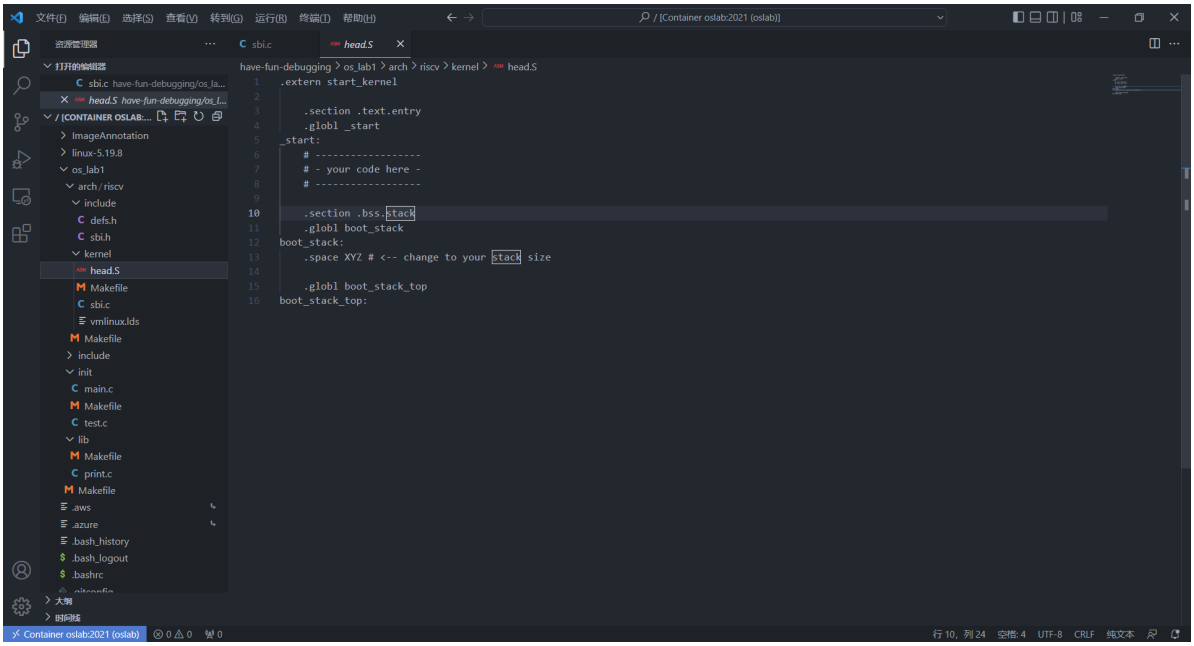
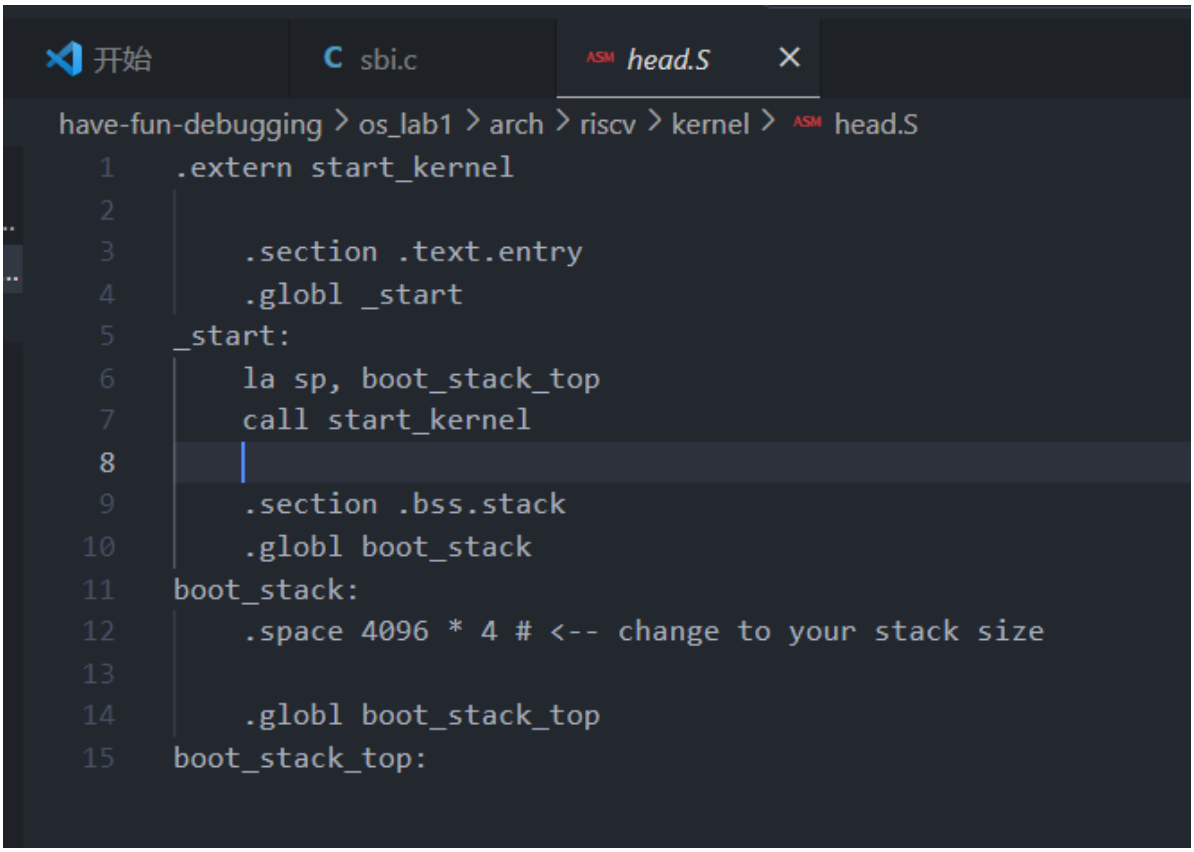
OS-lab1

