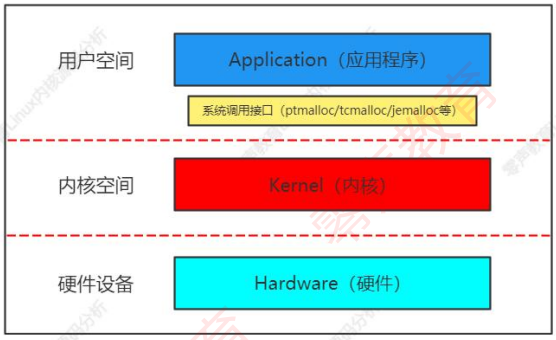
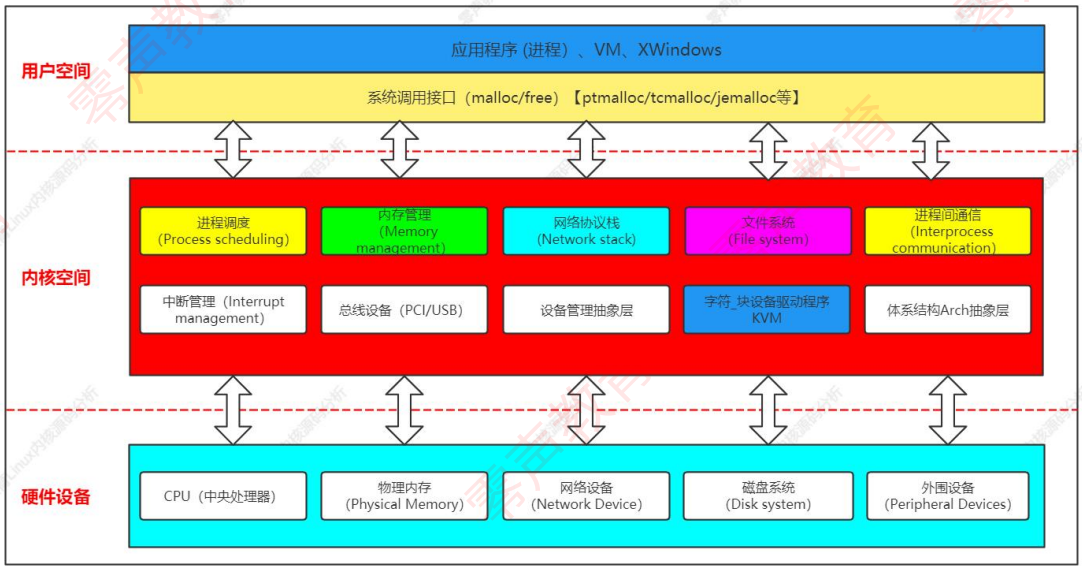
第 002 讲 Linux 内核《设备驱动管理专题》

Linux 内核源码分析架构图





一、块设备驱动分析

1、块设备基础

块设备是一种能够随机访问的存储介质，与字符设备不同，块设备能够保存文件系统数据。块设备特性如下：

- 可以在一次 I/O 操作中传送固定大小的数据块。
- 可以随机访问设备中所存放的块：传送数据块所需要的时间独立于块在设备中的位置，也独立于当前设备的状态。

2、常见存储技术与设备驱动程序相关

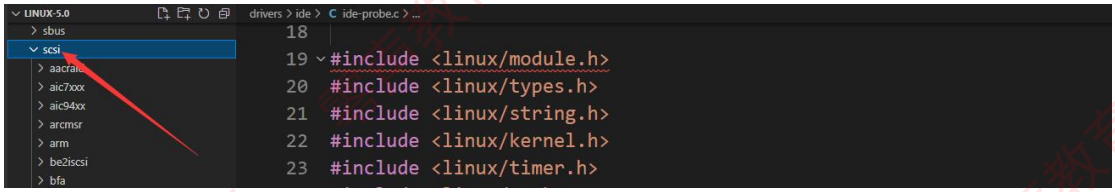
IDE/ATA（PC 存储接口技术）：

```
drivers > ide > C ide-io.c > ...
27  #include <linux/module.h>
```

