lzu_os lab

lab1

1、注释makefile文件。

```
#first step, func $subst(FROM,TO,TEXT) :substitute FROM with TO in TEXT, then return the subtituted text
#second step,func $foreach(VAR,TEXT,COMMAND): for each unit separated by space do COMMAND,then return the list separated by space after all commands
#third step, func $wildcard( PATTERN...):enable pattern matching,return matched files
#finally, ifneq  judges whether the expression value is 0,then decide to jump to which branch

#this block is to check whether you have the 'riscv64-linux-gnu tool chain,
#and if doesn't exist, then use 'riscv64-unknown-elf' as tool chain
ifneq ($(wildcard $(foreach p,$(subst :, ,$(PATH)),$(p)/riscv64-linux-gnu-*)),)
    PREFIX := riscv64-linux-gnu
else
    PREFIX := riscv64-unknown-elf
endif

CC := $(PREFIX)-gcc     #declare complier
LD := $(PREFIX)-ld      #linker
AR := $(PREFIX)-ar      #archive library
OBJCOPY := $(PREFIX)-objcopy    #copy and convert binary file
OBJDUMP := $(PREFIX)-objdump    #disassebler
READELF := $(PREFIX)-readelf    #read elf file
NM := $(PREFIX)-nm      #symbol table,shared library
AS := $(PREFIX)-as      #assembler
TMUX := tmux            #divide screen tool
QEMU := qemu-system-riscv64 #riscv64 arch, running on qemu system emulator
GDB := riscv64-unknown-elf-gdb  #debugger

KERN_IMG := kernel.img  #the kernel iso , include bios
KERN_BIN := kernel.bin  #the kernel ios(binary)
KERN_MAP := kernel.map  #include symbol table(func,var), and address of these table
KERN_SYM := kernel.sym  #symbol table of kernel
KERN_ASM := kernel.asm  #assemble language of kernel

#$1: memeory model = medany(handle medium scale memory)
#$2: enable warning messages
#$3: generate debugging info with level O3
#$4: not use built-in funcs
#$5: disable stack protector
#$6: disable strict aliasing rules
```

```
#$7: not include standard library headers
#$8: refers to including file, and look for headers in current directory
#all these options form CFLAGS(compile flags)
CFLAGS := -mcmodel=medany -Wall -g3 -fno-builtin -fno-stack-protector -fno-
strict-aliasing -nostdinc -I .

#search for all .c files and substitute it with .o file, then generate the target
objects
objects := $(patsubst %.c, %.o, $(wildcard *.c)) entry.o

#these are make command, do not track them
.PHONY : all build run run-gui symbol debug clean disassembly

all: build

build : $(KERN_BIN) #generate kernel.bin, with given kernel.map,kernel.img and
all objects

$(KERN_BIN) : $(objects)
    $(LD) -T linker.ld -Map=$(KERN_MAP) -o $(KERN_BIN) $^
    $(OBJCOPY) $(KERN_BIN) --strip-all -O binary $(KERN_IMG)

#run non-graphic qemu system,use kernel.img as kernel,init address at 0x80200000
run : build
    @$(QEMU) \
            -machine virt \
            -nographic \
            -bios fw_jump.bin \
            -device loader,file=$(KERN_IMG),addr=0x80200000

#run graphic terminal,same as above
run-gui : build
    @$(QEMU) \
            -machine virt \
            -bios fw_jump.bin \
            -device loader,file=$(KERN_IMG),addr=0x80200000
#run debug mode with tmux
debug :
    $(TMUX) new -s debug -d "$(QEMU) \
                -machine virt \
                -s -S \
                -serial mon:stdio \
                -nographic \
                -bios fw_jump.bin \
                -device loader,file=$(KERN_IMG),addr=0x80200000" && $(TMUX)
split-window -h "$(GDB) -q -x gdbinit"
    $(TMUX) attach-session -t debug

#create file kernel.sym which includes kernel symbol infos
symbol : $(KERN_BIN)
    $(NM) -s $(KERN_BIN) > $(KERN_SYM)

#create file kernel.asm which include asm forms of kernel
disassembly: $(KERN_BIN)
    $(OBJDUMP) -d $(KERN_BIN) > $(KERN_ASM)
```

```


clean:  #clean all the files that make build
	-rm -f *.o $(KERN_BIN) $(KERN_IMG) $(KERN_SYM) $(KERN_ASM)

```

2、img文件是如何生成的?