连接并开启docker

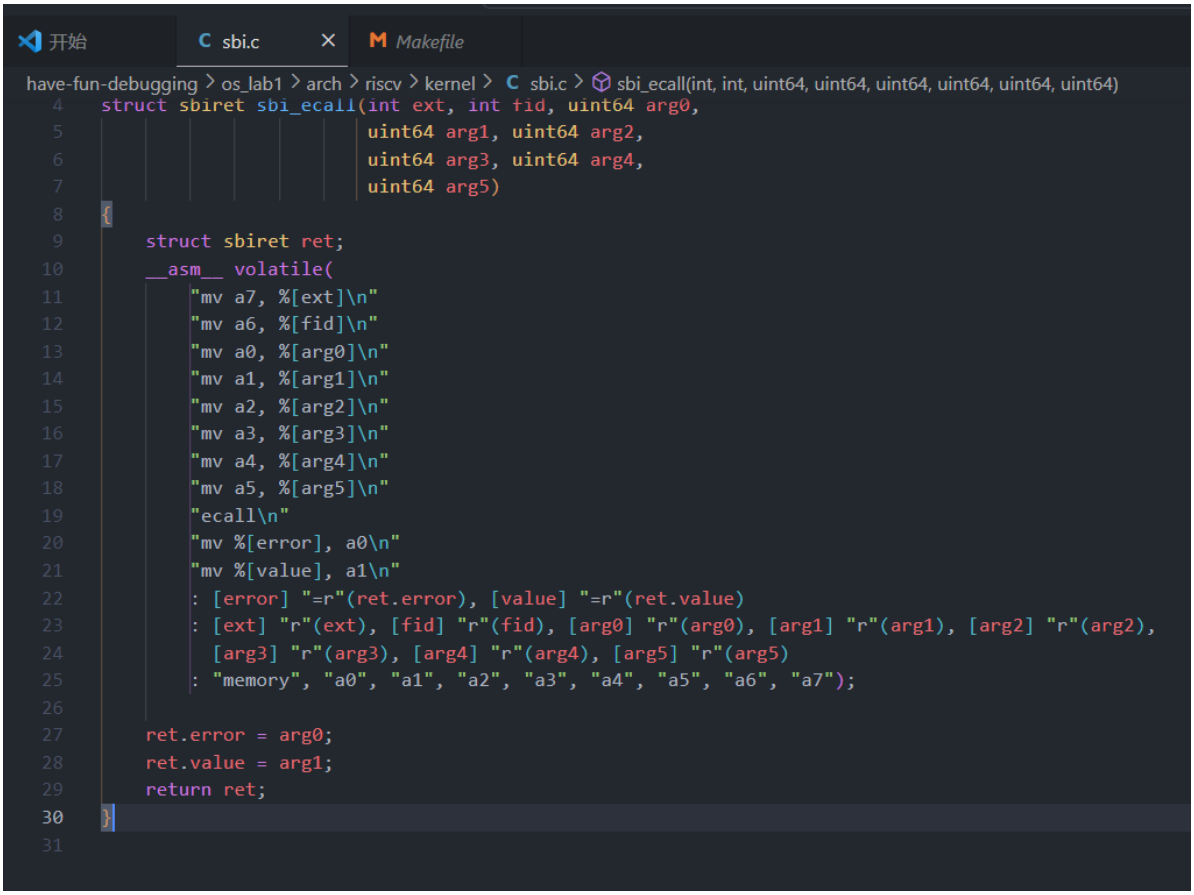


编写head.S



编写lib/Makefile

补充sbi.c



puts()和puti()

have-fun-debugging > os_lab1 > lib > C print.c > ...

```c
#include "print.h"
#include "sbi.h"

void puts(char *s)
{
    char tmp;
    for (int i = 0;; i++)
    {
        if (s[i] != '\0')
            sbi_ecall(0x1, 0x0, s[i], 0, 0, 0, 0, 0);
        else
            break;
    }
}

void puti(int x)
{
    char a[10];
    int count = 0;
    while(x != 0){
        a[count++] = x % 10 + '0';
        x /= 10;
    }
    for(int i = count-1; i >=0; i--){
        struct sbiret ret = sbi_ecall(0x1, 0x0, a[i], 0, 0, 0, 0, 0);
    }

}

```

修改defs

思考题

1

- 变量应该尽量存放在寄存器中，且避免频繁恢复和保存寄存器
- 储存返回值的寄存器、传递参数的寄存器都可以不保留原值。其他寄存器需要保留原值。
- 如果参数和局部变量太多而无法在寄存器中存下，函数的开头会在栈中为函数帧分配空间来存放。当一个函数的功能完成后将会释放栈帧并返回调用点。

> Caller Saved Register字面意思是由调用方负责保存的寄存器，被调用方可以随意使用。
>
> Callee Saved Regiser字面意思是由被调用法负责保存的寄存器，在调用结束时，被调用方需要恢复被调用前的寄存器的值。

2

```
root@f40b9b9cbdfb:/have-fun-debugging/os_lab1# ls
Makefile  System.map  arch  include  init  lib  vmlinux
root@f40b9b9cbdfb:/have-fun-debugging/os_lab1# nm vmlinux
0000000080200000 A BASE_ADDR
0000000080202000 d _GLOBAL_OFFSET_TABLE_
0000000080207000 B _ebss
0000000080202000 D _edata
0000000080207000 B _ekernel
000000008020100f R _erodata
00000000802002cc T _etext
0000000080203000 B _sbss
0000000080202000 D _sdata
0000000080200000 T _skernel
0000000080201000 R _srodata
0000000080200000 T _start
0000000080200000 T _stext
0000000080203000 B boot_stack
0000000080207000 B boot_stack_top
00000000802001d8 T puti
0000000080200150 T puts
000000008020000c T sbi_ecall
0000000080200100 T start_kernel
0000000080200140 T test
root@f40b9b9cbdfb:/have-fun-debugging/os_lab1#
```