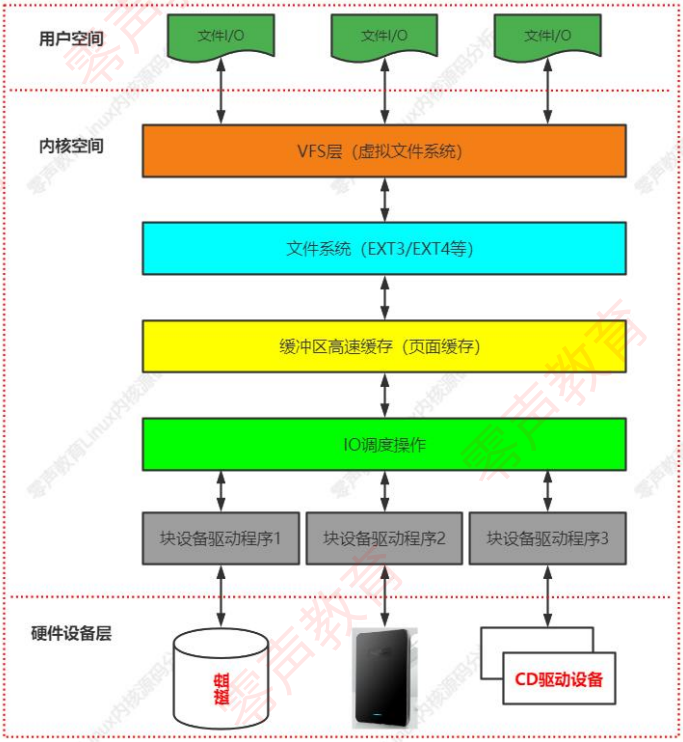
```
fs > C block_dev.c > ...
 8  #include <linux/init.h>
 9  #include <linux/mm.h>
```

```
drivers > ide > C ide-probe.c
18
19  #include <linux/module.h>
20  #include <linux/types.h>
21  #include <linux/string.h>
```

SCSI（服务器环境常用存储技术）：



3、Linux 块 I/O 层架构视图



4、Linux 内核块驱动程序数据结构和方法

```
include > linux > C genhd.h > gendisk > devnode
175 struct gendisk {
176     /* major, first_minor and minors are input parameters only,
177      * don't use directly.  Use disk_devt() and disk_max_parts().
178      */
179     int major;              /* major number of driver */
180     int first_minor;
181     int minors;                     /* maximum number of minors, =1 for
```

每个块驱动程序对应 I/O 请求队列使用 request_queue 结构体描述如下：

```
include > linux > C blkdev.h > request
131
132 struct request {
133     struct request_queue *q;
134     struct blk_mq_ctx *mq_ctx;
135     struct blk_mq_hw_ctx *mq_hctx;
136
```

块驱动对应操作入口函数为：

include > linux > C blkdev.h > bdev_read_page(block_device *, sector_t, page *)

```
1642
1643 struct block_device_operations {
1644     int (*open) (struct block_device *, fmode_t);
1645     void (*release) (struct gendisk *, fmode_t);
1646     int (*rw_page)(struct block_device *, sector_t, struct page *, unsigned int);
1647     int (*ioctl) (struct block_device *, fmode_t, unsigned, unsigned long);
1648     int (*compat_ioctl) (struct block_device *, fmode_t, unsigned, unsigned long);
1649     unsigned int (*check_events) (struct gendisk *disk,
1650                                   unsigned int clearing);
1651     /* ->media_changed() is DEPRECATED, use ->check_events() instead */
1652     int (*media_changed) (struct gendisk *);
1653     void (*unlock_native_capacity) (struct gendisk *);
1654     int (*revalidate_disk) (struct gendisk *);
1655     int (*getgeo)(struct block_device *, struct hd_geometry *);
1656     /* this callback is with swap_lock and sometimes page table lock held */
1657     void (*swap_slot_free_notify) (struct block_device *, unsigned long);
1658     int (*report_zones)(struct gendisk *, sector_t sector,
1659                         struct blk_zone *zones, unsigned int *nr_zones,
1660                         gfp_t gfp_mask);
1661     struct module *owner;
1662     const struct pr_ops *pr_ops;
1663 };
```

二、字符设备驱动分析

1、字符设备特性

- 可以在一次 I/O 操作中传送任意大小的数据。实际上，诸如打印机之类的字符设备可以一次传送一个字节，而诸如磁带之类的设备可以一次传送可变大小的数据块。
- 通常访问连续的字符。

2、字符设备数据结构

include > linux > C cdev.h > ...

