操作系统 Lab1 实验报告

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练习1

1 execvp: bin/sign: 权限不够

安装好gcc和qemu，执行make命令立刻出现了第一个问题：make之后执行到ld bin/bootblock就提示出错,，使用sudo也没有用：

```
+ ld bin/bootblock
make: execvp: bin/sign: 权限不够
Makefile:202: recipe for target 'bin/bootblock' failed
make: *** [bin/bootblock] Error 127
```

于是去查看了bin/sign的权限：

应当是执行权限的问题，但是需要勾选上允许可执行却发现选不上（会立刻取消）

查了好多博客没有类似情况，最后在一个论坛的评论里找到答案：原因是我将工作区放到了我的移动硬盘里，而需要移到ubuntu的/home工作区才能修改权限。

于是重新迁移工作区到/home目录，执行make，成功运行。输出如下：

```
+ cc kern/init/init.c
+ cc kern/libs/stdio.c
+ cc kern/libs/readline.c
+ cc kern/debug/panic.c
+ cc kern/debug/kdebug.c
+ cc kern/debug/kmonitor.c
+ cc kern/driver/clock.c
+ cc kern/driver/console.c
+ cc kern/driver/picirq.c
+ cc kern/driver/intr.c
+ cc kern/trap/trap.c
+ cc kern/trap/vectors.S
+ cc kern/trap/trapentry.S
+ cc kern/mm/pmm.c
+ cc libs/string.c
+ cc libs/printfmt.c
+ ld bin/kernel
# 执行链接脚本利用kobjs生成kernel对象
+ cc boot/bootasm.S
+ cc boot/bootmain.c
+ cc tools/sign.c
+ ld bin/bootblock
'obj/bootblock.out' size: 488 bytes
build 512 bytes boot sector: 'bin/bootblock' success!
记录了10000+0 的读入
记录了10000+0 的写出
5120000 bytes (5.1 MB, 4.9 MiB) copied, 0.0298493 s, 172 MB/s
记录了1+0 的读入
记录了1+0 的写出
512 bytes copied, 0.000176146 s, 2.9 MB/s
记录了155+1 的读入
记录了155+1 的写出
79840 bytes (80 kB, 78 KiB) copied, 0.000772137 s, 103 MB/s
```

2 一个被系统认为是符合规范的硬盘主引导扇区的特征是什么?

这是练习里的问题，查看Makefile文件对应bootblock的部分如下：

```
# create bootblock
bootfiles = $(call listf_cc,boot)
$(foreach f,$(bootfiles),$(call cc_compile,$(f),$(CC),$(CFLAGS) -Os -nostdinc))

bootblock = $(call totarget,bootblock)

$(bootblock): $(call toobj,$(bootfiles)) | $(call totarget,sign)
	@echo + ld $@
	$(V)$(LD) $(LDFLAGS) -N -e start -Ttext 0x7C00 $^ -o $(call toobj,bootblock)
	@$(OBJDUMP) -S $(call objfile,bootblock) > $(call asmfile,bootblock)
	@$(OBJDUMP) -t $(call objfile,bootblock) | $(SED) '1,/SYMBOL TABLE/d; s/ .* / /; /^$$/d' > $(call
symfile,bootblock)
	@$(OBJCOPY) -S -O binary $(call objfile,bootblock) $(call outfile,bootblock)
	@$(call totarget,sign) $(call outfile,bootblock) $(bootblock)

$(call create_target,bootblock)
```

`@$(call totarget,sign) $(call outfile,bootblock) $(bootblock)` 这里使用了sign工具重写文件，查看sign.c的代码：

```
int main(int argc, char *argv[]) {
    struct stat st;
    if (argc != 3) {
        fprintf(stderr, "Usage: <input filename> <output filename>\n");
        return -1;
    }
    if (stat(argv[1], &st) != 0) {
        fprintf(stderr, "Error opening file '%s': %s\n", argv[1], strerror(errno));
        return -1;
    }
    printf("'%s' size: %lld bytes\n", argv[1], (long long)st.st_size);
    if (st.st_size > 510) {
        fprintf(stderr, "%lld >> 510!!\n", (long long)st.st_size);
        return -1;
    }
    char buf[512];
    memset(buf, 0, sizeof(buf));
    FILE *ifp = fopen(argv[1], "rb");
    int size = fread(buf, 1, st.st_size, ifp);
    if (size != st.st_size) {
        fprintf(stderr, "read '%s' error, size is %d.\n", argv[1], size);
        return -1;
    }
    fclose(ifp);
    buf[510] = 0x55;
    buf[511] = 0xAA;
    FILE *ofp = fopen(argv[2], "wb+");
    size = fwrite(buf, 1, 512, ofp);
    if (size != 512) {
        fprintf(stderr, "write '%s' error, size is %d.\n", argv[2], size);
        return -1;
    }
```

```
    fclose(ofp);
    printf("build 512 bytes boot sector: '%s' success!\n", argv[2]);
    return 0;
}
```