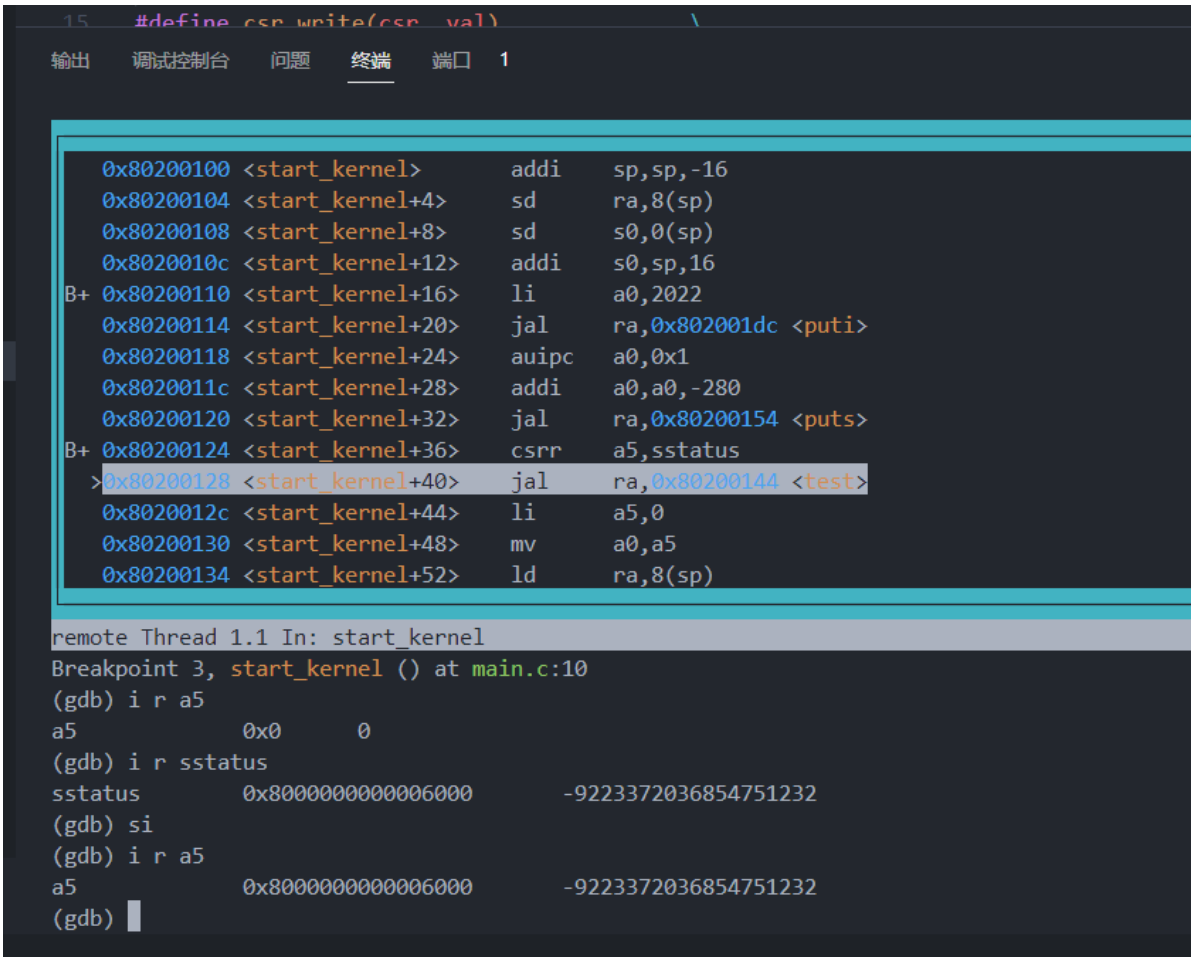
3

修改了main.c使得我们可以读取sstatus

have-fun-debugging > os_lab1 > init > C main.c > start_kernel()

```c
#include "print.h"
#include "sbi.h"
#include "defs.h"

extern void test();

int start_kernel() {
    puti(2022);
    puts(" Hello RISC-V\n");
    csr_read(0x100);

    test(); // DO NOT DELETE !!!

    return 0;
}
```

重新编译并开启debug，使用gdb查看，最终的读取结果是：



说明读取成功。

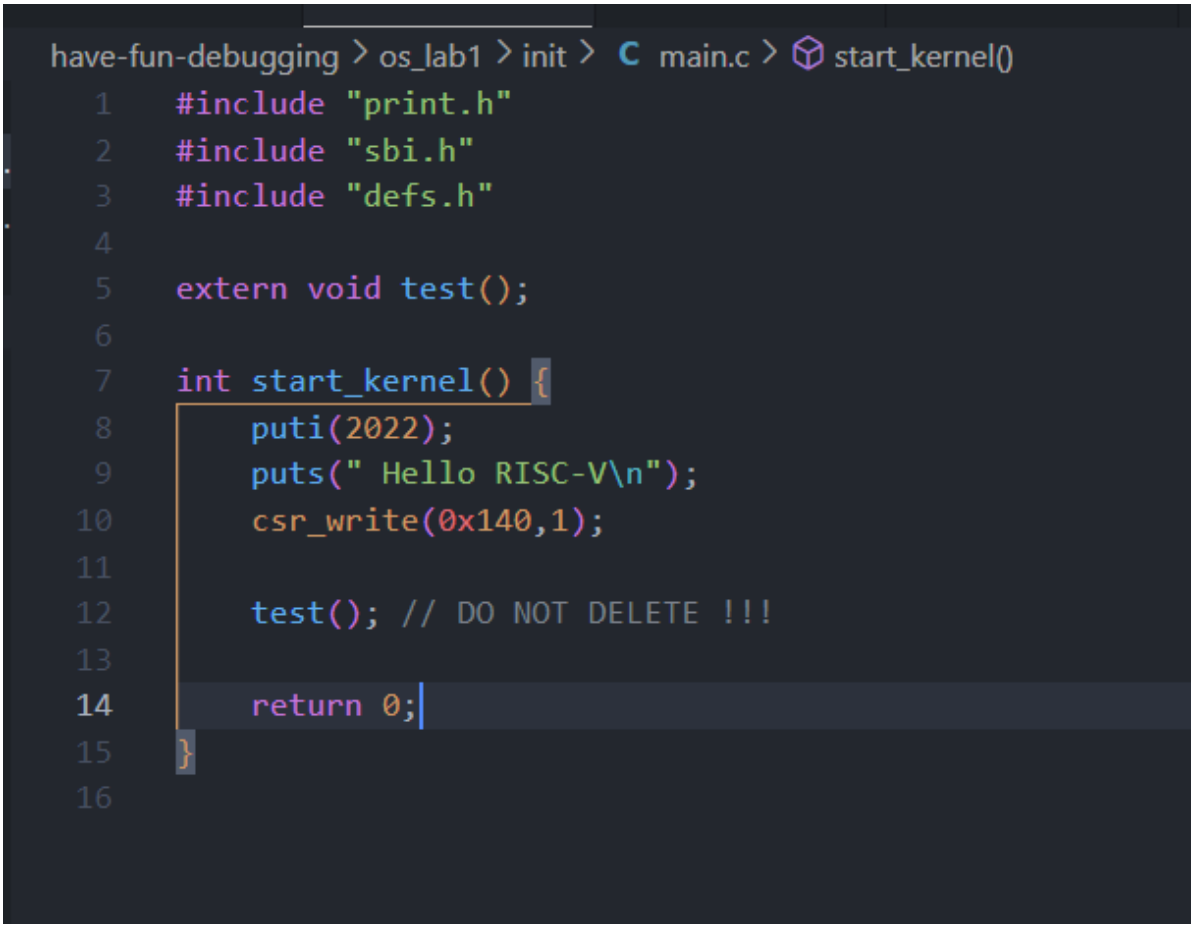
查询资料后可以得知：

SD 位是一个只读位，被置1，说明了 FS、VS 或 XS 字段存在一些需要将扩展用户上下文保存到内存的脏状态。

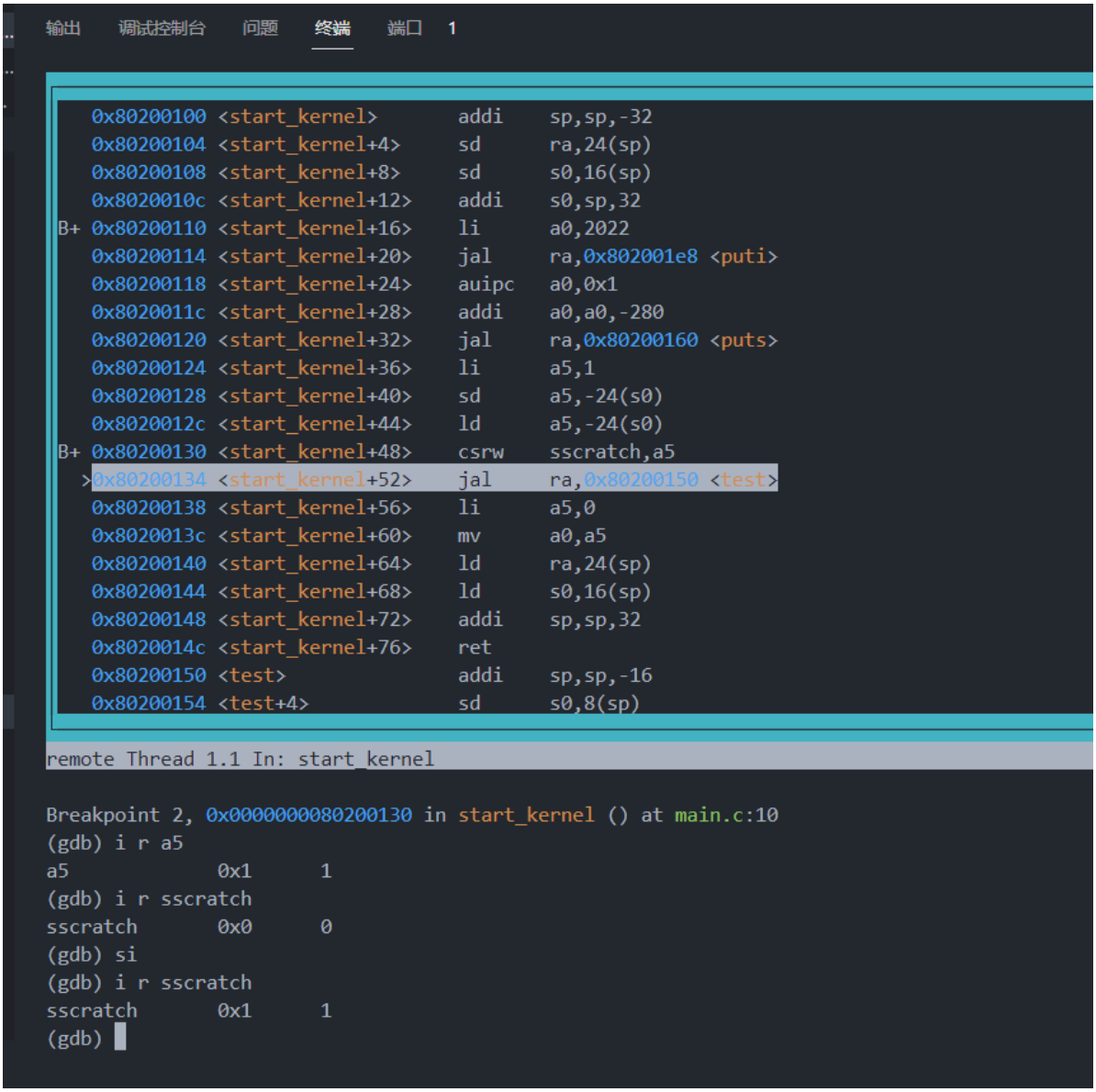
而FS域描述浮点数单元状态，被置11，说明浮点数单元设置为dirty状态。全局关闭中断模式。