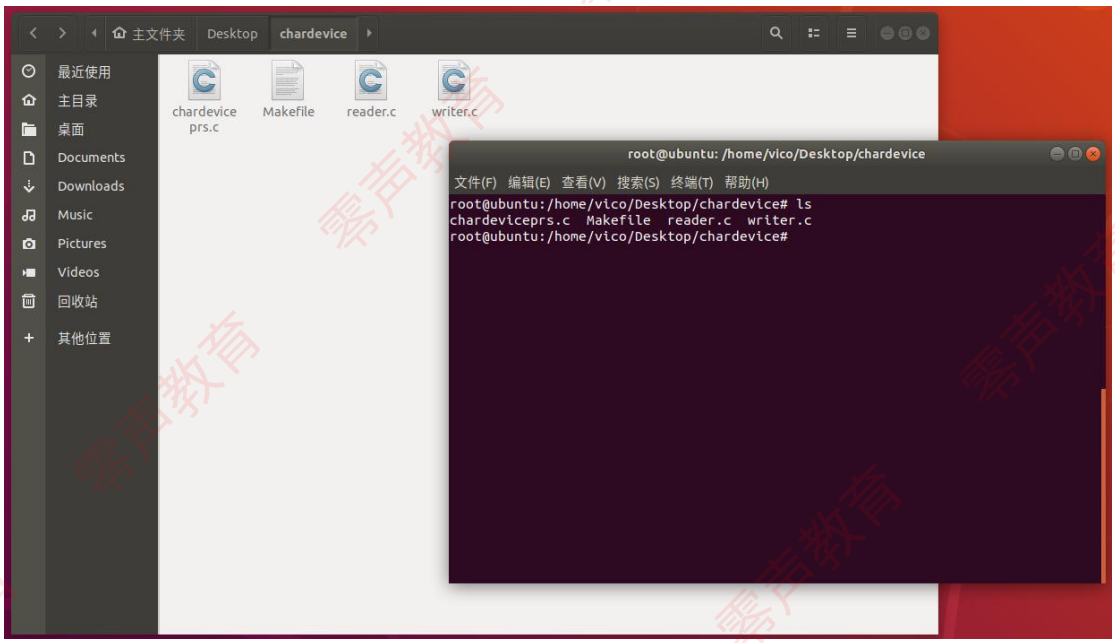
```
15 struct cdev {
16     struct kobject kobj;
17     struct module *owner;
18     const struct file_operations *ops;
19     struct list_head list;
20     dev_t dev;
21     unsigned int count;
22 } __randomize_layout;
23
```

include > linux > C fs.h > file_operations

```
1781
1782 struct file_operations {
1783     struct module *owner;
1784     loff_t (*llseek) (struct file *, loff_t, int);
1785     ssize_t (*read) (struct file *, char __user *, size_t, loff_t *);
1786     ssize_t (*write) (struct file *, const char __user *, size_t, loff_t *);
1787     ssize_t (*read_iter) (struct kiocb *, struct iov_iter *);
1788     ssize_t (*write_iter) (struct kiocb *, struct iov_iter *);
1789     int (*iterate) (struct file *, struct dir_context *);
1790     int (*iterate_shared) (struct file *, struct dir_context *);
1791     __poll_t (*poll) (struct file *, struct poll_table_struct *);
```

3、字符设备驱动程序通信实战

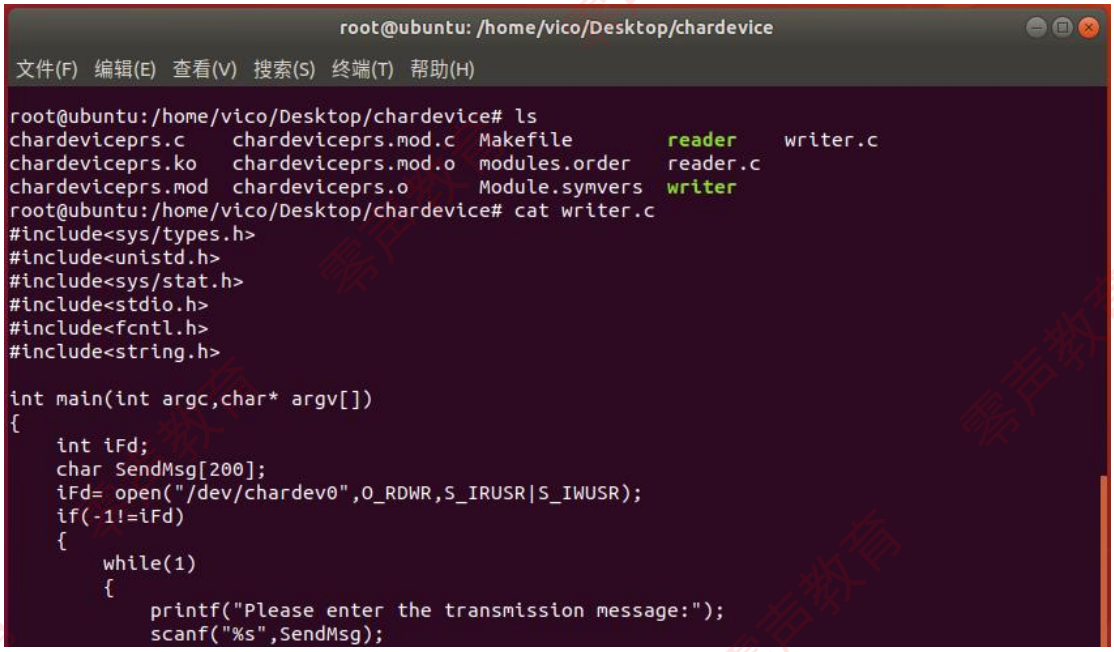
a、编码实现字符设备驱动程序，通过对字符设备的同步操作完成应用程序之间的数据通信。



