1. Linux Device driver

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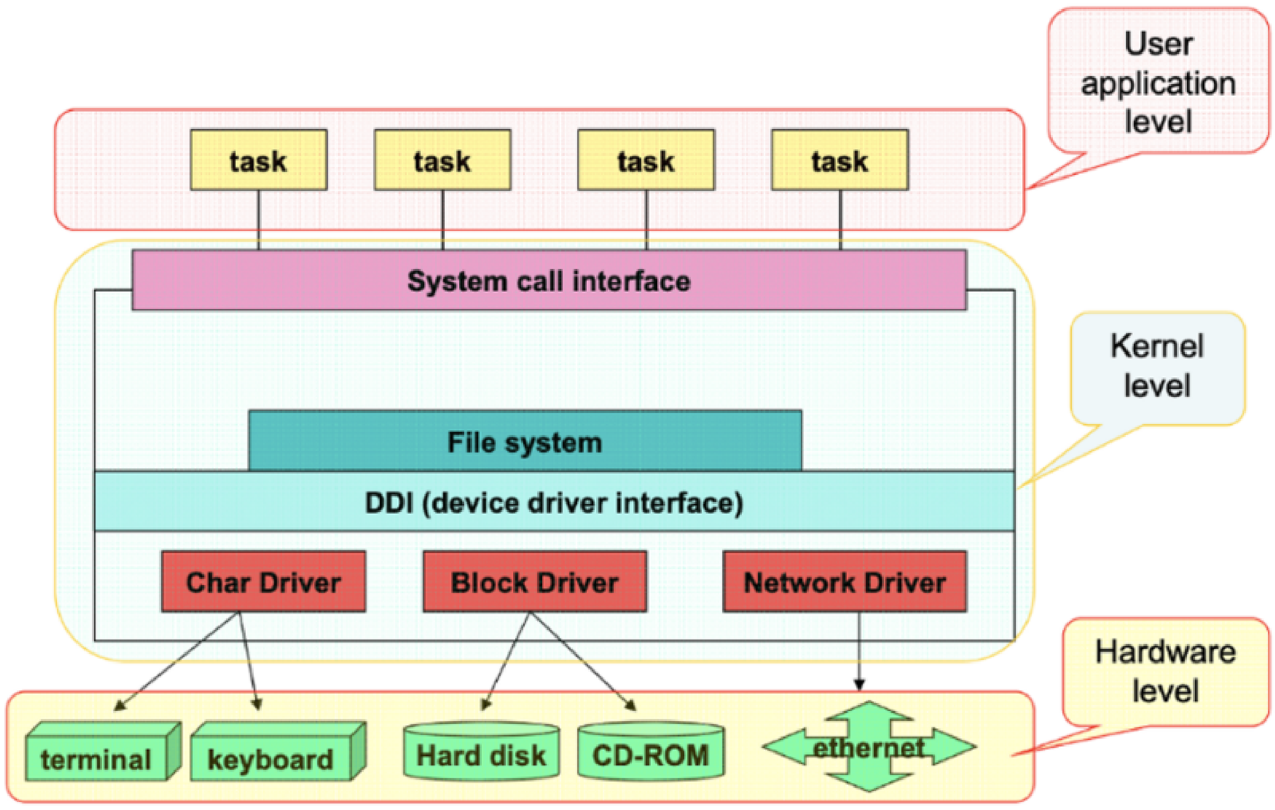


1.1 Character Devices

- **Description**: Character devices, also known as "char devices," handle data one character at a time.
- **Use Cases**: They are typically used for devices that require sequential access, such as keyboards, mice, serial ports, and more.
- **Access**: Accessed through files in the `/dev` directory. Examples include `/dev/tty` for the terminal, `/dev/null`, and `/dev/random`.

1.2 Block Devices

- **Description**: Block devices handle data in blocks, which means they read and write data in fixed-size chunks. This allows for random access to data blocks, enabling users to jump to different locations on the device.
- **Use Cases**: Commonly used for storage devices, such as hard drives, SSDs, and USB flash drives.

- **Access**: Accessed through files in the `/dev` directory. Examples include `/dev/sda` for the first SATA drive, `/dev/nvme0n1` for the first NVMe drive, etc.