4

修改main.c为：



开启gdb进行调试，发现csrw成功修改sscratch的值



5

下载并解压linux-6.0源码

```
root@f40b9b9cbdfb:/have-fun-debugging# ls
C                linux-5.19.8          linux-6.0-rc5.tar.gz                os_lab1     server_xlab  test.c
ImageAnnotation  linux-5.19.8.tar.xz   linux-6.0-rc5.tar.gz:Zone.Identifier  rootfs.img  test         test.txt
root@f40b9b9cbdfb:/have-fun-debugging# tar -xf linux-6.0-rc5.tar.gz
root@f40b9b9cbdfb:/have-fun-debugging# ls
C                linux-5.19.8.tar.xz   linux-6.0-rc5.tar.gz:Zone.Identifier  server_xlab  test.txt
ImageAnnotation  linux-6.0-rc5         os_lab1                               test
linux-5.19.8     linux-6.0-rc5.tar.gz  rootfs.img                            test.c
root@f40b9b9cbdfb:/have-fun-debugging# cd linux-6.0-rc5
root@f40b9b9cbdfb:/have-fun-debugging/linux-6.0-rc5# ls
COPYING        Kbuild    MAINTAINERS  arch    crypto   include   ipc     mm       scripts   tools
CREDITS        Kconfig   Makefile     block   drivers  init      kernel  net      security  usr
Documentation  LICENSES  README       certs   fs       io_uring  lib     samples  sound     virt
root@f40b9b9cbdfb:/have-fun-debugging/linux-6.0-rc5#
```

选择arm64架构

```
root@f40b9b9cbdfb:/have-fun-debugging/linux-6.0-rc5# make ARCH=arm64 defconfig
  HOSTCC  scripts/basic/fixdep
  HOSTCC  scripts/kconfig/conf.o
  HOSTCC  scripts/kconfig/confdata.o
  HOSTCC  scripts/kconfig/expr.o
  LEX     scripts/kconfig/lexer.lex.c
  YACC    scripts/kconfig/parser.tab.[ch]
  HOSTCC  scripts/kconfig/lexer.lex.o
  HOSTCC  scripts/kconfig/menu.o
  HOSTCC  scripts/kconfig/parser.tab.o
  HOSTCC  scripts/kconfig/preprocess.o
  HOSTCC  scripts/kconfig/symbol.o
  HOSTCC  scripts/kconfig/util.o
  HOSTLD  scripts/kconfig/conf
*** Default configuration is based on 'defconfig'
#
# configuration written to .config
#
root@f40b9b9cbdfb:/have-fun-debugging/linux-6.0-rc5#
```

开始用arm64架构交叉编译

```
root@f40b9b9cbdfb:/have-fun-debugging/linux-6.0-rc5# make ARCH=arm64 CROSS_COMPILE=aarch64-linux-gnu- -j$(nproc) arch/arm64/kernel/sys.i
arch/arm64/Makefile:36: Detected assembler with broken .inst; disassembly will be unreliable
  SYNC    include/config/auto.conf.cmd
*
* Restart config...
*
*
* ARMv8.3 architectural features
*
Enable support for pointer authentication (ARM64_PTR_AUTH) [Y/n/?] y
  Use pointer authentication for kernel (ARM64_PTR_AUTH_KERNEL) [Y/n/?] (NEW)
```

编译完成后我们可以看到我们成功获得了sys.i

```
root@f40b9b9cbdfb:/have-fun-debugging/linux-6.0-rc5# ls
COPYING  Documentation  Kconfig   MAINTAINERS  README  block  crypto  fs       init      ipc     lib  net      scripts
 sound  usr
CREDITS  Kbuild         LICENSES  Makefile     arch    certs  drivers  include  io_uring  kernel  mm   samples  security
 tools  virt
root@f40b9b9cbdfb:/have-fun-debugging/linux-6.0-rc5# cd arch/
root@f40b9b9cbdfb:/have-fun-debugging/linux-6.0-rc5/arch# cd arm64
root@f40b9b9cbdfb:/have-fun-debugging/linux-6.0-rc5/arch/arm64# ls
Kbuild  Kconfig  Kconfig.debug  Kconfig.platforms  Makefile  boot  configs  crypto  hyperv  include  kernel  kvm  lib  mm
  net  tools  xen
root@f40b9b9cbdfb:/have-fun-debugging/linux-6.0-rc5/arch/arm64# cd kernel/
root@f40b9b9cbdfb:/have-fun-debugging/linux-6.0-rc5/arch/arm64/kernel# ls
Makefile                cacheinfo.c   crash_dump.c      entry-fpsimd.S   hw_breakpoint.c   jump_label.c          module.
c          pi                reloc_test_syms.S  sleep.S          sys32.c                vdso-wrap.S
acpi.c                  cpu-reset.S   debug-monitors.c  entry-ftrace.S   hyp-stub.S        kaslr.c               mte.c
           pointer_auth.c    relocate_kernel.S  smccc-call.S     sys_compat.c           vdso.c
acpi_numa.c             cpu_errata.c  efi-entry.S       entry.S          idle.c            kexec_image.c         paravir
t.c        probes            return_address.c   smp.c            syscall.c              vdso32
acpi_parking_protocol.c  cpu_ops.c     efi-header.S      fpsimd.c         idreg-override.c  kgdb.c                patchin
g.c        process.c         sdei.c             smp_spin_table.c  time.c                 vdso32-wrap.S
alternative.c           cpufeature.c  efi-rt-wrapper.S  ftrace.c         image-vars.h      kuser32.S             pci.c
           proton-pack.c     setup.c            stacktrace.c      topology.c             vmlinux.lds.S
armv8_deprecated.c      cpuidle.c     efi.c             head.S           image.h           machine_kexec.c       perf_ca
llchain.c  psci.c            signal.c           suspend.c         trace-events-emulation.h
asm-offsets.c           cpuinfo.c     elfcore.c         hibernate-asm.S  io.c              machine_kexec_file.c  perf_ev
ent.c      ptrace.c          signal32.c         sys.c             traps.c
asm-offsets.s           crash_core.c  entry-common.c    hibernate.c      irq.c             module-plts.c         perf_re
gs.c       reloc_test_core.c  sigreturn32.S      sys.i             vdso
root@f40b9b9cbdfb:/have-fun-debugging/linux-6.0-rc5/arch/arm64/kernel#
```

