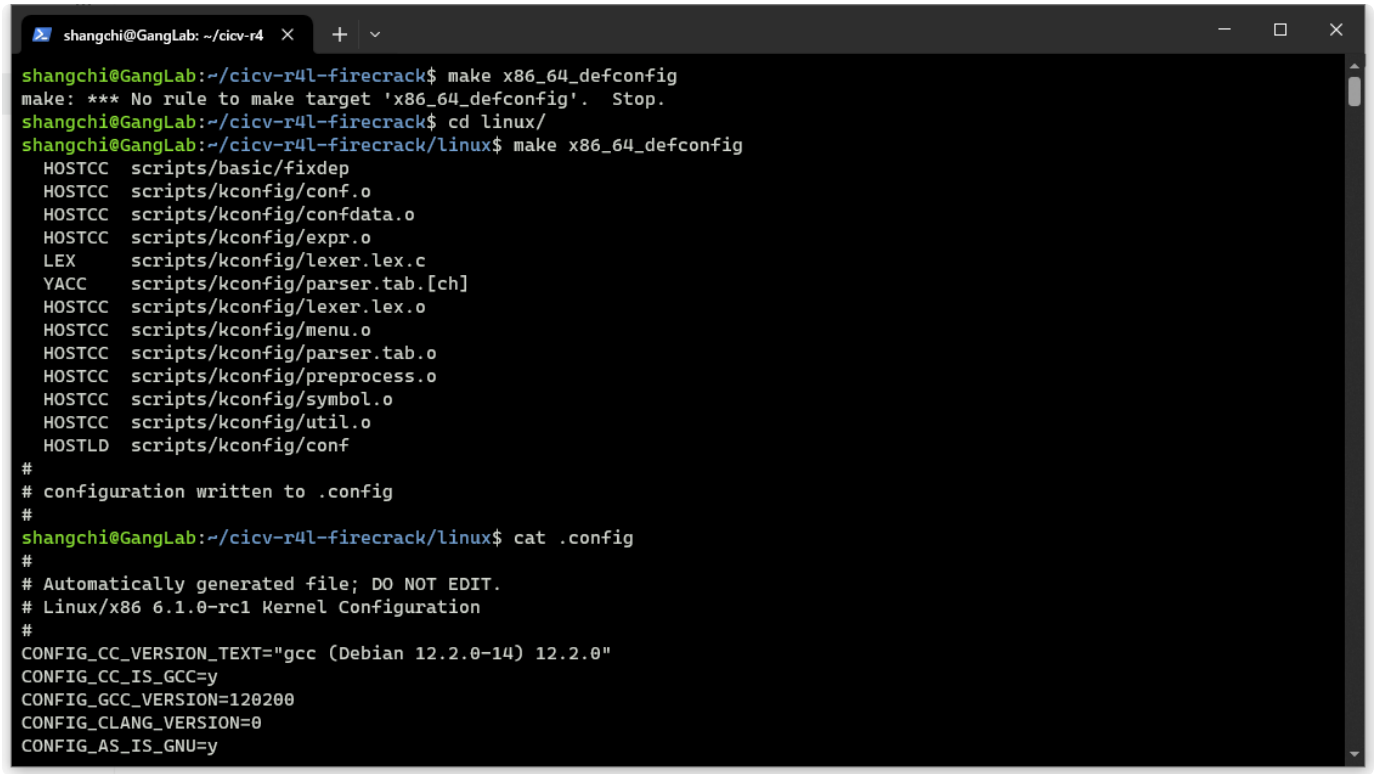
作业

作业一

1. `make x86_64_defconfig`

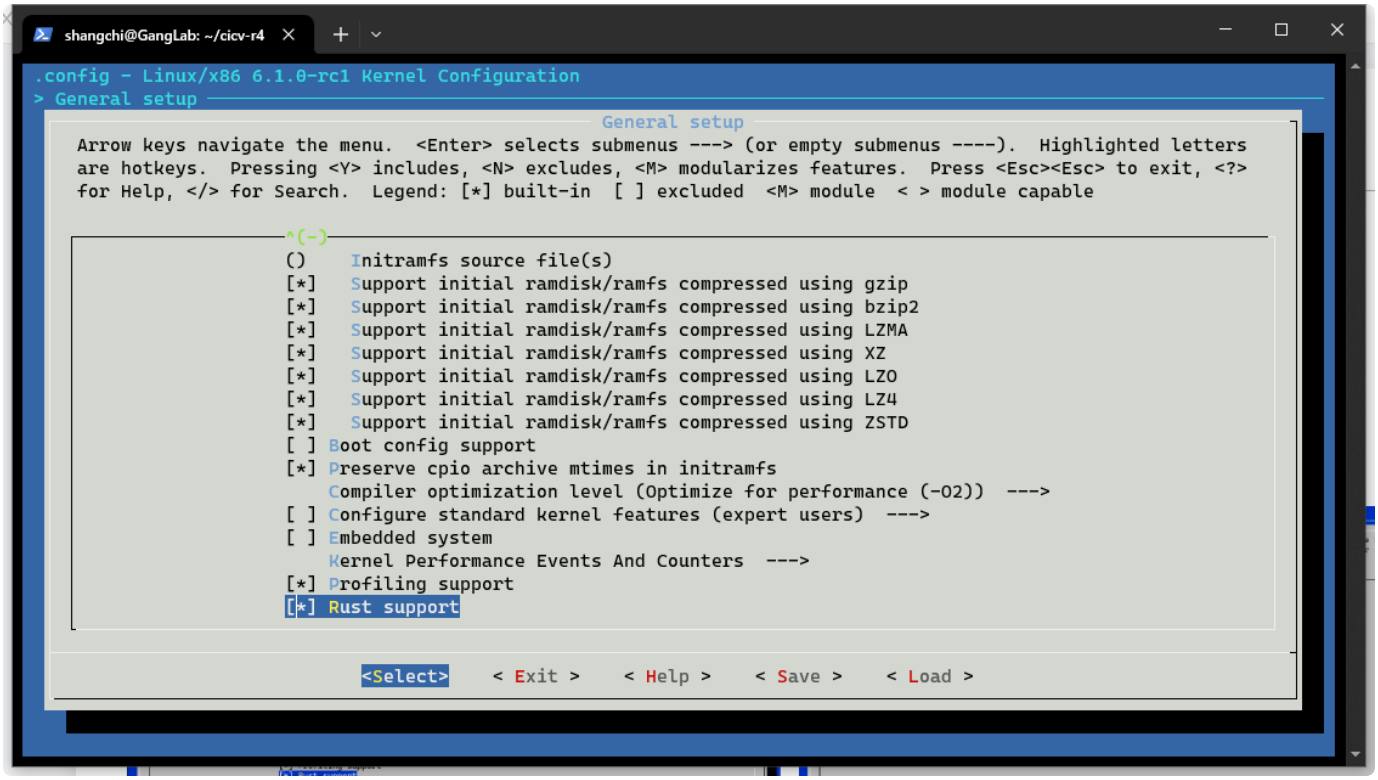
生成一个x86_64架构的默认配置文件，其包含了相关的内核配置选项的默认值。



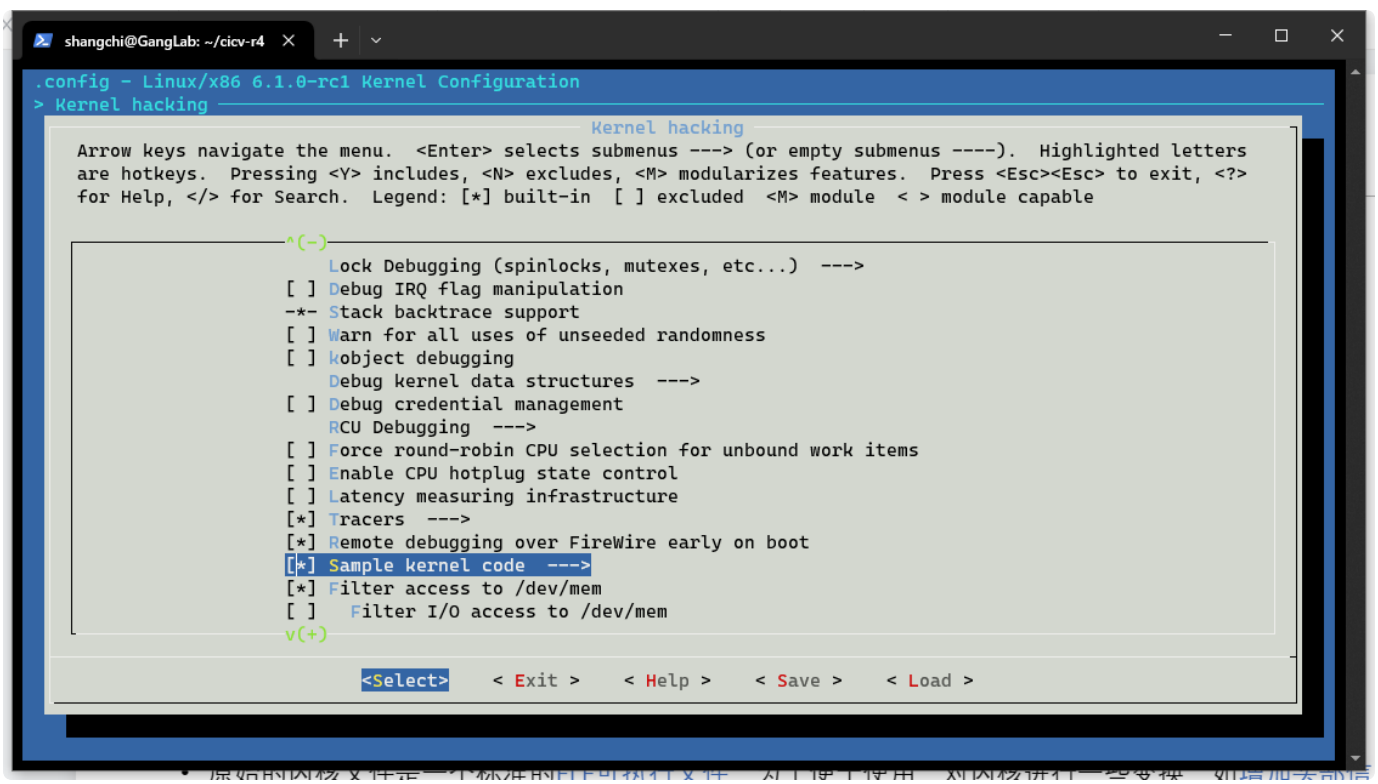
2. `makeLLVM=1 menuconfig`

- `LLVM=1` 表示使用LLVM编译器来构建内核
- `menuconfig` 启动Linux内核配置工具的文本菜单界面

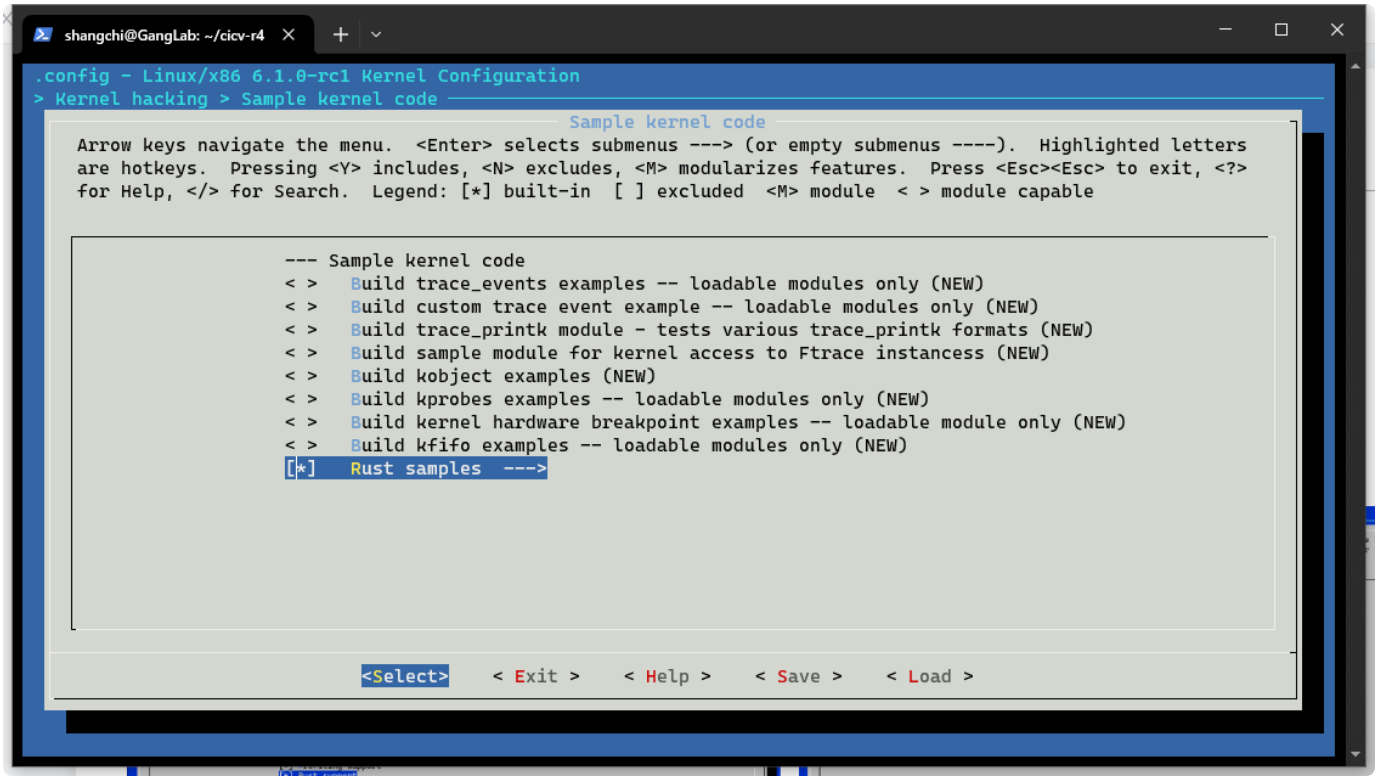
选中 `Rust support`



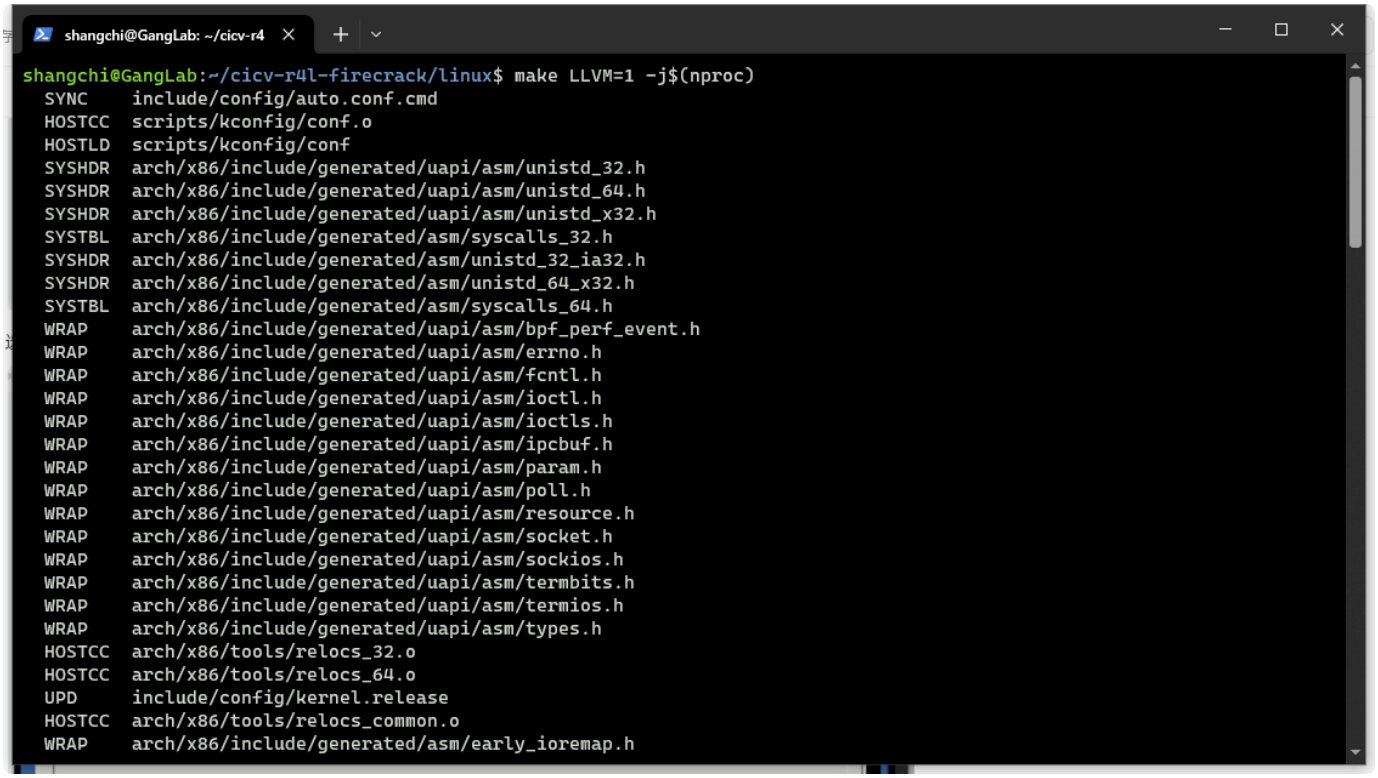
选中 `Sample kernel code`



选中 `Rust samples`



3. `make LLVM=1 -j$(proc)` 开始编译内核



编译完成后会在linux目录中生成 `vmlinux` 文件

```
shangchi@GangLab: ~/cicv-r4
  CC      arch/x86/boot/compressed/pgtable_64.o