1.3 Network Devices

- **Description**: Network devices are used to send and receive data packets over a network.
- **Use Cases**: Examples include Ethernet adapters, Wi-Fi cards, and other interfaces that facilitate network communication.
- **Access**: Network interfaces are listed under /sys/class/net/ or can be seen using the ip addr command. They can be interacted with through the utilities like `ifconfig`, `ip`, `netstat`, and others.

2. Misc Driver

Misc drivers (miscellaneous drivers) in Linux are a category of device drivers that don't fit well into other standard categories of drivers like network, USB, or block drivers.

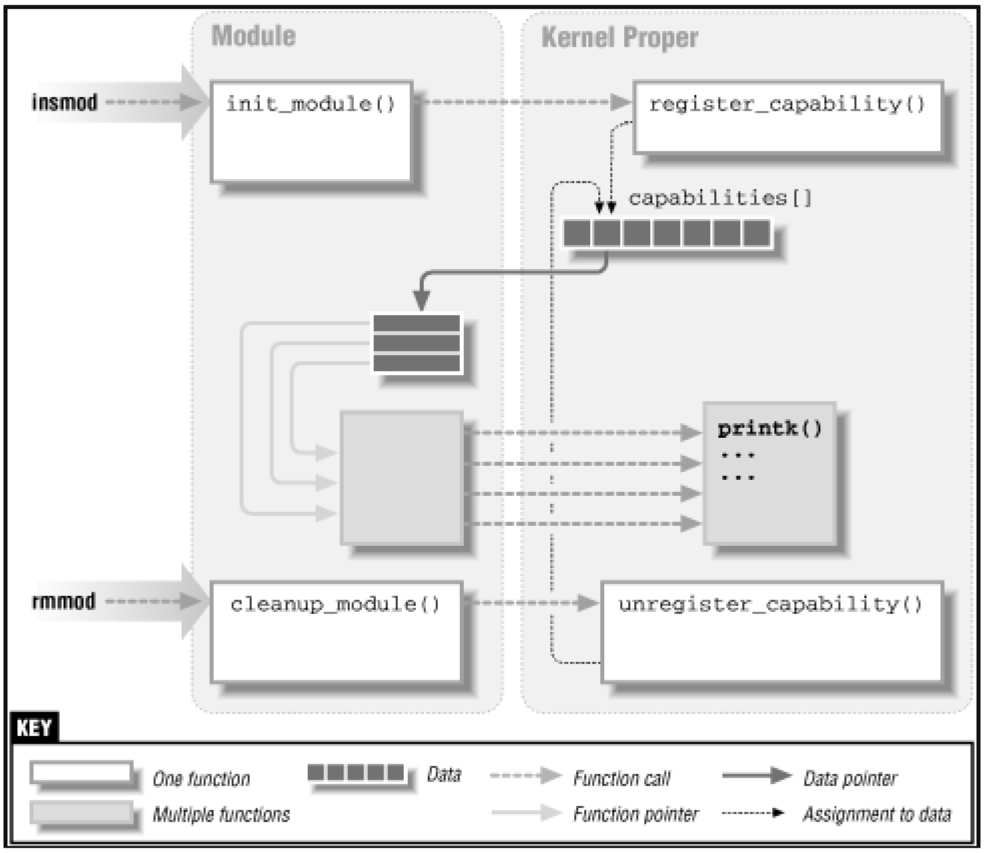
They are used for controlling various types of devices that do not belong to a common device class.

3. Module Driver

3.1 Explanation

- **Definition**: Module drivers refer to any drivers that are compiled as modules in the Linux kernel. This can include drivers for network interfaces, block devices, USB devices, etc.
- **Characteristics**:
    - **Loadable Kernel Modules (LKMs)**: Module drivers can be dynamically loaded into and unloaded from the running kernel, allowing hardware to be added or removed without rebooting the system. (LKM is an option)
    - **Modularity**: This approach supports modularity and extensibility, enabling the kernel to stay lean by loading only the necessary modules for the hardware present.
    - **Maintainability**: Modularization makes it easier to maintain the software. When code is organized into modules, developers can quickly update parts of the application without affecting the entire system.
    - **Tools for Management**: Utilities like `modprobe`, `insmod`, and `rmmod` are used to manage loading and unloading of module drivers.

3.2 Diagram showing how LKMs are loaded



4. Adding a dummy module driver to the kernel

This section describes how to add a loadable kernel module to the kernel.