6

ARM32，x86(32 bit)，x86_64

我们使用find命令在文件夹里面寻找，可以发现ARM32，x86(32 bit)，x86_64的syscall_table已经存在了。

```
root@f40b9b9cbdfb:/have-fun-debugging/linux-6.0-rc5# find . -name '*.tbl'
./arch/m68k/kernel/syscalls/syscall.tbl
./arch/x86/entry/syscalls/syscall_32.tbl
./arch/x86/entry/syscalls/syscall_64.tbl
./arch/s390/kernel/syscalls/syscall.tbl
./arch/powerpc/kernel/syscalls/syscall.tbl
./arch/parisc/kernel/syscalls/syscall.tbl
./arch/sparc/kernel/syscalls/syscall.tbl
./arch/microblaze/kernel/syscalls/syscall.tbl
./arch/sh/kernel/syscalls/syscall.tbl
./arch/xtensa/kernel/syscalls/syscall.tbl
./arch/ia64/kernel/syscalls/syscall.tbl
./arch/arm/tools/syscall.tbl
./arch/mips/kernel/syscalls/syscall_n32.tbl
./arch/mips/kernel/syscalls/syscall_o32.tbl
./arch/mips/kernel/syscalls/syscall_n64.tbl
./arch/alpha/kernel/syscalls/syscall.tbl
./scripts/atomic/atomics.tbl
./tools/perf/arch/x86/entry/syscalls/syscall_64.tbl
./tools/perf/arch/s390/entry/syscalls/syscall.tbl
./tools/perf/arch/powerpc/entry/syscalls/syscall.tbl
./tools/perf/arch/mips/entry/syscalls/syscall_n64.tbl
root@f40b9b9cbdfb:/have-fun-debugging/linux-6.0-rc5#
```

接下来我们需要的就是RISC-V的syscall_table

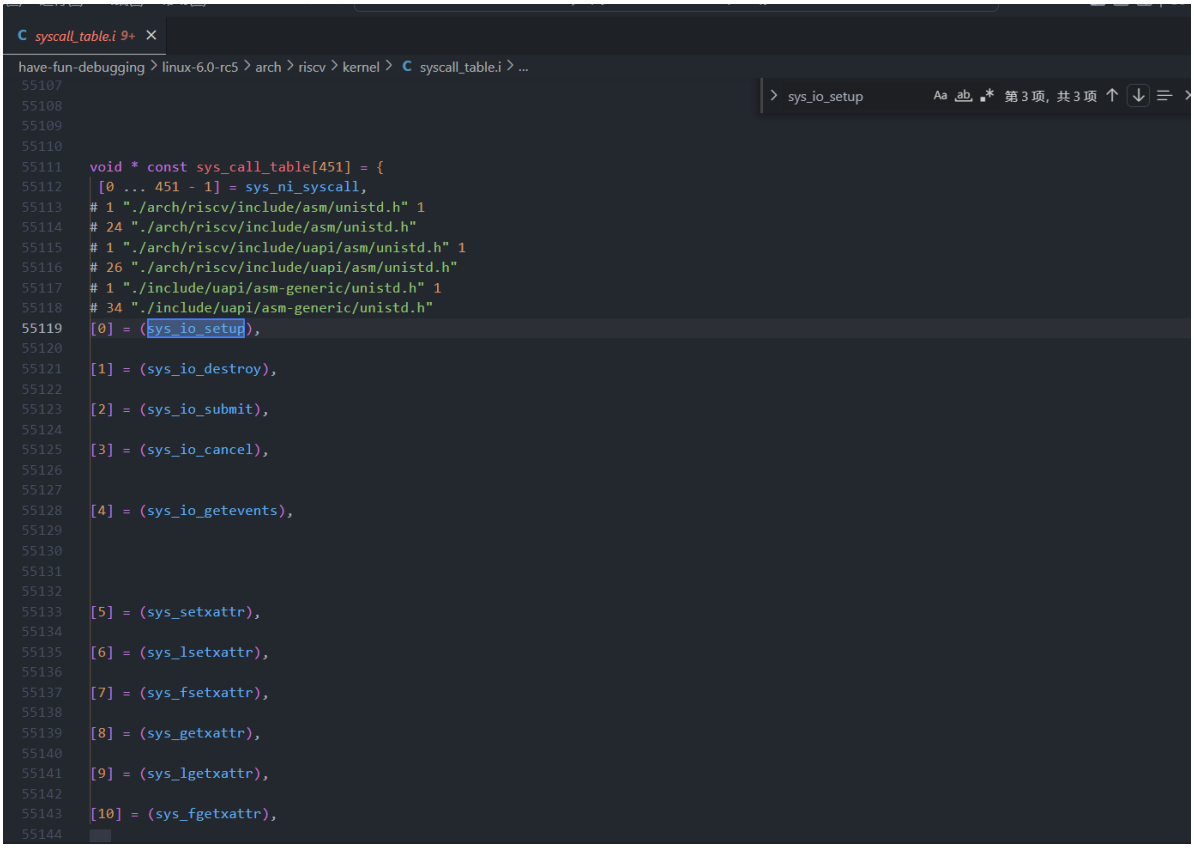
RISC-V(64 bit)

我们使用64位编译配置，使用交叉编译编译出arch/riscv/kernel/syscall_table.i

```
root@f40b9b9cbdfb:/have-fun-debugging/linux-6.0-rc5# make ARCH=riscv CROSS_COMPILE=riscv64-linux-gnu- defconfig
  HOSTCC  scripts/basic/fixdep
  HOSTCC  scripts/kconfig/conf.o
  HOSTCC  scripts/kconfig/confdata.o
  HOSTCC  scripts/kconfig/expr.o
  LEX     scripts/kconfig/lexer.lex.c
  YACC    scripts/kconfig/parser.tab.[ch]
  HOSTCC  scripts/kconfig/lexer.lex.o
  HOSTCC  scripts/kconfig/menu.o
  HOSTCC  scripts/kconfig/parser.tab.o
  HOSTCC  scripts/kconfig/preprocess.o
  HOSTCC  scripts/kconfig/symbol.o
  HOSTCC  scripts/kconfig/util.o
  HOSTLD  scripts/kconfig/conf
*** Default configuration is based on 'defconfig'
#
# configuration written to .config
#
root@f40b9b9cbdfb:/have-fun-debugging/linux-6.0-rc5#
```

```
root@f40b9b9cbdfb:/have-fun-debugging/linux-6.0-rc5# make ARCH=riscv CROSS_COMPILE=riscv64-linux-gnu- -j$(nproc) ./arch/r
iscv/kernel/syscall_table.i
  CALL    scripts/atomic/check-atomics.sh
  CALL    scripts/checksyscalls.sh
  CPP     arch/riscv/kernel/syscall_table.i
root@f40b9b9cbdfb:/have-fun-debugging/linux-6.0-rc5#
```