  CC      arch/x86/boot/compressed/acpi.o
  AS      arch/x86/boot/compressed/efi_thunk_64.o
  CC      arch/x86/boot/compressed/efi.o
  CC      arch/x86/boot/compressed/misc.o
  CC      arch/x86/boot/video-vga.o
  CC      arch/x86/boot/video-vesa.o
  GZIP    arch/x86/boot/compressed/vmlinux.bin.gz
  CC      arch/x86/boot/video-bios.o
  HOSTCC  arch/x86/boot/tools/build
  CPUSTR  arch/x86/boot/cpustr.h
  CC      arch/x86/boot/cpu.o
  MKPIGGY arch/x86/boot/compressed/piggy.S
  AS      arch/x86/boot/compressed/piggy.o
  LD      arch/x86/boot/compressed/vmlinux
  ZOFFSET arch/x86/boot/zoffset.h
  OBJCOPY arch/x86/boot/vmlinux.bin
  AS      arch/x86/boot/header.o
  LD      arch/x86/boot/setup.elf
  OBJCOPY arch/x86/boot/setup.bin
  BUILD   arch/x86/boot/bzImage
Kernel: arch/x86/boot/bzImage is ready  (#1)
shangchi@GangLab:~/cicv-r4l-firecrack/linux$ ls
arch        crypto         io_uring  LICENSES                modules.order   samples     usr
block       Documentation  ipc       MAINTAINERS             Module.symvers  scripts     virt
built-in.a  drivers        Kbuild    Makefile                net             security    vmlinux
certs       fs             Kconfig   mm                      README          sound       vmlinux.a