首先，当在makefile中直接或者间接执行make build指令时，会生成kernel.bin,这个目标的依赖是所有的.o文件，当有源文件发生改动后，就会重新生成kernel.bin，生成该文件需要需要链接器（$LD）进行链接，同时使用使用 `linker.ld` 文件作为链接脚本，这个脚本定义了链接的规则和地址布局。`-Map=$(KERN_MAP)` 用于生成kernel.map，记录了链接器的详细信息。-o $(KERN_BIN) 指定链接后生成的可执行文件的名称。$^ 是一个自动变量，代表所有的依赖文件，也就是 $(objects) 中的所有对象文件。最后利用工具objcopy将kernel.bin转为二进制文件kernel.img。

核心代码为以下三行:

```
$(KERN_BIN) : $(objects)
	$(LD) -T linker.ld -Map=$(KERN_MAP) -o $(KERN_BIN) $^
	$(OBJCOPY) $(KERN_BIN) --strip-all -O binary $(KERN_IMG)
```

3、通过 cat kernel.map来查看链结器命令稿和内存映射，通过 readelf -a kernel.bin了解kernel的程序段和节，需要加载的段等信息，画出启动后的内存地址空间布局。

kernlel的程序段有:

1、RISCV_ATTRIBUTE段，该段的起始地址为0x0，大小为0x33个字节，标志为R（可读）。

2、LOAD段（1），起始地址为0x80200000，大小为0x11e8个字节，标志为RE（可读可执行）。

3、LOAD段（2），起始地址为0x80202000，大小为0x10000字节，标志为RW（可读可写）。

4、GNU_STACK段，并没有分配大小，标志位RW（可读可写）。

节信息:

1、NULL节，无效的节，不分配空间

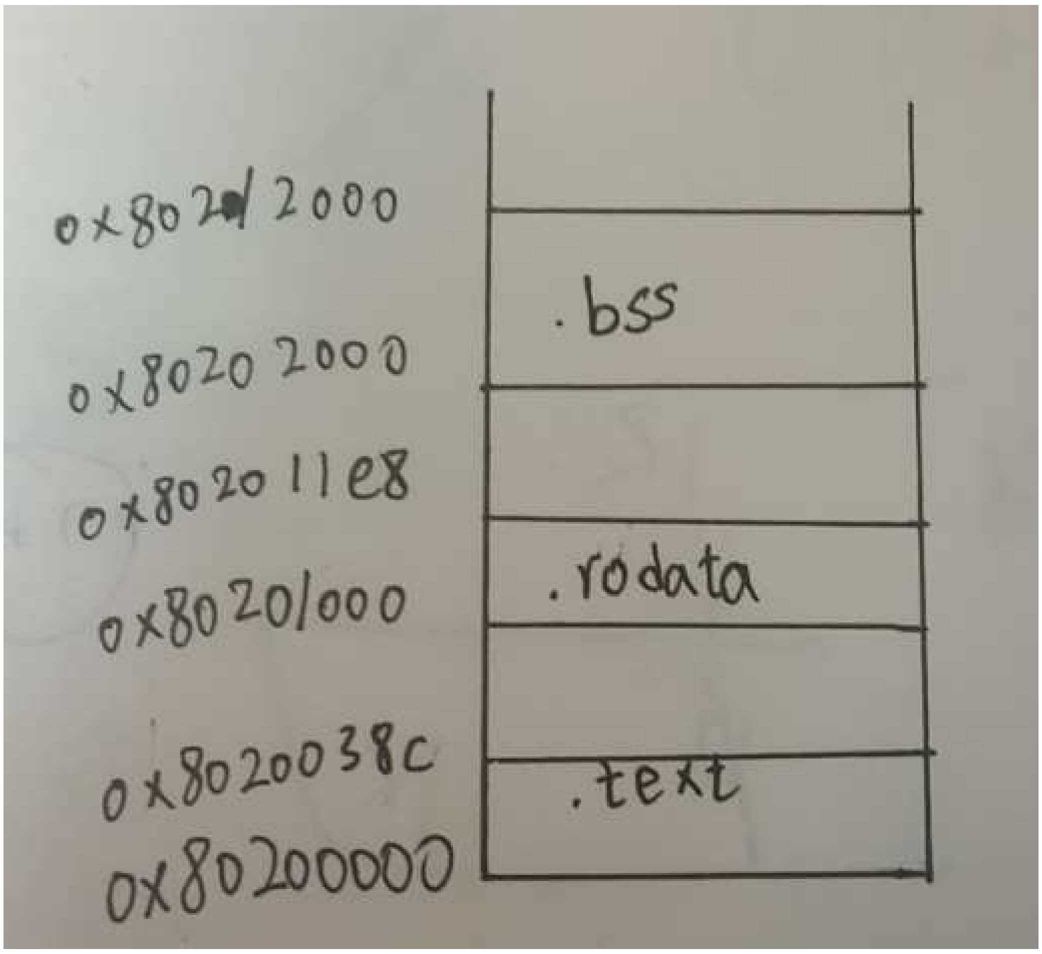
2、.text节，程序代码，大小为0x38字节，标志为AX（可分配可执行）

3、.rodata节，只读数据，大小为0x1e8字节，标志为A（可分配）

4、.bss节，未初始化的数据段，大小为0x1000，标志为AW（可写可分配）

5、.debug_*等节，负责调试信息

内存空间布局:

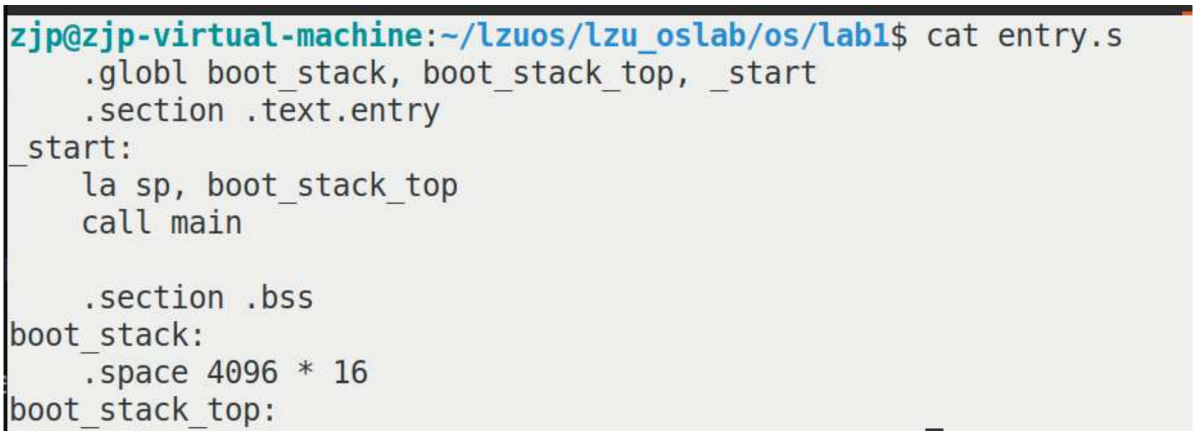


4、反汇编得到kerne.bin的汇编代码，并与entry.s部分的代码进行比较。gdb调试找到while（1）的PC值。

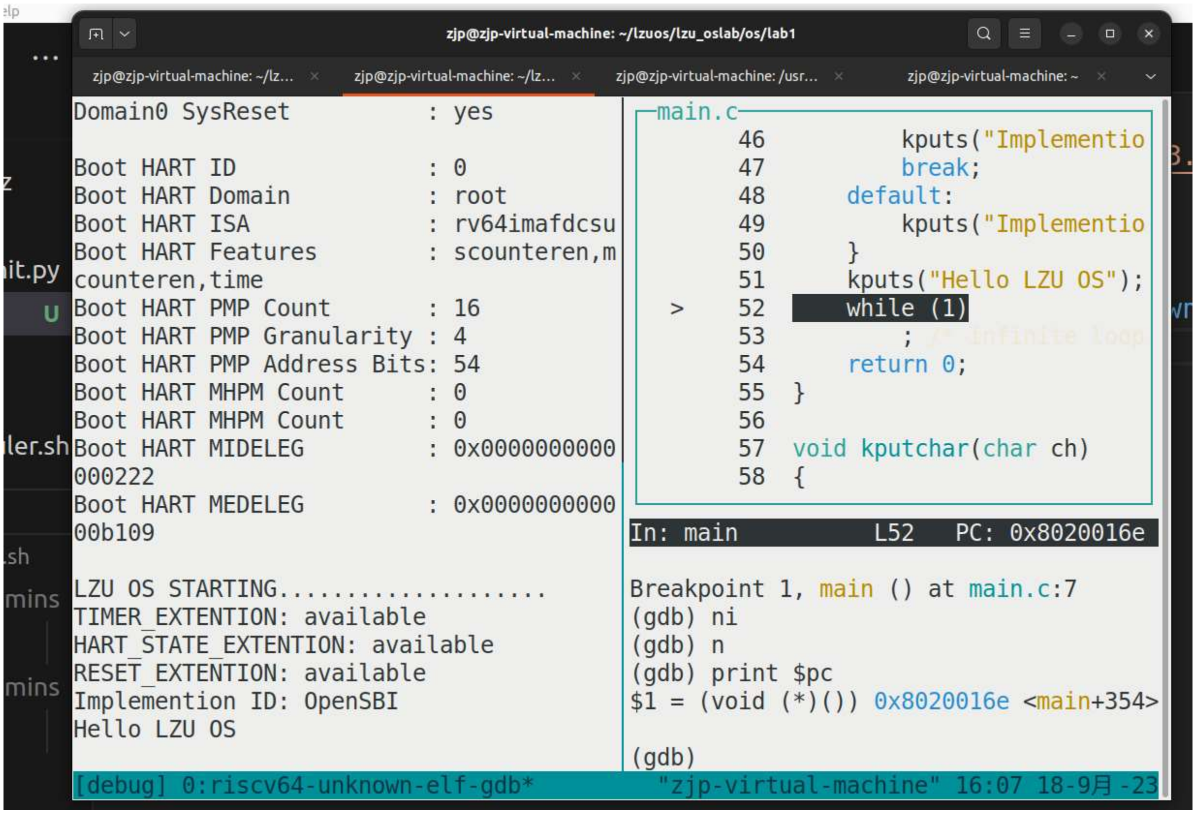
kernel.bin的反汇编代码：

```
Disassembly of section .text:

0000000080200000 <_start>:
    80200000:   00012117                auipc   sp,0x12
    80200004:   00010113                mv      sp,sp
    80200008:   004000ef                jal     ra,8020000c <main>

000000008020000c <main>:
    8020000c:   1101                    addi    sp,sp,-32 # 80211fe0 <boot_stack+0xffe0>
    8020000e:   ec06                    sd      ra,24(sp)
    80200010:   e822                    sd      s0,16(sp)
    80200012:   1000                    addi    s0,sp,32
    80200014:   00001517                auipc   a0,0x1
    80200018:   fec50513                addi    a0,a0,-20 # 80201000 <rodata_start>
    8020001c:   176000ef                jal     ra,80200192 <kputs>
    80200020:   544957b7                lui     a5,0x54495
    80200024:   d4578513                addi    a0,a5,-699 # 54494d45 <_start-0x2bd6b2bb
    80200028:   302000ef                jal     ra,8020032a <sbi_probe_extension>
    8020002c:   872a                    mv      a4,a0
    8020002e:   87ae                    mv      a5,a1
    80200030:   fee43023                sd      a4,-32(s0)
    80200034:   fef43423                sd      a5,-24(s0)
    80200038:   fe843783                ld      a5,-24(s0)
    8020003c:   cb81                    beqz    a5,8020004c <main+0x40>
    8020003e:   00001517                auipc   a0,0x1
    80200042:   fea50513                addi    a0,a0,-22 # 80201028 <rodata_start+0x28>
    80200046:   14c000ef                jal     ra,80200192 <kputs>
    8020004a:   a039                    j       80200058 <main+0x4c>
    8020004c:   00001517                auipc   a0,0x1
    80200050:   ffc50513                addi    a0,a0,-4 # 80201048 <rodata_start+0x48>
    80200054:   13e000ef                jal     ra,80200192 <kputs>
```