可以看到syscall_table就在该文件中。



RISC-V(32 bit)

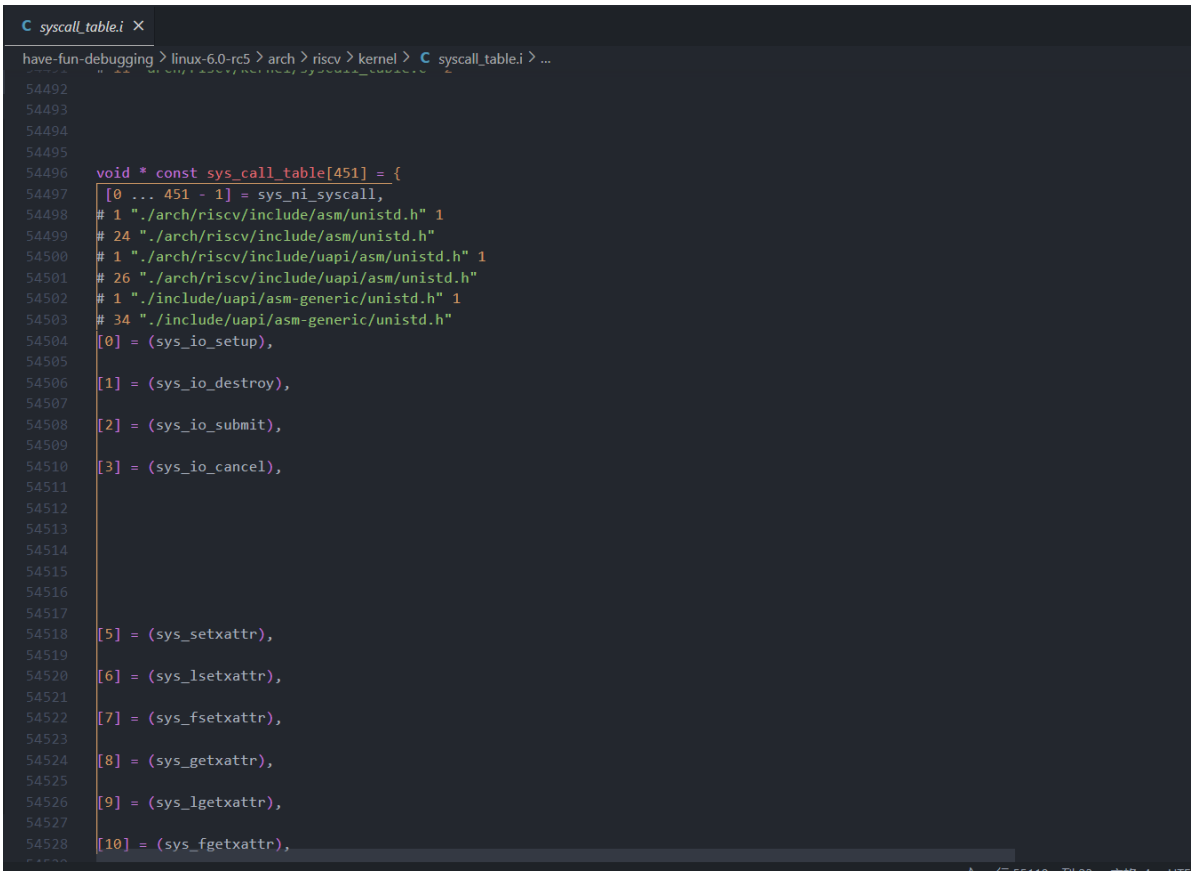
我们使用32位编译配置。

```
root@f40b9b9cbdfb:/have-fun-debugging/linux-6.0-rc5# make ARCH=riscv CROSS_COMPILE=riscv64-linux-gnu- rv32_defconfig
  HOSTCC  scripts/basic/fixdep
  HOSTCC  scripts/kconfig/conf.o
  HOSTCC  scripts/kconfig/confdata.o
  HOSTCC  scripts/kconfig/expr.o
  LEX     scripts/kconfig/lexer.lex.c
  YACC    scripts/kconfig/parser.tab.[ch]
  HOSTCC  scripts/kconfig/lexer.lex.o
  HOSTCC  scripts/kconfig/menu.o
  HOSTCC  scripts/kconfig/parser.tab.o
  HOSTCC  scripts/kconfig/preprocess.o
  HOSTCC  scripts/kconfig/symbol.o
  HOSTCC  scripts/kconfig/util.o
  HOSTLD  scripts/kconfig/conf
*** Default configuration is based on 'defconfig'
#
# configuration written to .config
#
Using .config as base
Merging ./arch/riscv/configs/32-bit.config
Value of CONFIG_PORTABLE is redefined by fragment ./arch/riscv/configs/32-bit.config:
Previous value: CONFIG_PORTABLE=y
New value: # CONFIG_PORTABLE is not set
```

使用交叉编译工具进行编译。

```
root@f40b9b9cbdfb:/have-fun-debugging/linux-6.0-rc5# make ARCH=riscv CROSS_COMPILE=riscv64-linux-gnu- -j$(nproc) ./arch/r
iscv/kernel/syscall_table.i
  SYNC    include/config/auto.conf.cmd
  WRAP    arch/riscv/include/generated/uapi/asm/errno.h
  WRAP    arch/riscv/include/generated/uapi/asm/fcntl.h
  WRAP    arch/riscv/include/generated/uapi/asm/ioctl.h
  WRAP    arch/riscv/include/generated/uapi/asm/ioctls.h
  WRAP    arch/riscv/include/generated/uapi/asm/ipcbuf.h
  WRAP    arch/riscv/include/generated/uapi/asm/mman.h
  WRAP    arch/riscv/include/generated/uapi/asm/msgbuf.h
  WRAP    arch/riscv/include/generated/uapi/asm/param.h
  WRAP    arch/riscv/include/generated/uapi/asm/poll.h
  WRAP    arch/riscv/include/generated/uapi/asm/posix_types.h
  WRAP    arch/riscv/include/generated/uapi/asm/resource.h
  WRAP    arch/riscv/include/generated/uapi/asm/sembuf.h
  WRAP    arch/riscv/include/generated/uapi/asm/setup.h
```

成功得到32位的syscall_table



7

> ELF文件是一种用于二进制文件、可执行文件、目标代码、共享库和核心转储格式文件的文件格式。

我们以本次lab的head.S编译出的head.o文件为例

```
root@f40b9b9cbdfb:/have-fun-debugging/os_lab1/arch/riscv/kernel# ls
Makefile  head.S  head.o  sbi.c  sbi.o  vmlinux.lds
root@f40b9b9cbdfb:/have-fun-debugging/os_lab1/arch/riscv/kernel# file head.o
head.o: ELF 64-bit LSB relocatable, UCB RISC-V, version 1 (SYSV), with debug_info, not stripped
root@f40b9b9cbdfb:/have-fun-debugging/os_lab1/arch/riscv/kernel#
```

