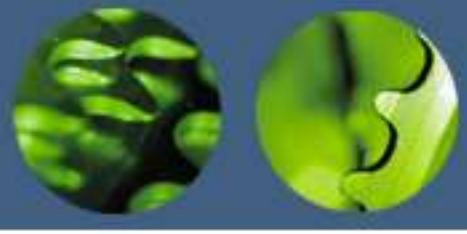
Linux Device Drivers

- A set of API subroutines (typically system calls) interface to hardware
- Hide implementation and hardware-specific details from a user program
- Typically use a file interface metaphor
- Device is a special file



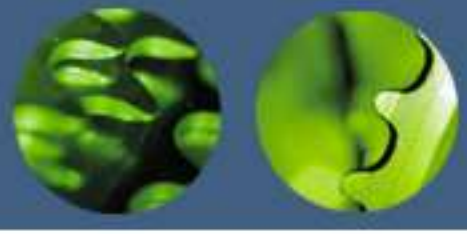
Linux Device Drivers (continued)

- Manage data flow between a user program and devices
- A self-contained component (add/remove from kernel)
- A user can access the device via file name in /dev , e.g. /dev/lp0



General implementation steps

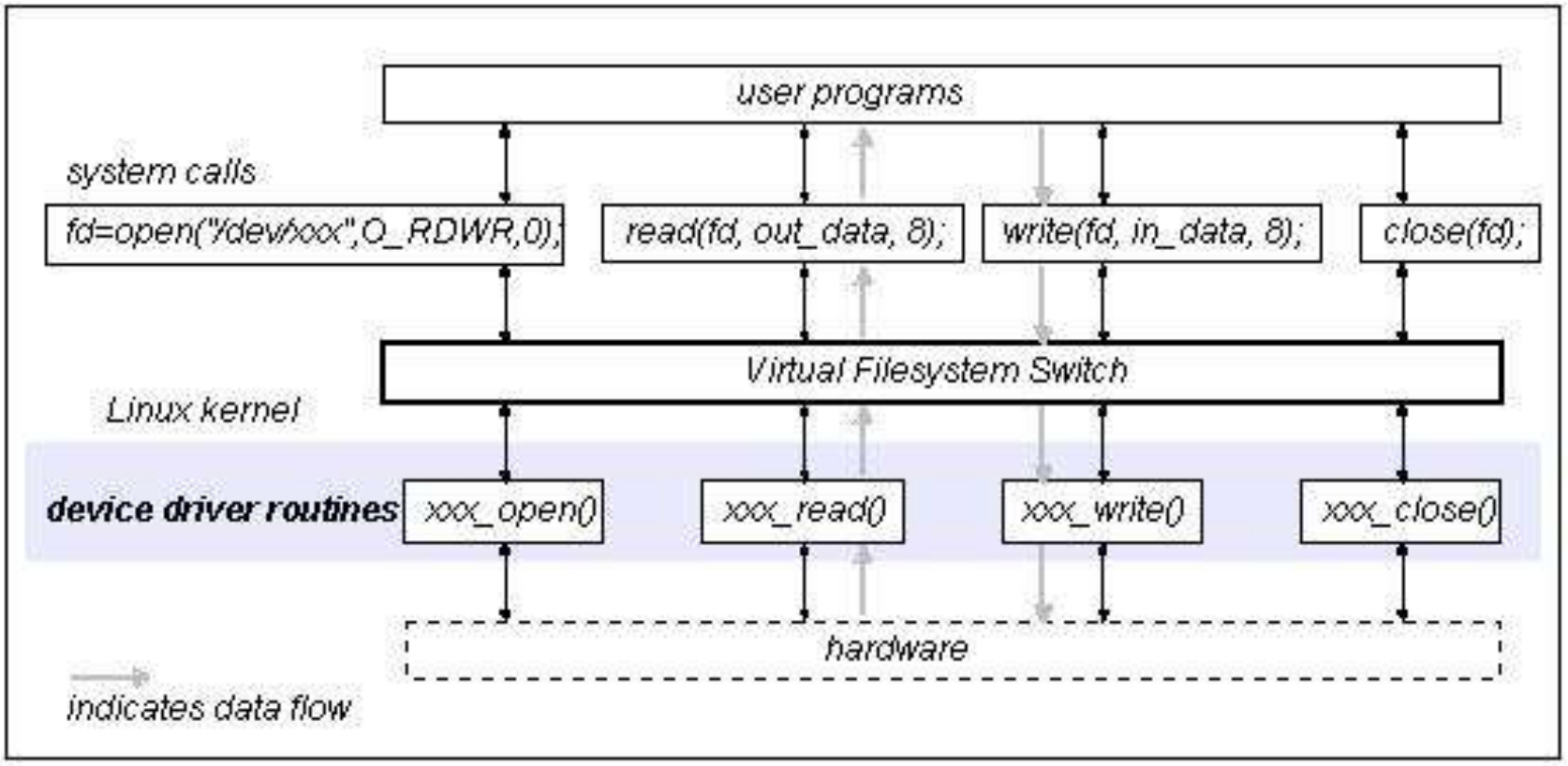
1. Understand the device characteristic and supported commands.
2. Map device specific operations to unix file operation
3. Select the device name (user interface)
   - Namespace (2-3 characters, /dev/lp0)
4. (optional) select a major number and minor (a device special file creation) for VFS interface
   - Mapping the number to right device sub-routines
5. Implement file interface subroutines
6. Compile the device driver
7. Install the device driver module with loadable kernel module (LKM)
8. or Rebuild (compile) the kernel