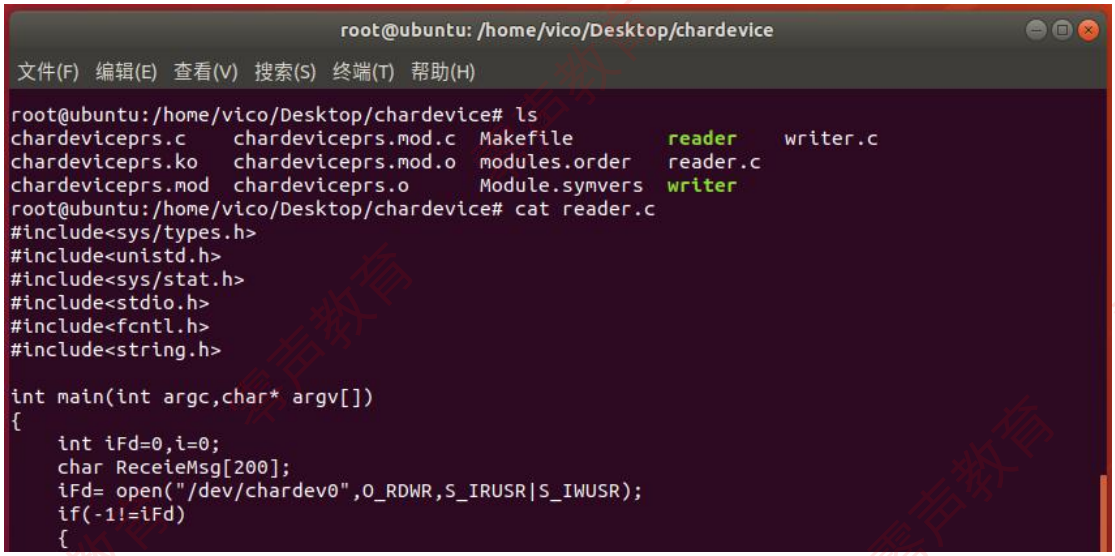
b、字符驱动设备源码

```
root@ubuntu: /home/vico/Desktop/chardevice
文件(F)  编辑(E)  查看(V)  搜索(S)  终端(T)  帮助(H)
root@ubuntu:/home/vico/Desktop/chardevice# ls
chardeviceprs.c     chardeviceprs.mod.c  Makefile        reader     writer.c
chardeviceprs.ko    chardeviceprs.mod.o  modules.order   reader.c
chardeviceprs.mod   chardeviceprs.o      Module.symvers  writer
root@ubuntu:/home/vico/Desktop/chardevice# cat chardeviceprs.c
#include <linux/module.h>
#include <linux/init.h>
#include <linux/fs.h>
#include <asm/uaccess.h>
#include <linux/wait.h>
#include <linux/semaphore.h>
#include <linux/sched.h>
#include <linux/cdev.h>
#include <linux/types.h>
#include <linux/kdev_t.h>
#include <linux/device.h>
#include <linux/uaccess.h>

#define MAXNUM 1000
#define MAJOR_NUM 466

struct dev{
    struct cdev devm;
    struct semaphore sem;
    wait_queue_head_t outq;
    int flag;
    char buffer[MAXNUM+1];
    char *rd,*wr,*end;
}globalvar;
static struct class *my_class;
int major=MAJOR_NUM;
```