答案就很明确了，符合规范的硬盘主引导扇区的特征如下：

- 主引导扇区的长度为512个字节长
- `buf[510] = 0x55;buf[511] = 0xAA;` ——以0x55AA结尾

练习2

1 qemu命令不存在

安装之后可以显示版本，却无法执行命令qemu

```
Command 'qemu' not found, did you mean:

  command 'aqemu' from deb aqemu

Try: sudo apt install <deb name>
```

看到一篇博客上的方法——按q+tab查看可使用的命令：

```
hzkz@hzkz-Surface-Pro-6:~$ q
qemu-aarch64              qemu-ppc64abi32           qemu-system-ppc
qemu-alpha                qemu-ppc64le              qemu-system-ppc64
qemu-arm                  qemu-s390x                qemu-system-ppc64le
qemu-armeb                qemu-sh4                  qemu-system-ppcemb
qemu-cris                 qemu-sh4eb                qemu-system-s390x
qemu-hppa                 qemu-sparc                qemu-system-sh4
qemu-i386                 qemu-sparc32plus          qemu-system-sh4eb
qemu-img                  qemu-sparc64              qemu-system-sparc
qemu-io                   qemu-system-aarch64       qemu-system-sparc64
qemu-m68k                 qemu-system-alpha         qemu-system-tricore
qemu-make-debian-root     qemu-system-arm           qemu-system-unicore32
qemu-microblaze           qemu-system-cris          qemu-system-x86_64
qemu-microblazeel         qemu-system-i386          qemu-system-xtensa
qemu-mips                 qemu-system-lm32          qemu-system-xtensaeb
qemu-mips64               qemu-system-m68k          qemu-tilegx
qemu-mips64el             qemu-system-microblaze    qemu-x86_64
qemu-mipsel               qemu-system-microblazeel  qpdf
qemu-mipsn32              qemu-system-mips          qpdldecode
qemu-mipsn32el            qemu-system-mips64        qrttoppm
qemu-nbd                  qemu-system-mips64el      quirks-handler
qemu-nios2                qemu-system-mipsel        quote
qemu-or1k                 qemu-system-moxie         quote_readline
qemu-ppc                  qemu-system-nios2
qemu-ppc64                qemu-system-or1k
```

使用命令qemu-system-i386就行,也可以建立软链接以使用qemu。

```
qemu-system-i386 -s -S -hda ./bin/ucore.img -monitor stdio -D qemu.log
```

2 简要说明运行过程

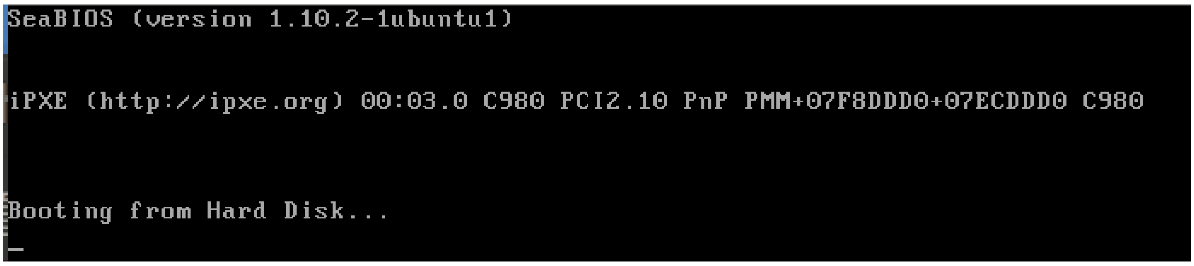
执行qemu，将ucore暂停住

```
qemu-system-i386 -s -S -hda ./bin/ucore.img -monitor stdio -D qemu.log
```

开另一个终端，运行gdb，运行以下命令调试

```
set architecture i8086
target remote localhost:1234
file ./bin/kernel    #为了让gdb在调试的过程中获取到符号信息
b *0x7c00        #对地址c进行断点设置的方法
c        #continue
x /10i $pc       #查看反汇编代码
si          #以机器代码的形式单步调试
```

运行到0x7c00如下图：



这时 `x /10i $pc` 查看之后的反汇编代码：

```
=> 0x7c00:  cli
   0x7c01:  cld
   0x7c02:  xor    %eax,%eax
   0x7c04:  mov    %eax,%ds
   0x7c06:  mov    %eax,%es
   0x7c08:  mov    %eax,%ss
   0x7c0a:  in     $0x64,%al
   0x7c0c:  test   $0x2,%al
   0x7c0e:  jne    0x7c0a
   0x7c10:  mov    $0xd1,%al
```