entry.s代码：



```
zjp@zjp-virtual-machine:~/lzuos/lzu_oslab/os/lab1$ cat entry.s
    .globl boot_stack, boot_stack_top, _start
    .section .text.entry
_start:
    la sp, boot_stack_top
    call main

    .section .bss
boot_stack:
    .space 4096 * 16
boot_stack_top:
```



```
zjp@zjp-virtual-machine: ~/lzuos/lzu_oslab/os/lab1
```

zjp@zjp-virtual-machine: ~/lz...
zjp@zjp-virtual-machine: ~/lz...
zjp@zjp-virtual-machine: /usr...
zjp@zjp-virtual-machine: ~

```
Domain0 SysReset          : yes

Boot HART ID              : 0
Boot HART Domain          : root
Boot HART ISA             : rv64imafdcsu
Boot HART Features        : scounteren,m
counteren,time
Boot HART PMP Count       : 16
Boot HART PMP Granularity : 4
Boot HART PMP Address Bits: 54
Boot HART MHPM Count      : 0
Boot HART MHPM Count      : 0
Boot HART MIDELEG         : 0x0000000000
000222
Boot HART MEDELEG         : 0x0000000000
00b109

LZU OS STARTING....................
TIMER_EXTENTION: available
HART_STATE_EXTENTION: available
RESET_EXTENTION: available
Implemention ID: OpenSBI
Hello LZU OS
```

```
main.c
                kputs("Implementio
                break;
            default:
                kputs("Implementio
            }
            kputs("Hello LZU OS");
  >         while (1)
                ; /* infinite loop
            return 0;
        }

        void kputchar(char ch)
        {
In: main                  L52    PC: 0x8020016e

Breakpoint 1, main () at main.c:7
(gdb) ni
(gdb) n
(gdb) print $pc
$1 = (void (*)()) 0x8020016e <main+354>

(gdb)
[debug] 0:riscv64-unknown-elf-gdb*      "zjp-virtual-machine" 16:07 18-9月 -23
```

5、注释一个sbi封装函数。

以用来将字符输出到控制台的函数sbi_console_putchar(char ch)为例：

```
void sbi_console_putchar(char ch)
{
    //define a 64bit var as a0, then associated it with register a0 using
'asm("a0")'.It is used to store the 'ch',cause register a0 is uesd to pass
arguments in system call.
    register uint64_t a0 asm("a0") = ch;

    //define a 64bit var a6 which is assigned to zero, then associated it with
register a6 using 'asm("a6")'.In RISCV, register a6 is used to keep the system
call number, and zero stands for the exact number of system call(when it happens
in Linux, it's called sys_call )
    register uint64_t a6 asm("a6") = 0;
    //define a 64bit var a7 which is assigned to 1, then associated it with
register a7 using 'asm("a7")'.In RISCV, register a7 is used to keep the system
call argument. It's set to 1, indicating the system call to perform a 'write'
operation.
    register uint64_t a7 asm("a7") = 1;

    //the '__asm__volatile__' key word indicates this is an inline assembly
instruction.And __volatile tells the complier not to optimize this assembly
code.
    //ecall is a special RISCV instruction used to trigger a system call.
    //the 'empty output list' after colon indicates there is no output list in
this case,so it's empty.
    //': "r"(a0), "r"(a6), "r"(a7)': these are input arguments,specifying the
input register for the ecall. r(a0) stands for the value of resiter a0, and a6,a7
are the same as a0.
    // : "memory": this tells the compiler that this assembly code may modify the
memory, so it need to ensure memory is updated correctly. In programmer's case,
they often use it to tell complier not to swtich the sequence in this assembly
code(if it has context), it's another way to tell complier not to optimize the
code.
    __asm__ __volatile__("ecall \n\t"
                 : /* empty output list */
                 : "r"(a0), "r"(a6), "r"(a7)
                 : "memory");
}
```