Read/write (I/O)

- Pooling (or synchronous)
- Interrupt based

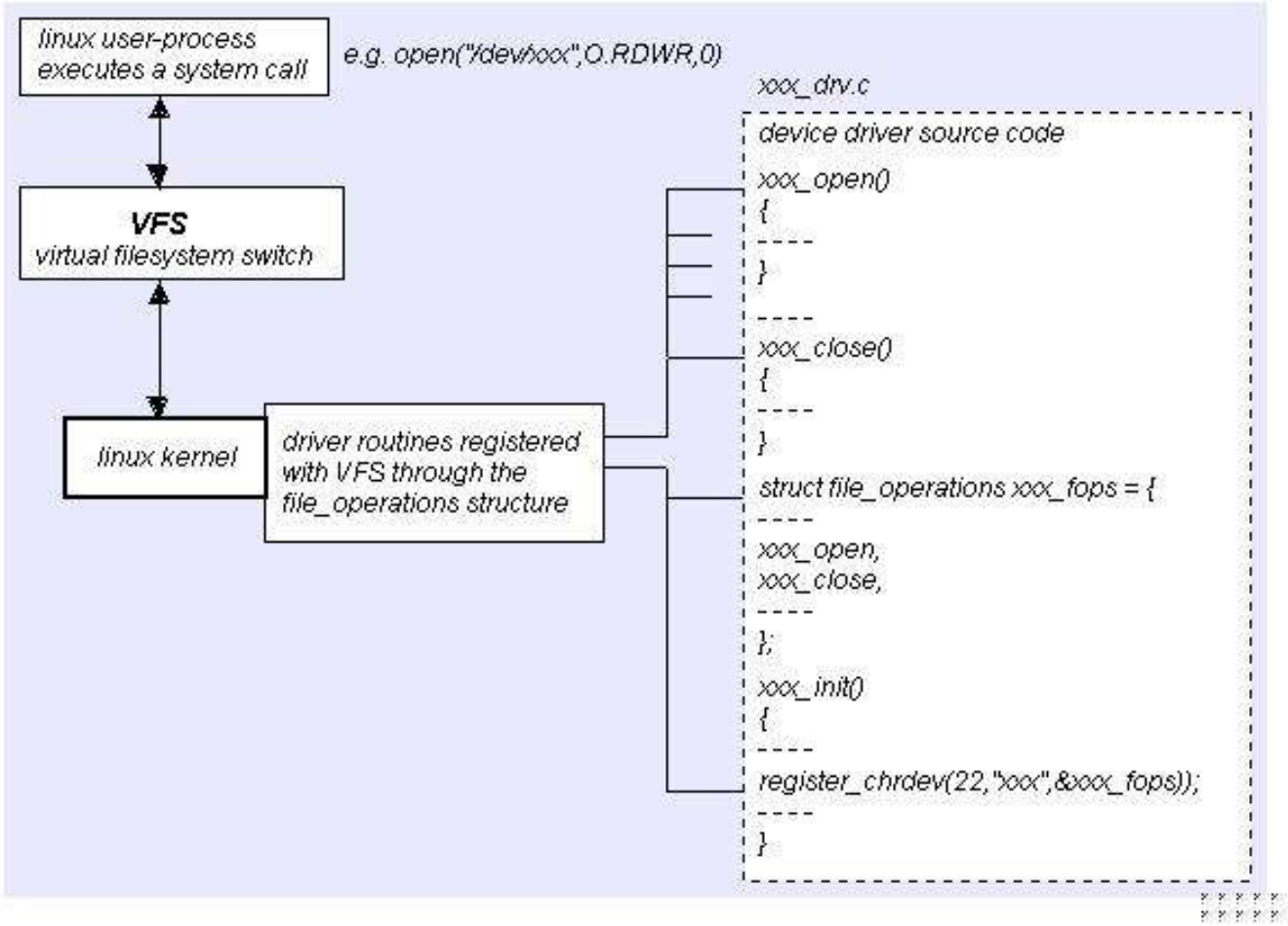
Device Driver interface



Note: This picture is excerpted from Write a Linux Hardware Device Driver, Andrew O'Shauqhnessy, Unix world

VSF & Major number

- principal interface between a device driver and Linux kernel

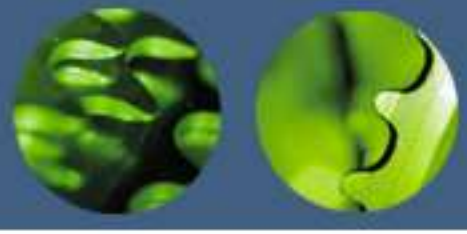


File operation structure

- struct file_operations Fops = {
  - NULL, /* seek */
  - xxx_read
  - xxx_wri
  - NULL, /
  - NULL,
  - NULL,
  - NULL, /* /
  - xxx_open,
  - NULL, /* flush */
  - xxx_release /* a.k.a. close */
- };

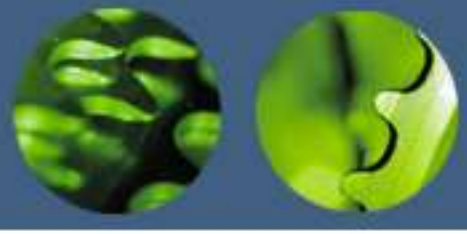
- struct file_operations Fops = {
  - read: xxx_read,
  - write: xxx_write,
  - open: xxx_open,
  - release: xxx_release, /* a.k.a. close */
- };

Watch out compatibility issue with Linux version



Device special file

- Device number
  - Major (used to VFS mapping to right functions)
  - Minor (sub-devices)
- mknod /dev/stk c 38 0
- ls –l /dev/tty
  - crw-rw-rw- 1 root root 5, 0 Apr 21 18:33 /dev/tty



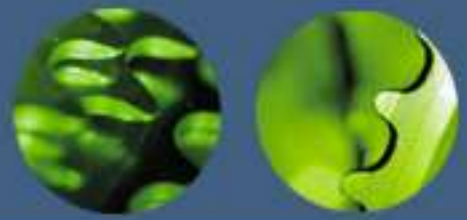
Register and unregister device

```