对比bootasm.S：

```
.globl start
start:
.code16                             # Assemble for 16-bit mode
  cli                           # Disable interrupts
  cld                           # String operations increment

  # Set up the important data segment registers (DS, ES, SS).
  xorw %ax, %ax                         # Segment number zero
  movw %ax, %ds                         # -> Data Segment
  movw %ax, %es                         # -> Extra Segment
  movw %ax, %ss                         # -> Stack Segment

  # Enable A20:
  #  For backwards compatibility with the earliest PCs, physical
  #  address line 20 is tied low, so that addresses higher than
  #  1MB wrap around to zero by default. This code undoes this.
seta20.1:
  inb $0x64, %al                        # Wait for not busy(8042 input buffer empty).
  testb $0x2, %al
  jnz seta20.1
```

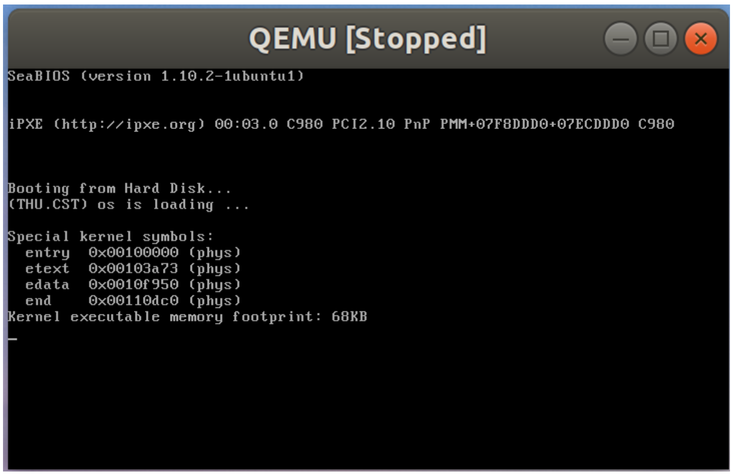
bootblock.asm：

```
.globl start
start:
.code16                         # Assemble for 16-bit mode
  cli                           # Disable interrupts
  7c00:  fa               cli
  cld                           # String operations increment
  7c01:  fc               cld

  # Set up the important data segment registers (DS, ES, SS).
  xorw %ax, %ax                 # Segment number zero
  7c02:  31 c0            xor    %eax,%eax
  movw %ax, %ds                 # -> Data Segment
  7c04:  8e d8            mov    %eax,%ds
  movw %ax, %es                 # -> Extra Segment
  7c06:  8e c0            mov    %eax,%es
  movw %ax, %ss                 # -> Stack Segment
  7c08:  8e d0            mov    %eax,%ss

00007c0a <seta20.1>:
  # Enable A20:
  #  For backwards compatibility with the earliest PCs, physical
  #  address line 20 is tied low, so that addresses higher than
  #  1MB wrap around to zero by default. This code undoes this.
seta20.1:
  inb $0x64, %al                # Wait for not busy(8042 input buffer empty).
  7c0a:  e4 64            in     $0x64,%al
  testb $0x2, %al
  7c0c:  a8 02            test   $0x2,%al
  jnz seta20.1
  7c0e:  75 fa            jne    7c0a <seta20.1>
```

在kernel.asm中找到print_stackframe

```
void
print_stackframe(void) {
  100baa:  55                 push   %ebp
  100bab:  89 e5              mov    %esp,%ebp
  100bad:  53                 push   %ebx
  100bae:  83 ec 24           sub    $0x24,%esp
  100bb1:  e8 ca f6 ff ff     call   100280 <__x86.get_pc_thunk.bx>
  100bb6:  81 c3 9a ed 00 00  add    $0xed9a,%ebx
     *          the calling funciton's ebp = ss:[ebp]
     */
    //print the important info of register ebp and esp
    uint32_t ebp_value; //the value is the address of ebp register
    uint32_t eip_value;
    uint32_t argu_count = 4;
  100bbc:  c7 45 e4 04 00 00 00   movl   $0x4,-0x1c(%ebp)
}
```