4.1 Source code

The code in this section registers a device driver controlled by file operations

Example code of char driver

my_char.c

```
#include <linux/kernel.h>
#include <linux/init.h>
#include <linux/module.h>
#include <linux/kdev_t.h>
#include <linux/fs.h>
#include <linux/err.h>
#include <linux/cdev.h>
#include <linux/device.h>
#include <linux/err.h>

dev_t dev = 0;
static struct class *dev_class;
static struct cdev my_cdev;

/*
** Function Prototypes
*/
static int      __init my_driver_init(void);
static void     __exit my_driver_exit(void);
static int      my_open(struct inode *inode, struct file *file);
static int      my_release(struct inode *inode, struct file *file);
static ssize_t  my_read(struct file *filp, char __user *buf, size_t len,loff_t *
off);
static ssize_t  my_write(struct file *filp, const char *buf, size_t len, loff_t *
off);

static struct file_operations fops =
{
    .owner      = THIS_MODULE,
    .read       = my_read,
    .write      = my_write,
    .open       = my_open,
    .release    = my_release,
};

/*
** This function will be called when we open the Device file
*/
static int my_open(struct inode *inode, struct file *file)
{
        pr_info("YANG Driver Open Function Called...!!!\n");
        return 0;
}

/*
** This function will be called when we close the Device file
*/
static int my_release(struct inode *inode, struct file *file)
{
        pr_info("YANG Driver Release Function Called...!!!\n");
        return 0;
}

/*
** This function will be called when we read the Device file
*/
static ssize_t my_read(struct file *filp, char __user *buf, size_t len, loff_t *off)
{
        pr_info("YANG Driver Read Function Called...!!!\n");
        return 0;
}

/*
** This function will be called when we write the Device file
*/
static ssize_t my_write(struct file *filp, const char __user *buf, size_t len, loff_t
*off)
{
        pr_info("YANG Driver Write Function Called...!!!\n");
        return len;
}

/*
** Module Init function
*/
static int __init my_driver_init(void)
{
        /*Allocating Major number*/
        if((alloc_chrdev_region(&dev, 0, 1, "my_char_Dev")) <0){
                pr_err("Cannot allocate major number\n");
                return -1;
        }
        pr_info("Major = %d Minor = %d \n",MAJOR(dev), MINOR(dev));

        /*Creating cdev structure*/
        cdev_init(&my_cdev,&fops);

        /*Adding character device to the system*/
        if((cdev_add(&my_cdev,dev,1)) < 0){
            pr_err("Cannot add the device to the system\n");
            goto r_class;
        }

        /*Creating struct class*/
        if(IS_ERR(dev_class = class_create(THIS_MODULE,"my_char_class"))){
            pr_err("Cannot create the struct class\n");
            goto r_class;
        }

        /*Creating device*/
        if(IS_ERR(device_create(dev_class,NULL,dev,NULL,"my_char_device"))){
            pr_err("Cannot create the Device 1\n");
            goto r_device;
        }
        pr_info("YANG Device Driver Insert...Done!!!\n");
      return 0;

r_device:
        class_destroy(dev_class);
r_class:
        unregister_chrdev_region(dev,1);
        return -1;
}

/*
** Module exit function
*/
static void __exit my_driver_exit(void)
{
        device_destroy(dev_class,dev);
        class_destroy(dev_class);
        cdev_del(&my_cdev);
        unregister_chrdev_region(dev, 1);
        pr_info("Device Driver Remove...Done!!!\n");
}

module_init(my_driver_init);
module_exit(my_driver_exit);

MODULE_LICENSE("GPL");
MODULE_AUTHOR("your name");
MODULE_DESCRIPTION("Simple char device driver (File Operations)");
MODULE_VERSION("1.3");
```

Example code of misc driver

my_misc.c

```c
#include <linux/init.h>
#include <linux/module.h>
#include <linux/miscdevice.h>
#include <linux/fs.h>
static int my_misc_device_open(struct inode *inode, struct file *file) {
    pr_info("my_misc_device: open\n");
    return 0;
}

static int my_misc_device_close(struct inode *inodep, struct file *filp) {
    pr_info("my_misc_device: close\n");
    return 0;
}

static const struct file_operations my_misc_fops = {
    .owner = THIS_MODULE,
    .open = my_misc_device_open,
    .release = my_misc_device_close,
};

static struct miscdevice my_misc_device = {
    .minor = MISC_DYNAMIC_MINOR, // Dynamically allocate a minor number
    .name = "my_misc",     // Name of the device file
    .fops = &my_misc_fops,        // File operations
};

static int __init my_misc_init(void) {
    int status;

    // Register the misc device
    status = misc_register(&my_misc_device);
    if (status) {
        pr_err("Failed to register misc device\n");
        return status;
    }

    pr_info("my_misc_device registered\n");
    return 0;
}

static void __exit my_misc_exit(void) {
    // Unregister the misc device
    misc_deregister(&my_misc_device);
    pr_info("my_misc_device unregistered\n");
}

module_init(my_misc_init);
module_exit(my_misc_exit);
```

```
MODULE_LICENSE("GPL");
MODULE_AUTHOR("Your Name");
MODULE_DESCRIPTION("A simple example of a Linux misc driver");
```