int init_module(void) /*used for all initialition stuff*/
{
        /* Register the character device (atleast try) */
        Major = register_chrdev(0,
                                DEVICE_NAME,
                                &Fops);
      :

}
void cleanup_module(void) /*used for a clean shutdown*/

    {ret = unregister_chrdev(Major, DEVICE_NAME);

...
}
```



Register and unregister device

- compile

  -Wall -DMODULE -D__KERNEL__ -DLINUX –DDEBUG -I /usr/include/linux/version.h -I/lib/modules/`uname -r`/build/include

- Install the module

  %insmod module.o

- List the module

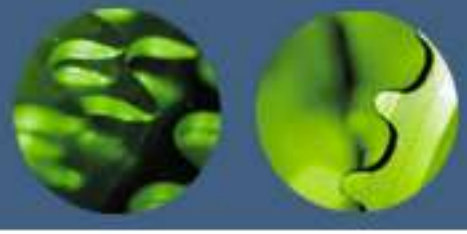
  %lsmod

- If you let the system pick Major number, you can find the major number (for special creation) by

  % more /proc/devices

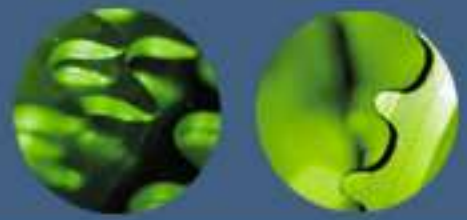
- Make a special file

  % mknod /dev/device_name c major minor



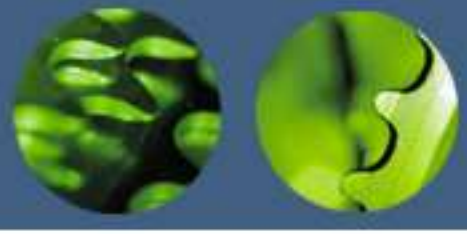
Device Driver Types

- A character device driver (c)
  - Most devices are this type (e.g.Modem, lp, USB
  - No buffer.
- A block device driver (b)
  - through a system buffer that acts as a data cache.
  - Hard drive controller and HDs