设置断点到 0x100baa，输入c继续运行，可以查看到print_stackframe的汇编代码




```
Breakpoint 2, print_stackframe () at kern/debug/kdebug.c:292
292     print_stackframe(void) {
(gdb) x /10i $pc
=> 0x100baa <print_stackframe>: push   %ebp
   0x100bab <print_stackframe+1>:       mov    %esp,%ebp
   0x100bad <print_stackframe+3>:       push   %ebx
   0x100bae <print_stackframe+4>:       sub    $0x24,%esp
   0x100bb1 <print_stackframe+7>:       call   0x100280 <__x86.get_pc_thunk.bx>
   0x100bb6 <print_stackframe+12>:      add    $0xed9a,%ebx
   0x100bbc <print_stackframe+18>:      movl   $0x4,-0x1c(%ebp)
   0x100bc3 <print_stackframe+25>:      mov    %ebp,%eax
   0x100bc5 <print_stackframe+27>:      mov    %eax,-0x24(%ebp)
   0x100bc8 <print_stackframe+30>:      mov    -0x24(%ebp),%eax
```

练习3

启动CPU:

切换到32位保护模式，跳转到C代码段
BIOS将这段代码从硬盘的第一个扇区加载到物理地址0x7c00的内存中，并以%cs= 0% ip=7c00的实际模式开始执行。

```
#include <asm.h>

.set PROT_MODE_CSEG,      0x8             # 核心代码段选择器
.set PROT_MODE_DSEG,      0x10            # 核心数据段选择器
.set CR0_PE_ON,           0x1             # 保护模式启用标志

# 开始地址应该是0:7c00，在实模式下，运行的引导汇编程序的开始地址
.globl start  #以下几步是关闭中断操作
start:
.code16                                   # 16位汇编模式
    cli                                   # cli 禁止中断发生
    cld                                   # 串操作指令，使得DF寄存器置零

    # 设置重要数据段寄存器(DS, ES, SS)
    xorw %ax, %ax                         # ax寄存器清零
    movw %ax, %ds                         # -> 数据段寄存器清零
    movw %ax, %es                         # -> 附加段寄存器清零
    movw %ax, %ss                         # -> 堆栈段清零
```

启用A20:
为了向后兼容最早的pc，物理地址行20被绑定得很低，所以高于1MB的地址在默认情况下循环回零（我个人理解为取模）。这段代码解除了这个功能。

```
seta20.1:   #告诉CPU这一步将要向8042的P2端口写数据
inb $0x64, %al
# inb 从I/O端口读取一个字节(BYTE, HALF-WORD)
# 读取状态寄存器，等待8042键盘控制器空闲
   testb $0x2, %al   #判断输入缓存是否为空
   jnz seta20.1

   movb $0xd1, %al                  # 0xd1 -> port 0x64
outb %al, $0x64
# outb指令是输出，向P2端口写入$0xdl

seta20.2:   #向端口0x60写数据0xdf，从而将A20置一
inb $0x64, %al             # inb 从I/O端口读取一个字节(BYTE, HALF-WORD)

testb $0x2, %al # 读取状态寄存器，等待8042键盘控制器空闲

   jnz seta20.2

   movb $0xdf, %al                  # 0xdf -> port 0x60
outb %al, $0x60                  #通过0x60写入数据11011111 即将A20置1
```

从实模式切换到保护模式，使用引导GDT和段转换，使虚拟地址与物理地址相同，这样有效内存映射在切换期间不会改变。

- 实模式： cs：ip寻址模式 也就是cs乘以16（左移4位）+ip 最大寻址空间1M
- 保护模式： 保护模式与实模式相比，主要是两个差别：一是提供了段间的保护机 制，防止程序间胡乱访问地址带来的问题，二是访问的内存空间变大。

```
lgdt gdtdesc   #加载GDT表：全局描述表
   movl %cr0, %eax
   orl $CR0_PE_ON, %eax
   movl %eax, %cr0

   # Jump to next instruction, but in 32-bit code segment.
   # Switches processor into 32-bit mode.
   ljmp $PROT_MODE_CSEG, $protcseg

.code32                          # Assemble for 32-bit mode
protcseg:
   # 设置保护模式的数据段寄存器
   movw $PROT_MODE_DSEG, %ax              # Our data segment selector
   movw %ax, %ds                    # -> DS: Data Segment
   movw %ax, %es                    # -> ES: Extra Segment
   movw %ax, %fs                    # -> FS
   movw %ax, %gs                    # -> GS
   movw %ax, %ss                    # -> SS: Stack Segment

# 设置堆栈指针并调用C 堆栈区域从0开始(0x7c00)
movl $0x0, %ebp
   movl $start, %esp
   call bootmain
```

```
    # If bootmain returns (it shouldn't), loop.
spin:
    jmp spin

# Bootstrap GDT
.p2align 2                          # force 4 byte alignment
gdt:
    SEG_NULLASM                             # null seg
    SEG_ASM(STA_X|STA_R, 0x0, 0xffffffff)         # code seg for bootloader and kernel
    SEG_ASM(STA_W, 0x0, 0xffffffff)             # data seg for bootloader and kernel
          #0x0-0xffffffff意味着每个段分配4G的长度
gdtdesc:
    .word 0x17                          # sizeof(gdt) - 1
.long gdt                           # address gdt
```