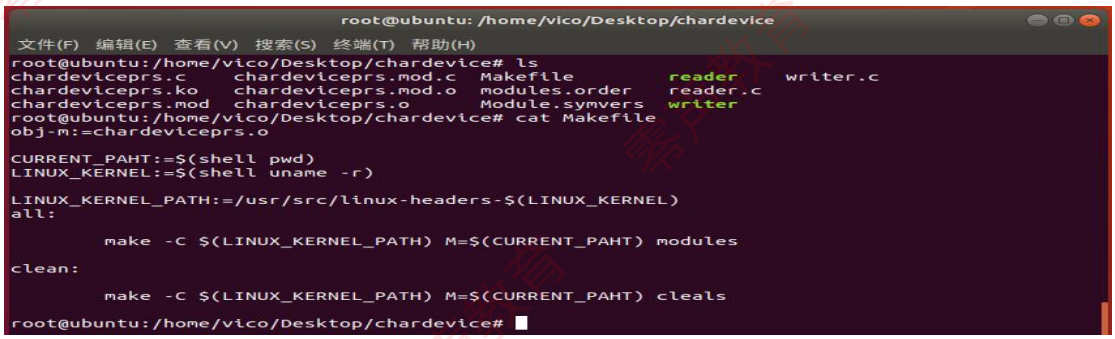
c、数据发送端源码



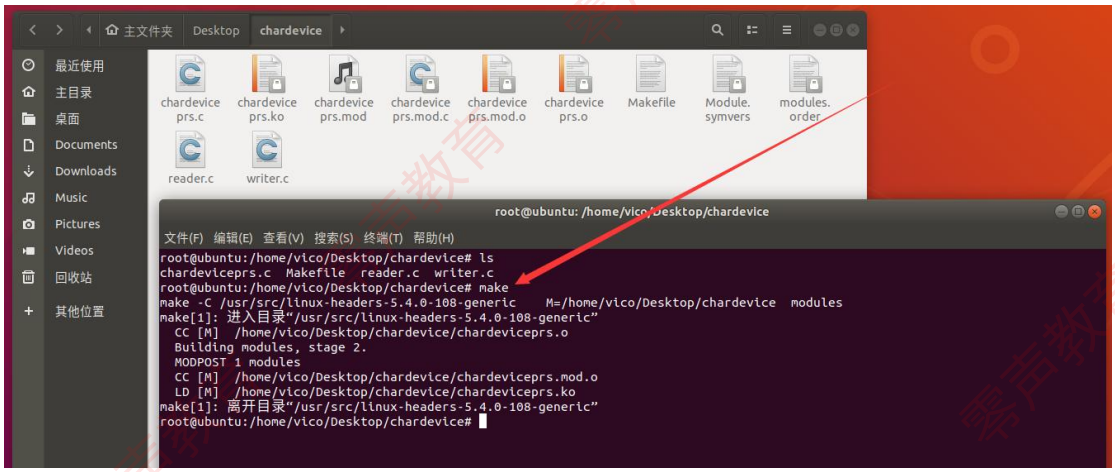
d、数据读取端源码



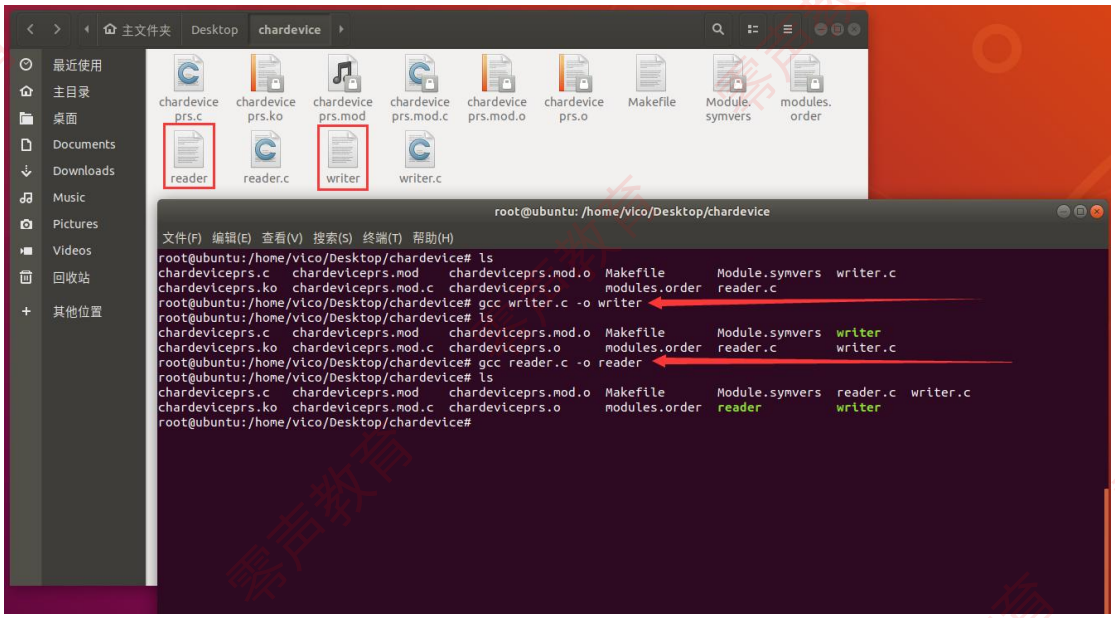
e、Makefile 文件设计



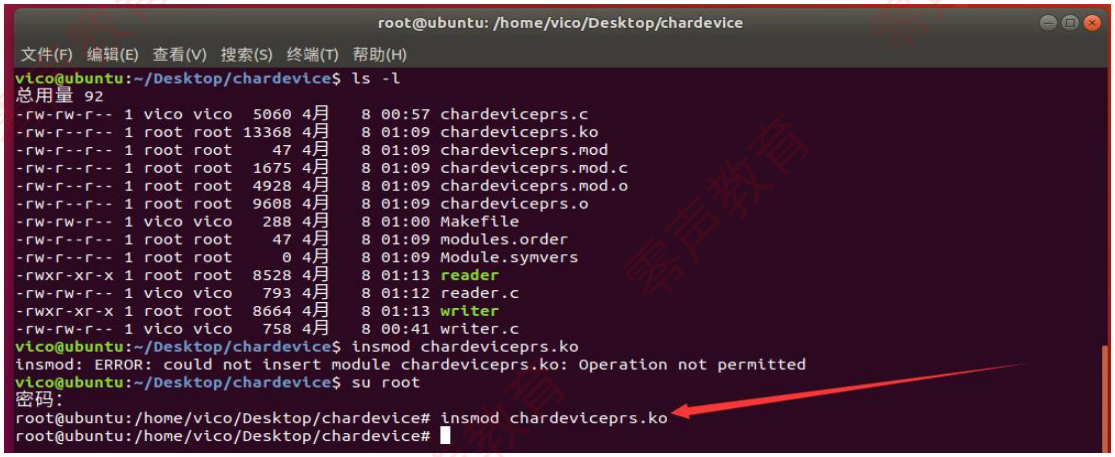
f、程序执行效果



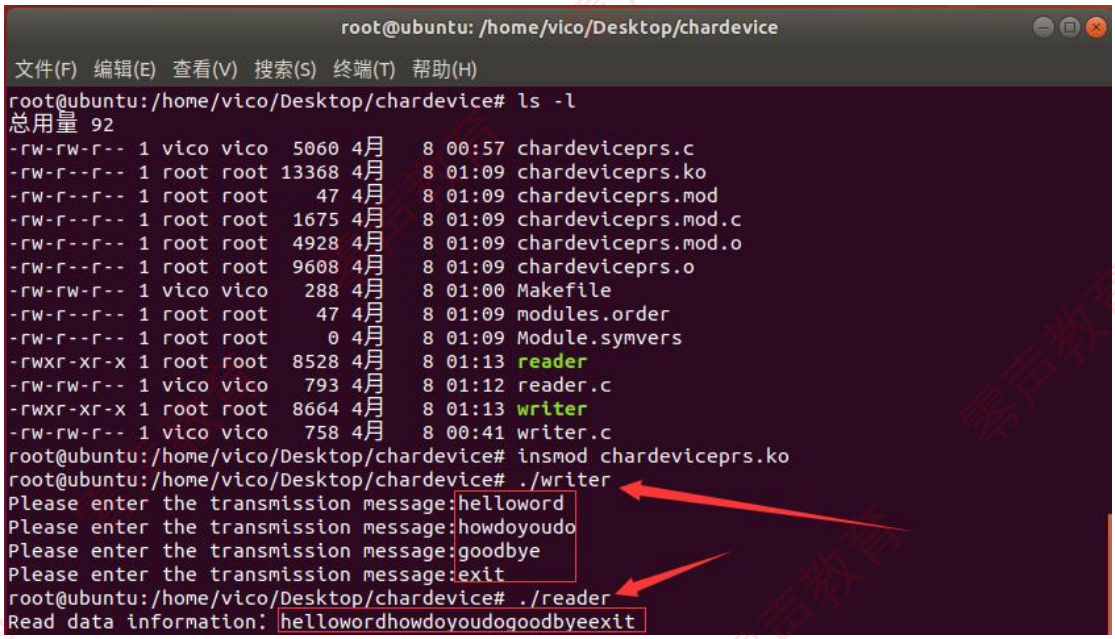
g、【编译】【数据发送端和数据读取端程序】



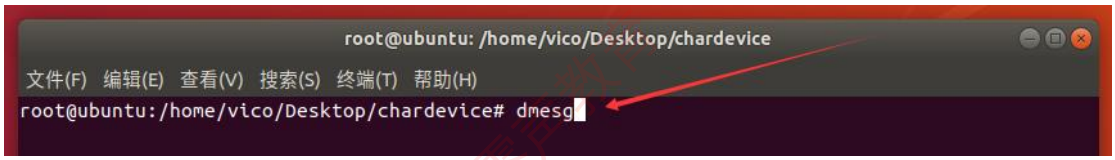
h、【插入字符设备驱动模块】

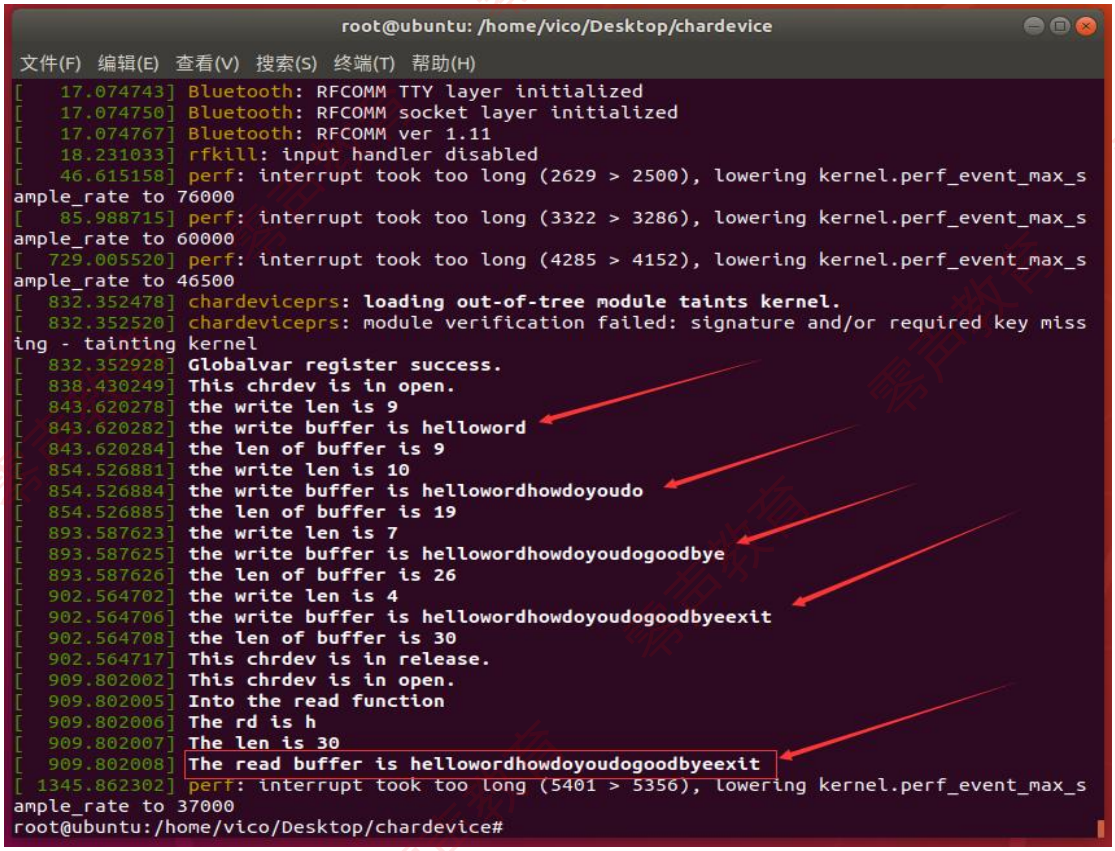


i、执行【数据发送端与数据读取端】

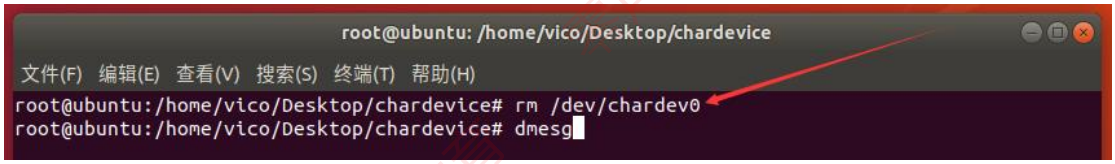


j、通过 dmesg 查看消息





k、删除字符设备驱动模块



三、设备驱动数据结构及 I/O 调度

1、device 表示元数据（代表一个物理设备）

include > linux > C device.h > ...

```
971  struct device {
972      struct device       *parent;
973
974      struct device_private   *p;
975
976      struct kobject kobj;
977      const char      *init_name; /* initial name of the device */
978      const struct device_type *type;
979
```

2、字符设备

include > linux > C cdev.h > cdev > ops