使用readelf命令：

```
root@f40b9b9cbdfb:/have-fun-debugging/os_lab1/arch/riscv/kernel# readelf -a head.o
ELF Header:
  Magic:   7f 45 4c 46 02 01 01 00 00 00 00 00 00 00 00 00
  Class:                             ELF64
  Data:                              2's complement, little endian
  Version:                           1 (current)
  OS/ABI:                            UNIX - System V
  ABI Version:                       0
  Type:                              REL (Relocatable file)
  Machine:                           RISC-V
  Version:                           0x1
  Entry point address:               0x0
  Start of program headers:          0 (bytes into file)
  Start of section headers:          1632 (bytes into file)
  Flags:                             0x0
  Size of this header:               64 (bytes)
  Size of program headers:           0 (bytes)
  Number of program headers:         0
  Size of section headers:           64 (bytes)
  Number of section headers:         18
  Section header string table index: 17

Section Headers:
  [Nr] Name              Type             Address           Offset
       Size              EntSize          Flags  Link  Info  Align
  [ 0]                   NULL             0000000000000000  00000000
       0000000000000000  0000000000000000           0     0     0
  [ 1] .text             PROGBITS         0000000000000000  00000040
       0000000000000000  0000000000000000  AX       0     0     4
  [ 2] .data             PROGBITS         0000000000000000  00000040
       0000000000000000  0000000000000000  WA       0     0     1
  [ 3] .bss              NOBITS           0000000000000000  00000040
       0000000000000000  0000000000000000  WA       0     0     1
  [ 4] .text.entry       PROGBITS         0000000000000000  00000040
       0000000000000010  0000000000000000  AX       0     0     1
  [ 5] .rela.text.entry  RELA             0000000000000000  000003d0
       0000000000000078  0000000000000018   I      15     4     8
  [ 6] .bss.stack        NOBITS           0000000000000000  00000050
       0000000000004000  0000000000000000  WA       0     0     1
  [ 7] .debug_line       PROGBITS         0000000000000000  00000050
       000000000000003f  0000000000000000           0     0     1
  [ 8] .rela.debug_line  RELA             0000000000000000  00000448
       0000000000000078  0000000000000018   I      15     7     8
  [ 9] .debug_info       PROGBITS         0000000000000000  0000008f
       000000000000002e  0000000000000000           0     0     1
  [10] .rela.debug_info  RELA             0000000000000000  000004c0
       00000000000000a8  0000000000000018   I      15     9     8
  [11] .debug_abbrev     PROGBITS         0000000000000000  000000bd
       0000000000000014  0000000000000000           0     0     1
  [12] .debug_aranges    PROGBITS         0000000000000000  000000e0
```

```
  [13] .rela.debug_arang RELA             0000000000000000  00000568
       0000000000000060  0000000000000018   I      15    12     8
  [14] .debug_str        PROGBITS         0000000000000000  00000110
       0000000000000041  0000000000000001  MS       0     0     1
  [15] .symtab           SYMTAB           0000000000000000  00000158
       0000000000000240  0000000000000018          16    20     8
  [16] .strtab           STRTAB           0000000000000000  00000398
       0000000000000034  0000000000000000           0     0     1
  [17] .shstrtab         STRTAB           0000000000000000  000005c8
       0000000000000097  0000000000000000           0     0     1
Key to Flags:
  W (write), A (alloc), X (execute), M (merge), S (strings), I (info),
  L (link order), O (extra OS processing required), G (group), T (TLS),
  C (compressed), x (unknown), o (OS specific), E (exclude),
  p (processor specific)

There are no section groups in this file.

There are no program headers in this file.

There is no dynamic section in this file.

Relocation section '.rela.text.entry' at offset 0x3d0 contains 5 entries:
  Offset          Info           Type           Sym. Value    Sym. Name + Addend
000000000000  001500000014 R_RISCV_GOT_HI20  0000000000004000 boot_stack_top + 0
000000000004  001100000018 R_RISCV_PCREL_LO1 0000000000000000 .L0  + 0
000000000004  000000000033 R_RISCV_RELAX                        0
000000000008  001600000012 R_RISCV_CALL      0000000000000000 start_kernel + 0
000000000008  000000000033 R_RISCV_RELAX                        0

Relocation section '.rela.debug_line' at offset 0x448 contains 5 entries:
  Offset          Info           Type           Sym. Value    Sym. Name + Addend
00000000002a  000500000002 R_RISCV_64        0000000000000000 .L0  + 0
000000000036  000600000022 R_RISCV_ADD16     0000000000000008 .L0  + 0
000000000036  000500000026 R_RISCV_SUB16     0000000000000000 .L0  + 0
00000000003a  000800000022 R_RISCV_ADD16     0000000000000010 .L0  + 0
00000000003a  000600000026 R_RISCV_SUB16     0000000000000008 .L0  + 0

Relocation section '.rela.debug_info' at offset 0x4c0 contains 7 entries:
  Offset          Info           Type           Sym. Value    Sym. Name + Addend
000000000006  000f00000001 R_RISCV_32        0000000000000000 .debug_abbrev + 0
00000000000c  001000000001 R_RISCV_32        0000000000000000 .debug_line + 0
000000000010  000a00000002 R_RISCV_64        0000000000000000 .L0  + 0
000000000018  000b00000002 R_RISCV_64        0000000000000010 .L0  + 0
000000000020  000c00000001 R_RISCV_32        0000000000000000 .L0  + 0
000000000024  000d00000001 R_RISCV_32        0000000000000007 .L0  + 0
000000000028  000e00000001 R_RISCV_32        0000000000000035 .L0  + 0

Relocation section '.rela.debug_aranges' at offset 0x568 contains 4 entries:
  Offset          Info           Type           Sym. Value    Sym. Name + Addend
000000000006  000900000001 R_RISCV_32        0000000000000000 .debug_info + 0
000000000010  000a00000002 R_RISCV_64        0000000000000000 .L0  + 0
000000000018  000b00000024 R_RISCV_ADD64     0000000000000010 .L0  + 0
```

```
000000000018  000a00000028 R_RISCV_SUB64     0000000000000000 .L0  + 0

The decoding of unwind sections for machine type RISC-V is not currently supported.

Symbol table '.symtab' contains 24 entries:
   Num:    Value          Size Type    Bind   Vis      Ndx Name
     0: 0000000000000000     0 NOTYPE  LOCAL  DEFAULT  UND
     1: 0000000000000000     0 SECTION LOCAL  DEFAULT    1
     2: 0000000000000000     0 SECTION LOCAL  DEFAULT    2
     3: 0000000000000000     0 SECTION LOCAL  DEFAULT    3
     4: 0000000000000000     0 SECTION LOCAL  DEFAULT    4
     5: 0000000000000000     0 NOTYPE  LOCAL  DEFAULT    4 .L0
     6: 0000000000000008     0 NOTYPE  LOCAL  DEFAULT    4 .L0
     7: 0000000000000000     0 SECTION LOCAL  DEFAULT    6
     8: 0000000000000010     0 NOTYPE  LOCAL  DEFAULT    4 .L0
     9: 0000000000000000     0 SECTION LOCAL  DEFAULT    9
    10: 0000000000000000     0 NOTYPE  LOCAL  DEFAULT    4 .L0
    11: 0000000000000010     0 NOTYPE  LOCAL  DEFAULT    4 .L0
    12: 0000000000000000     0 NOTYPE  LOCAL  DEFAULT   14 .L0
    13: 0000000000000007     0 NOTYPE  LOCAL  DEFAULT   14 .L0
    14: 0000000000000035     0 NOTYPE  LOCAL  DEFAULT   14 .L0
    15: 0000000000000000     0 SECTION LOCAL  DEFAULT   11
    16: 0000000000000000     0 SECTION LOCAL  DEFAULT    7
    17: 0000000000000000     0 NOTYPE  LOCAL  DEFAULT    4 .L0
    18: 0000000000000000     0 SECTION LOCAL  DEFAULT   12
    19: 0000000000000000     0 SECTION LOCAL  DEFAULT   14
    20: 0000000000000000     0 NOTYPE  GLOBAL DEFAULT    4 _start
    21: 0000000000004000     0 NOTYPE  GLOBAL DEFAULT    6 boot_stack_top
    22: 0000000000000000     0 NOTYPE  GLOBAL DEFAULT  UND start_kernel
    23: 0000000000000000     0 NOTYPE  GLOBAL DEFAULT    6 boot_stack

No version information found in this file.
root@f40b9b9cbdfb:/have-fun-debugging/os_lab1/arch/riscv/kernel#
```