GDTR：把全局描述符表的大小和起始地址共8个字节加载到全局描述符表寄存器GDTR中。从代码中可以看到全局描述符表的大小为0x17 + 1 = 0x18，也就是24字节。由于全局描述符表每项大小为8字节，因此一共有3项，而第一项是空白项，所以全局描述符表中只有两个有效的段描述符，分别对应代码段和数据段。

练习4

这里面没啥坑都是静态分析过程

练习5

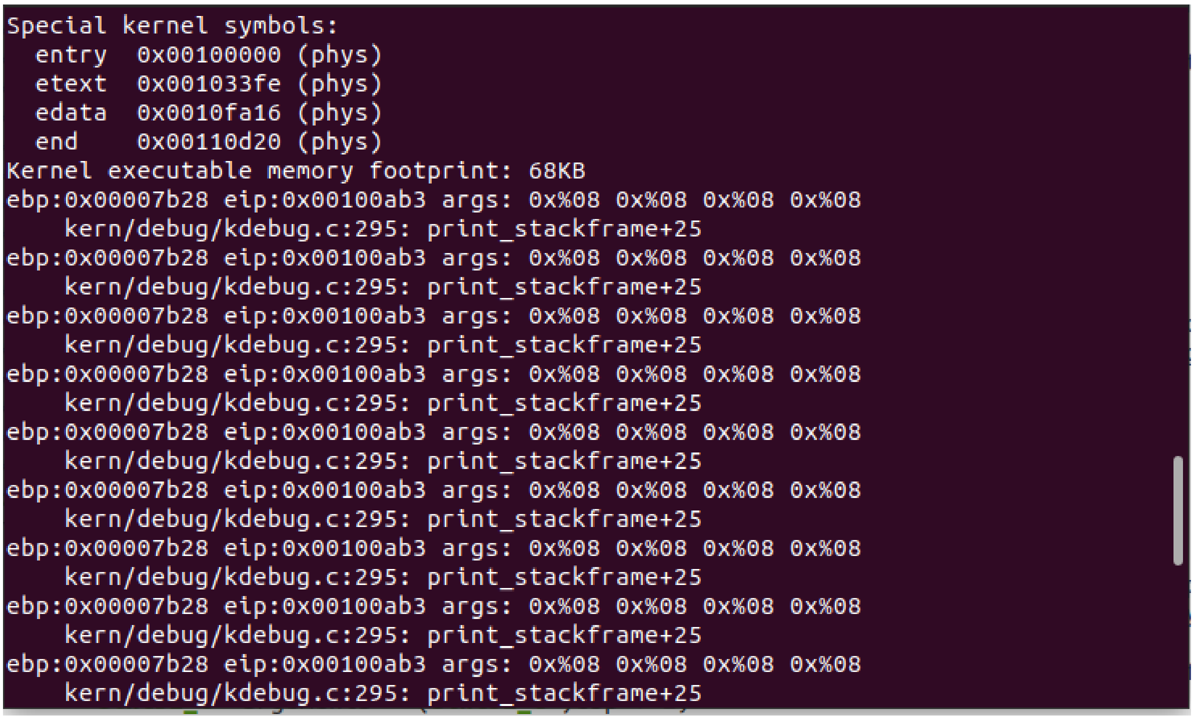
1 没有定义的函数printf

```
292 print_stackframe(void) {
293      /* LAB1 YOUR CODE : STEP 1 */
294     uint32_t ebp = read_ebp();//(1) call read_ebp() to get the value of ebp. the type is (uint32_t);
295     uint32_t eip = read_eip(); //(2) call read_eip() to get the value of eip. the type is (uint32_t);
296     for(auto it = 0; it <= STACKFRAME_DEPTH; it++){//(3) from 0 .. STACKFRAME_DEPTH
297         printf("ebp:0x%08x eip:0x%08x args: ", ebp, eip);//   (3.1) printf value of ebp, eip
298         uint32_t *arguments = (uint32_t*)ebp + 2;
299         for(auto i = 0; i < 4; i++){        //   (3.2) (uint32_t)calling arguments [0..4] = the contents in address
    (uint32_t)ebp +2 [0..4]
300             printf("0x%08 ", arguments[i]);
301         }
302         printf("\n");     //   (3.3) cprintf("\n");
303         print_debuginfo(eip-1);//   (3.4) call print_debuginfo(eip-1) to print the C calling function name and line number, etc.
304      //  (3.5) popup a calling stackframe
305      //          NOTICE: the calling funciton's return addr eip  = ss:[ebp+4]
306      //                   the calling funciton's ebp = ss:[ebp]
307      //
308     }
309 }
```

```
ld: obj/kern/debug/kdebug.o: in function `print_stackframe':
kern/debug/kdebug.c:297: undefined reference to `printf'
ld: kern/debug/kdebug.c:300: undefined reference to `printf'
ld: kern/debug/kdebug.c:302: undefined reference to `printf'
make: *** [Makefile:147: bin/kernel] Error 1
```