```
15  struct cdev {
16      struct kobject kobj;
17      struct module *owner;
18      const struct file_operations *ops;
19      struct list_head list;
20      dev_t dev;
21      unsigned int count;
22  } __randomize_layout;
23
```

3、块设备

include > linux > C genhd.h > gendisk

```
174
175 struct gendisk {
176     /* major, first_minor and minors are input parameters only,
177      * don't use directly.  Use disk_devt() and disk_max_parts().
178      */
179     int major;          /* major number of driver */
180     int first_minor;
181     int minors;                     /* maximum number of minors, =1 for
182                                      * disks that can't be partitioned.
183
184     char disk_name[DISK_NAME_LEN];  /* name of major driver */
185     char *(*devnode)(struct gendisk *gd, umode_t *mode);
186
187     unsigned int events;        /* supported events */
```

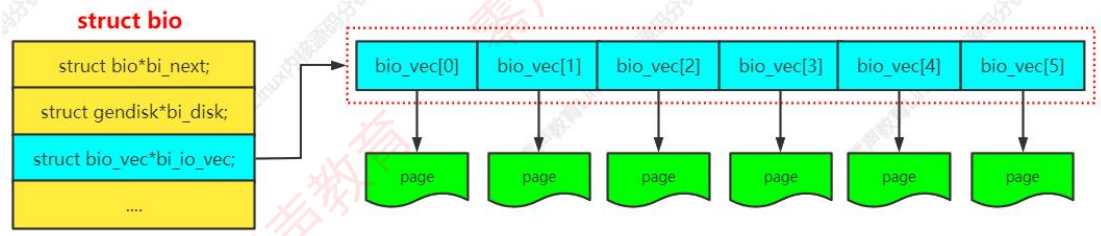
3、bio 结构体包含大量的基础信息，这些都是一个基本单元的属性，他们代表着当前这个 bio 的状态，比如是读还是写或者是一些特殊的操作命令等等。一个 bio 所请求的数据块在设备当中是连续的，bio 所携带的数据大小有上限。

bio 数据结构分析如下：

include > linux > C blk_types.h > bio

```
139
140  /*
141   * main unit of I/O for the block layer and lower layers (ie drivers and
142   * stacking drivers)
143   */
144  struct bio {
145      struct bio      *bi_next;   /* request queue link */
146      struct gendisk      *bi_disk;
147      unsigned int        bi_opf;     /* bottom bits req flags,
148                               * top bits REQ_OP. Use
149                               * accessors.
150                               */
151      unsigned short      bi_flags;   /* status, etc and bvec pool number */
152      unsigned short      bi_ioprio;
153      unsigned short      bi_write_hint;
154      blk_status_t        bi_status;
155      u8          bi_partno;
156
157      /* Number of segments in this BIO after
158       * physical address coalescing is performed.
159       */
160      unsigned int        bi_phys_segments;
```

bio/bi_io_vec/page 之间的联系如下：



4、I/O 调度操作

Linux 内核采用的各种用于调度和重排 I/O 操作请求以获得最优的性能的算法，称为 I/O 调度器。在将请求提交给块设备时提供各种调度策略，具体通过 elevator_type 来管理及实现 I/O 调度器。具体源码如下：

include > linux > C elevator.h > elevator_type

```
62
63  /*
64   * identifies an elevator type, such as AS or deadline
65   */
66  struct elevator_type
67  {
68      /* managed by elevator core */
69      struct kmem_cache *icq_cache;
70
71      /* fields provided by elevator implementation */
72      struct elevator_mq_ops ops;
73
74      size_t icq_size;    /* see iocontext.h */
75      size_t icq_align;   /* ditto */
```