4.2 Build the module driver

This section describes how to build a misc driver. Building other drivers follows the same process.

4.2.1 Compiling the module along with the kernel

The source(e.g. my_misc.c) is located in drivers/misc.

4.2.1.1 Optional compile according to Kconfig

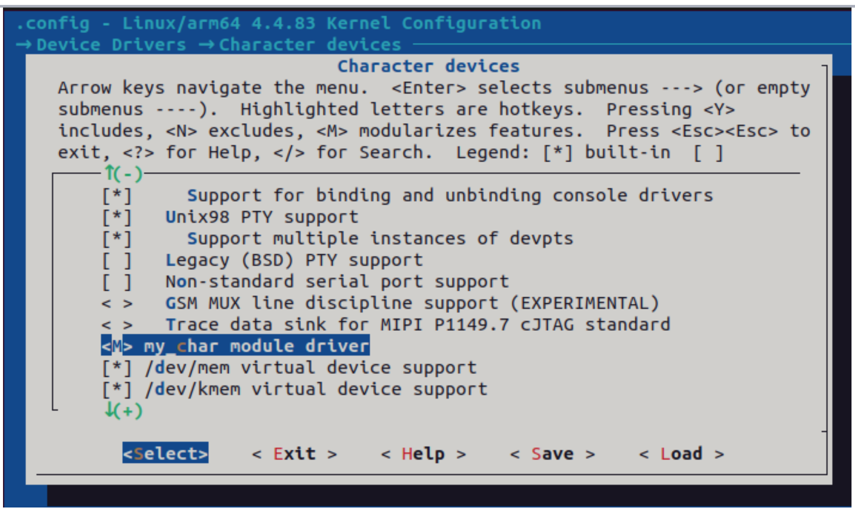
In this case, the module built can be included and excluded optionally via menuconfig

1. Edit `drivers/misc/Kconfig`

```
config MY_MISC
    tristate "my_misc module driver"
    default m
    help "my_misc"
```

2. Modify and save menuconfig

```
make ARCH=arm64 menuconfig
```



```
.config - Linux/arm64 4.4.83 Kernel Configuration
→ Device Drivers → Character devices
                          Character devices
   Arrow keys navigate the menu.  <Enter> selects submenus ---> (or empty
   submenus ----).  Highlighted letters are hotkeys.  Pressing <Y>
   includes, <N> excludes, <M> modularizes features.  Press <Esc><Esc> to
   exit, <?> for Help, </> for Search.  Legend: [*] built-in  [ ]
      ↑(-)
        [*]     Support for binding and unbinding console drivers
        [*]   Unix98 PTY support
        [*]     Support multiple instances of devpts
        [ ]   Legacy (BSD) PTY support
        [ ]   Non-standard serial port support
        < >   GSM MUX line discipline support (EXPERIMENTAL)
        < >   Trace data sink for MIPI P1149.7 cJTAG standard
        <M> my_char module driver
        [*] /dev/mem virtual device support
        [*] /dev/kmem virtual device support
      ↓(+)

        <Select>    < Exit >    < Help >    < Save >    < Load >
```

```
make ARCH=arm64 savedefconfig
```

```
cp defconfig ./arch/arm64/configs/s5p6818_bitminer_defconfig
```

3. Modify drivers/char/Makefile

```
obj-$(CONFIG_MY_MISC) += my_misc.o
```

4.2.1.2 Always compile along with the kernel build

In this case, the module is always built along with the kernel.