改成注释中要求的cprintf

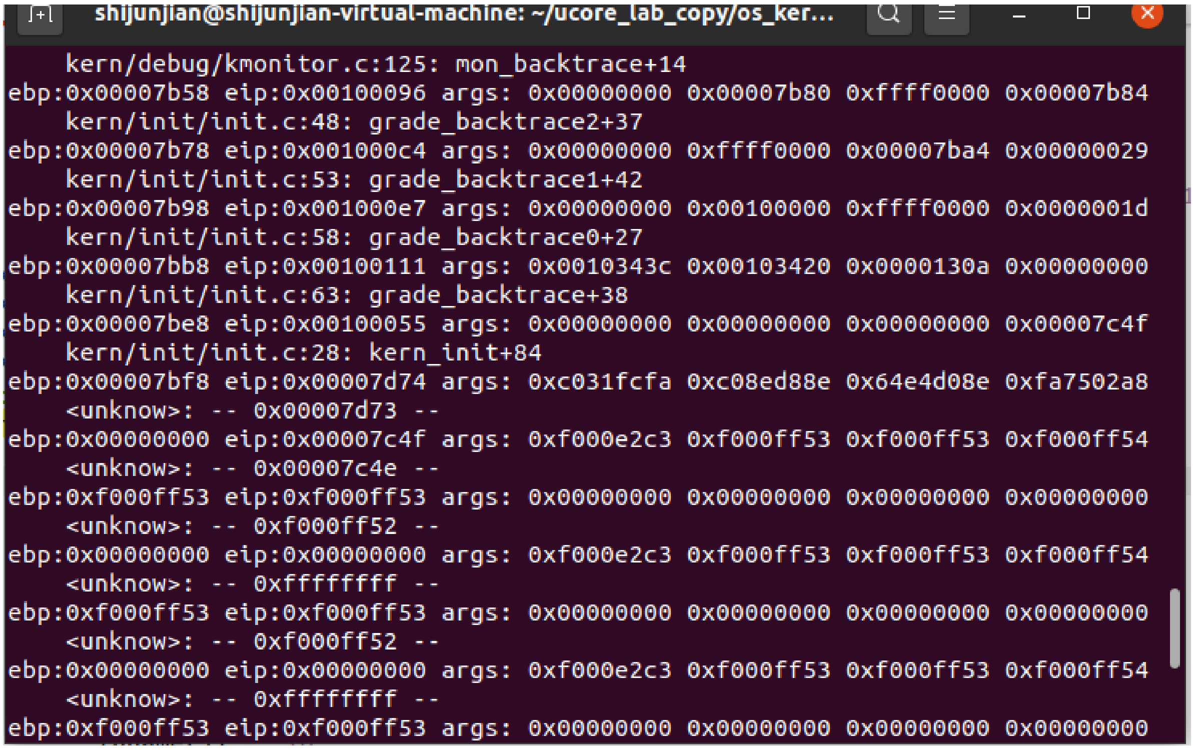
2 忘记切换ebp与eip以及C语言格式化输出有误



```
Special kernel symbols:
  entry  0x00100000 (phys)
  etext  0x001033fe (phys)
  edata  0x0010fa16 (phys)
  end    0x00110d20 (phys)
Kernel executable memory footprint: 68KB
ebp:0x00007b28 eip:0x00100ab3 args: 0x%08 0x%08 0x%08 0x%08
    kern/debug/kdebug.c:295: print_stackframe+25
ebp:0x00007b28 eip:0x00100ab3 args: 0x%08 0x%08 0x%08 0x%08
    kern/debug/kdebug.c:295: print_stackframe+25
ebp:0x00007b28 eip:0x00100ab3 args: 0x%08 0x%08 0x%08 0x%08
    kern/debug/kdebug.c:295: print_stackframe+25
ebp:0x00007b28 eip:0x00100ab3 args: 0x%08 0x%08 0x%08 0x%08
    kern/debug/kdebug.c:295: print_stackframe+25
ebp:0x00007b28 eip:0x00100ab3 args: 0x%08 0x%08 0x%08 0x%08
    kern/debug/kdebug.c:295: print_stackframe+25
ebp:0x00007b28 eip:0x00100ab3 args: 0x%08 0x%08 0x%08 0x%08
    kern/debug/kdebug.c:295: print_stackframe+25
ebp:0x00007b28 eip:0x00100ab3 args: 0x%08 0x%08 0x%08 0x%08
    kern/debug/kdebug.c:295: print_stackframe+25
ebp:0x00007b28 eip:0x00100ab3 args: 0x%08 0x%08 0x%08 0x%08
    kern/debug/kdebug.c:295: print_stackframe+25
ebp:0x00007b28 eip:0x00100ab3 args: 0x%08 0x%08 0x%08 0x%08
    kern/debug/kdebug.c:295: print_stackframe+25
```