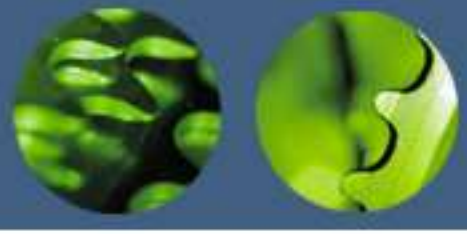
Implementation

- Assuming that your device name is Xxx
- Xxx_init() initialize the device when OS is booted
- Xxx_open() open a device
- Xxx_read() read from kernel memory
- Xxx_write() write
- Xxx_release() clean-up (close)
- init_module()
- cleanup_module()



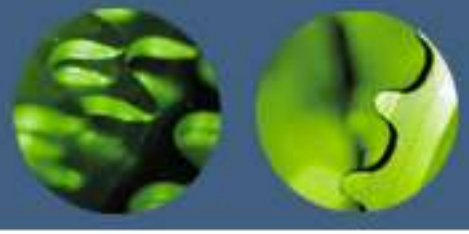
kernel functions

- add_timer()
  - Causes a function to be executed when a given amount of time has passed
- cli()
  - Prevents interrupts from being acknowledged
- end_request()
  - Called when a request has been satisfied or aborted
- free_irq()
  - Frees an IRQ previously acquired with request_irq() or irqaction()
- get_user*()
  - Allows a driver to access data in user space, a memory area distinct from the kernel
- inb(), inb_p()
  - Reads a byte from a port. Here, inb() goes as fast as it can, while inb_p() pauses before returning.
- irqaction()
  - Registers an interrupt like a signal.
- IS_*(inode)
  - Tests if inode is on a file system mounted with the corresponding flag.
- kfree*()
  - Frees memory previously allocated with kmalloc()
- kmalloc()
  - Allocates a chu nk of memory no larger than 4096 bytes.
- MAJOR()
  - Reports the major device number for a device.
- MINOR()
  - Reports the minor device number for a device.



kernel functions

- memcpy_*fs()
  - Copies chunks of memory between user space and kernel space
- outb(), outb_p()
  - Writes a byte to a port. Here, outb() goes as fast as it can, while outb_p() pauses before returning.
- printk()
  - A version of printf() for the kernel.
- put_user*()
  - Allows a driver to write data in user space.
- register_*dev()
  - Registers a device with the kernel.
- request_irq()
  - Requests an IRQ from the kernel, and, if successful, installs an IRQ interrupt handler.
- select_wait()
  - Adds a process to the proper select_wait queue.
- *sleep_on()
  - Sleeps on an event, puts a wait_queue entry in the list so that the process can be awakened on that event.
- sti()
  - Allows interrupts to be acknowledged.
- sys_get*()
  - System calls used to get information regarding the process, user, or group.
- wake_up*()
  - Wakes up a process that has been put to sleep by the matching *sleep_on() function.



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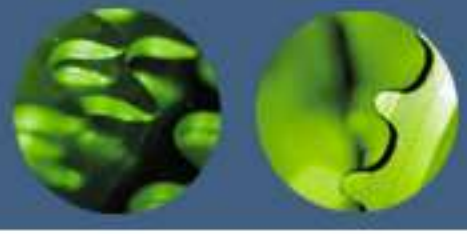
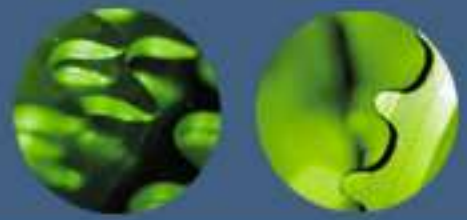


Pitfalls

1. **Using standard libraries**: can only use kernel functions, which are the functions you can see in /proc/ksyms.

2. **Disabling interrupts** You might need to do this for a short time and that is OK, but if you don't enable them afterwards, your system will be stuck
3. Changes from version to version



Resources

- Linux Kernel API: http://kernelnewbies.org/documents/kdoc/kernel-api/linuxkernelapi.html
- Kernel development tool http://www.jungo.com/products.html
- Linux Device Drivers 2nd Edition by Rubini & Corbet, O'Reilly Pub, ISBN 0-596-00008-1