Modify `drivers/misc/Makefile`

```
obj-m += my_misc.o
```

4.2.2 Manual build

1. Create this initial directory(my_misc.c

2. Write Makefile

```
obj-m += my_misc.o
KDIR = ~/work/dunfell-bitminer/sources/kernel/kernel-4.4.x
all:
    make -C $(KDIR)  M=$(shell pwd) modules ARCH=arm64
clean:
    make -C $(KDIR)  M=$(shell pwd) clean
```

3. Build

```
sudo make
```

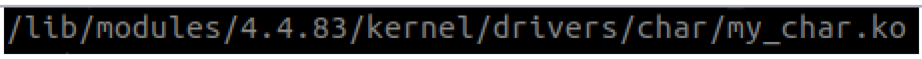
4.3 Loading the module driver

Install the built module driver(.ko) to /home/root as described below.

4.3.1 If the module was built along with the kernel

1. Find where the module is

```
find / -type f -name "my_misc.ko"
```



```
/lib/modules/4.4.83/kernel/drivers/char/my_char.ko
```

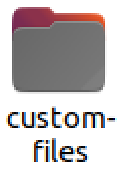
2. Load the module

```
insmod /lib/modules/4.4.83/kernel/drivers/char/my_misc.ko
```

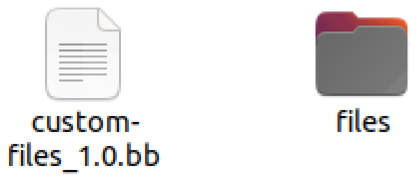
4.3.2 If the module was manually built

4.3.2.1 Using the yocto recipe

1. Create a recipe directory in recipes-core(or any recipes- directory)



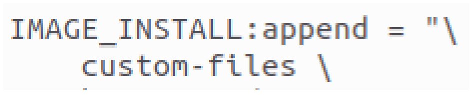
2. Create a recipe and a `files` directory and add necessary files in the `files` directory



3. Write the recipe

```
DESCRIPTION = "Install custom file to /home/root"
LICENSE = "MIT"

LIC_FILES_CHKSUM = "file://${COREBASE}/meta/
COPYING.MIT;md5=3da9cfbcb788c80a0384361b4de20420"

SRC_URI = "file://my_misc.ko"

do_install() {
    install -d ${D}/home/root  # Create the directory if it doesn't exist
    install -m 0644 ${WORKDIR}/my_misc.c ${D}/home/root/my_misc.ko
}

# package management system
FILES_${PN} += "/home/root/my_misc.ko"
```

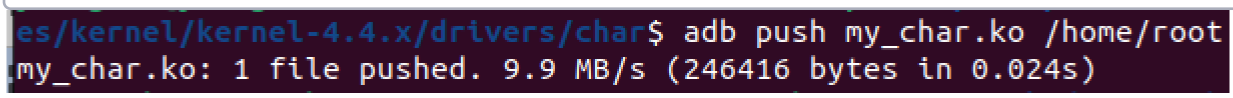
4. Add the recipe to the core recipe



```
IMAGE_INSTALL:append = "\
     custom-files \
```

4.3.2.2 Pushing the module to the target board

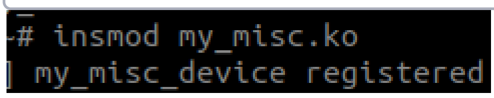
```
adb push my_misc.ko /home/root
```



```
es/kernel/kernel-4.4.x/drivers/char$ adb push my_char.ko /home/root
my_char.ko: 1 file pushed. 9.9 MB/s (246416 bytes in 0.024s)
```

4.3.2.3 Load the module driver in the target board

```
insmod my_misc.ko
```



```
# insmod my_misc.ko
 my_misc_device registered
```

`rmmod my_misc.ko` will remove the inserted module.

4.4 Performing operations of the loaded module driver

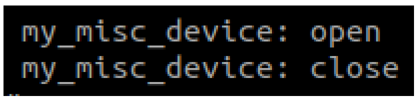
The registered driver is located in `/dev/<device_name>.` The driver's file operations can be performed using this file.

4.4.1 Source code

This code opens and closes the device driver file `/dev/my_misc` to trigger the file operations defined in struct file_operations within my_misc.c

```
#include <stdio.h>
#include <fcntl.h> // For O_RDWR
#include <unistd.h> // For open(), close()

void main() {
    int fd;
    fd = open("/dev/my_misc", O_RDWR);
    if (fd < 0) {
        perror("Failed to open the device");
        return -1;
    }
    return 0;
}
```

4.4.2 Result



```
my_misc_device: open
my_misc_device: close
```

Reference

- https://embetronicx.com/tutorials/linux/device-drivers