发现ebp和eip每次输出的结果都是一样的，打印出的东西也发生了错误（C语言格式化输出错误）。忘记编码最后一步（ebp和eip的切换）

3 忘记检查ebp边界，即是否为零检查



```
shijunjian@shijunjian-virtual-machine: ~/ucore_lab_copy/os_ker...
    kern/debug/kmonitor.c:125: mon_backtrace+14
ebp:0x00007b58 eip:0x00100096 args: 0x00000000 0x00007b80 0xffff0000 0x00007b84
    kern/init/init.c:48: grade_backtrace2+37
ebp:0x00007b78 eip:0x001000c4 args: 0x00000000 0xffff0000 0x00007ba4 0x00000029
    kern/init/init.c:53: grade_backtrace1+42
ebp:0x00007b98 eip:0x001000e7 args: 0x00000000 0x00100000 0xffff0000 0x0000001d
    kern/init/init.c:58: grade_backtrace0+27
ebp:0x00007bb8 eip:0x00100111 args: 0x0010343c 0x00103420 0x0000130a 0x00000000
    kern/init/init.c:63: grade_backtrace+38
ebp:0x00007be8 eip:0x00100055 args: 0x00000000 0x00000000 0x00000000 0x00007c4f
    kern/init/init.c:28: kern_init+84
ebp:0x00007bf8 eip:0x00007d74 args: 0xc031fcfa 0xc08ed88e 0x64e4d08e 0xfa7502a8
    <unknow>: -- 0x00007d73 --
ebp:0x00000000 eip:0x00007c4f args: 0xf000e2c3 0xf000ff53 0xf000ff53 0xf000ff54
    <unknow>: -- 0x00007c4e --
ebp:0xf000ff53 eip:0xf000ff53 args: 0x00000000 0x00000000 0x00000000 0x00000000
    <unknow>: -- 0xf000ff52 --
ebp:0x00000000 eip:0x00000000 args: 0xf000e2c3 0xf000ff53 0xf000ff53 0xf000ff54
    <unknow>: -- 0xffffffff --
ebp:0xf000ff53 eip:0xf000ff53 args: 0x00000000 0x00000000 0x00000000 0x00000000
    <unknow>: -- 0xf000ff52 --
ebp:0x00000000 eip:0x00000000 args: 0xf000e2c3 0xf000ff53 0xf000ff53 0xf000ff54
    <unknow>: -- 0xffffffff --
ebp:0xf000ff53 eip:0xf000ff53 args: 0x00000000 0x00000000 0x00000000 0x00000000
```

所以打印出一堆的堆栈信息。应该在代码循环处加上ebp!=0的边界情况。

```
Kernel executable memory footprint: 68KB
ebp:0x00007b28 eip:0x00100ab3 args: 0x00010094 0x00010094 0x00007b58 0x00100096
    kern/debug/kdebug.c:295: print_stackframe+25
ebp:0x00007b38 eip:0x00100db5 args: 0x00000000 0x00000000 0x00000000 0x00007ba8
    kern/debug/kmonitor.c:125: mon_backtrace+14
ebp:0x00007b58 eip:0x00100096 args: 0x00000000 0x00007b80 0xffff0000 0x00007b84
    kern/init/init.c:48: grade_backtrace2+37
ebp:0x00007b78 eip:0x001000c4 args: 0x00000000 0xffff0000 0x00007ba4 0x00000029
    kern/init/init.c:53: grade_backtrace1+42
ebp:0x00007b98 eip:0x001000e7 args: 0x00000000 0x00100000 0xffff0000 0x0000001d
    kern/init/init.c:58: grade_backtrace0+27
ebp:0x00007bb8 eip:0x00100111 args: 0x0010343c 0x00103420 0x0000130a 0x00000000
    kern/init/init.c:63: grade_backtrace+38
ebp:0x00007be8 eip:0x00100055 args: 0x00000000 0x00000000 0x00000000 0x00007c4f
    kern/init/init.c:28: kern_init+84
ebp:0x00007bf8 eip:0x00007d74 args: 0xc031fcfa 0xc08ed88e 0x64e4d08e 0xfa7502a8
    <unknow>: -- 0x00007d73 --
++ setup timer interrupts
shijunjian@shijunjian-virtual-machine:~/ucore_lab_copy/os_kernel_lab-master/labcodes/lab1$
```