使用objdump命令：

```
root@f40b9b9cbdfb:/have-fun-debugging/os_lab1/arch/riscv/kernel# objdump
Usage: objdump <option(s)> <file(s)>
 Display information from object <file(s)>.
 At least one of the following switches must be given:
  -a, --archive-headers    Display archive header information
  -f, --file-headers       Display the contents of the overall file header
  -p, --private-headers    Display object format specific file header contents
  -P, --private=OPT,OPT... Display object format specific contents
  -h, --[section-]headers  Display the contents of the section headers
  -x, --all-headers        Display the contents of all headers
  -d, --disassemble        Display assembler contents of executable sections
  -D, --disassemble-all    Display assembler contents of all sections
      --disassemble=<sym>  Display assembler contents from <sym>
  -S, --source             Intermix source code with disassembly
      --source-comment[=<txt>] Prefix lines of source code with <txt>
  -s, --full-contents      Display the full contents of all sections requested
  -g, --debugging          Display debug information in object file
  -e, --debugging-tags     Display debug information using ctags style
  -G, --stabs              Display (in raw form) any STABS info in the file
  -W[lLiaprmfFsoRtUuTgAckK] or
  --dwarf[=rawline,=decodedline,=info,=abbrev,=pubnames,=aranges,=macro,=frames,
          =frames-interp,=str,=loc,=Ranges,=pubtypes,
          =gdb_index,=trace_info,=trace_abbrev,=trace_aranges,
          =addr,=cu_index,=links,=follow-links]
                           Display DWARF info in the file
  --ctf=SECTION            Display CTF info from SECTION
  -t, --syms               Display the contents of the symbol table(s)
  -T, --dynamic-syms       Display the contents of the dynamic symbol table
  -r, --reloc              Display the relocation entries in the file
  -R, --dynamic-reloc      Display the dynamic relocation entries in the file
  @<file>                  Read options from <file>
  -v, --version            Display this program's version number
  -i, --info               List object formats and architectures supported
  -H, --help               Display this information
```

由于可打印选项太多，我们以objdump -f为例

```
root@f40b9b9cbdfb:/have-fun-debugging/os_lab1/arch/riscv/kernel# objdump -f head.o

head.o:     file format elf64-little
architecture: UNKNOWN!, flags 0x00000011:
HAS_RELOC, HAS_SYMS
start address 0x0000000000000000
```

为了演示一个可以直接run的elf文件，我们以我之前写的一个奇怪的c程序为例：

```
root@f40b9b9cbdfb:/have-fun-debugging/C/poem_translate# ls
 poem_translate.c     resource   voice.vbs
 poem_translate.exe   test       ''$'\345\244\247\350\213\261\344\275\234\344\270\232\347\232\204\350\257\227\346\255\214\347\277\273\350\257\221''.md'
root@f40b9b9cbdfb:/have-fun-debugging/C/poem_translate# file test
test: ELF 64-bit LSB shared object, x86-64, version 1 (SYSV), dynamically linked, interpreter /lib64/ld-linux-x86-64.so.2, BuildID[sha1]=0ef61fd2c52901350ce250691e5260febc
87bf2, for GNU/Linux 3.2.0, not stripped
root@f40b9b9cbdfb:/have-fun-debugging/C/poem_translate#
```

查询该程序的PID

```
root@f40b9b9cbdfb:/# ps -a
  PID TTY          TIME CMD
 6713 pts/1    00:00:00 test
 6917 pts/3    00:00:00 ps
root@f40b9b9cbdfb:/#
```

使用cat命令成功获取该程序的memory layout

```
root@f40b9b9cbdfb:/# cat /proc/6713/maps
564f15e55000-564f15e56000 r--p 00000000 08:10 324133                     /have-fun-debugging/C/poem_translate/test
564f15e56000-564f15e57000 r-xp 00001000 08:10 324133                     /have-fun-debugging/C/poem_translate/test
564f15e57000-564f15e58000 r--p 00002000 08:10 324133                     /have-fun-debugging/C/poem_translate/test
564f15e58000-564f15e59000 r--p 00002000 08:10 324133                     /have-fun-debugging/C/poem_translate/test
564f15e59000-564f15e5a000 rw-p 00003000 08:10 324133                     /have-fun-debugging/C/poem_translate/test
564f1627f000-564f162a0000 rw-p 00000000 00:00 0                          [heap]
7fd553722000-7fd553747000 r--p 00000000 08:10 62105                      /usr/lib/x86_64-linux-gnu/libc-2.31.so
7fd553747000-7fd5538bf000 r-xp 00025000 08:10 62105                      /usr/lib/x86_64-linux-gnu/libc-2.31.so
7fd5538bf000-7fd553909000 r--p 0019d000 08:10 62105                      /usr/lib/x86_64-linux-gnu/libc-2.31.so
7fd553909000-7fd55390a000 ---p 001e7000 08:10 62105                      /usr/lib/x86_64-linux-gnu/libc-2.31.so
7fd55390a000-7fd55390d000 r--p 001e7000 08:10 62105                      /usr/lib/x86_64-linux-gnu/libc-2.31.so
7fd55390d000-7fd553910000 rw-p 001ea000 08:10 62105                      /usr/lib/x86_64-linux-gnu/libc-2.31.so
7fd553910000-7fd553916000 rw-p 00000000 00:00 0
7fd55391b000-7fd55391c000 r--p 00000000 08:10 61879                      /usr/lib/x86_64-linux-gnu/ld-2.31.so
7fd55391c000-7fd55393f000 r-xp 00001000 08:10 61879                      /usr/lib/x86_64-linux-gnu/ld-2.31.so
7fd55393f000-7fd553947000 r--p 00024000 08:10 61879                      /usr/lib/x86_64-linux-gnu/ld-2.31.so
7fd553948000-7fd553949000 r--p 0002c000 08:10 61879                      /usr/lib/x86_64-linux-gnu/ld-2.31.so
7fd553949000-7fd55394a000 rw-p 0002d000 08:10 61879                      /usr/lib/x86_64-linux-gnu/ld-2.31.so
7fd55394a000-7fd55394b000 rw-p 00000000 00:00 0
7fffd856e000-7fffd858f000 rw-p 00000000 00:00 0                          [stack]
7fffd85c3000-7fffd85c7000 r--p 00000000 00:00 0                          [vvar]
7fffd85c7000-7fffd85c8000 r-xp 00000000 00:00 0                          [vdso]
root@f40b9b9cbdfb:/#
```