所以看出，加上边界检查之后一旦发现ebp为0就停止向下打印。

练习6

1 中断向量表的初始化

对中断向量表的初始化根本没有头绪，仔细阅读了一下代码后面的注释与提示，实际上setgate函数的构造函数在另外一个头文件mmu.h里已经定义好了，而其中的一些参数在另一个头文件memlayout.h定义好了。就是往里面填上相应的表项：

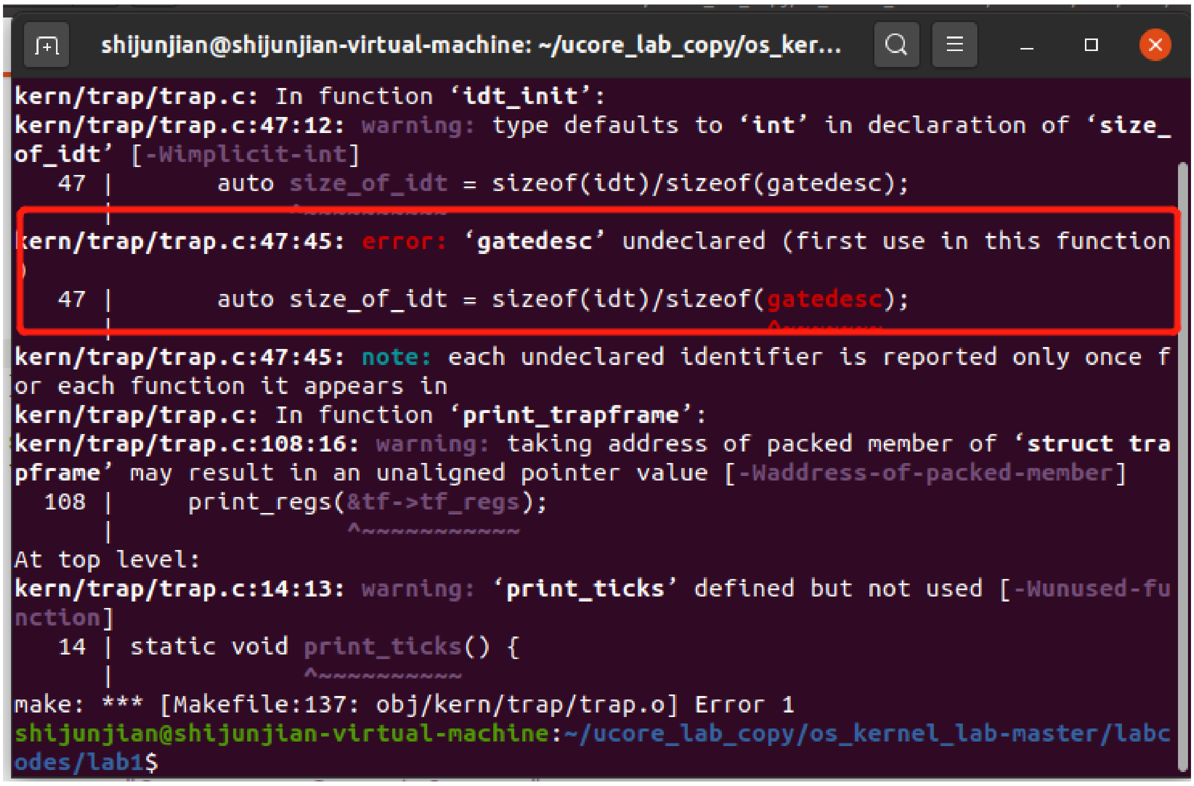
（这是网上资料对SETGATE函数的解释）

```
#define SETGATE(gate, istrap, sel, off, dpl)
```

简单解释一下参数

> `gate`：为相应的`idt[]`数组内容，处理函数的入口地址
> `istrap`：系统段设置为1，中断门设置为0
> `sel`：段选择子
> `off`：为`__vectors[]`数组内容
> `dpl`：设置特权级。这里中断都设置为内核级，即第0级

2 计算idt大小的问题，始终发现gatedesc需要定义



实际上这个也不能成为坑，只是怪自己C++没学好：这里是通过实例的大小除以这个结构体定义的大小来计算idt的大小，而结构体的大小是必须要指定struct的，否则会被识别为未定义标识符。

3 时钟两种实现方式孰优孰劣？

(1) If(ticks==100) ticks-=100; print_ticks();

(2) if(ticks%100==0) print_ticks();

第二种模运算非常耗时（甚至比除法更甚），所以会造成时钟周期相较于100ms偏差更大。