COPYING     include        kernel    modules.builtin         README.md       System.map  vmlinux.o
CREDITS     init           lib       modules.builtin.modinfo rust            tools
shangchi@GangLab:~/cicv-r4l-firecrack/linux$
```

作业二

- 构建网卡模块

  在 `src_e1000` 文件夹中执行 `make LLVM=1`，构建一个网卡驱动模块(.ko文件)

```
shangchi@GangLab:~/cicv-r4l-firecrack/src_e1000$ make LLVM=1
make -C ../linux M=$PWD
make[1]: Entering directory '/home/shangchi/cicv-r4l-firecrack/linux'
  RUSTC [M] /home/shangchi/cicv-r4l-firecrack/src_e1000/r4l_e1000_demo.o
  MODPOST /home/shangchi/cicv-r4l-firecrack/src_e1000/Module.symvers
  CC [M]  /home/shangchi/cicv-r4l-firecrack/src_e1000/r4l_e1000_demo.mod.o
  LD [M]  /home/shangchi/cicv-r4l-firecrack/src_e1000/r4l_e1000_demo.ko
make[1]: Leaving directory '/home/shangchi/cicv-r4l-firecrack/linux'
shangchi@GangLab:~/cicv-r4l-firecrack/src_e1000$
```

- 使用 `./build_image.sh` 脚本运行qemu

  `ifconfig` 查看网卡，这里启动的网卡驱动是Linux 内核本身具有的

```
Please press Enter to activate this console.
~ # ifconfig
eth0      Link encap:Ethernet  HWaddr 52:54:00:12:34:56
          inet addr:10.0.2.15  Bcast:10.0.2.255  Mask:255.255.255.0
          inet6 addr: fec0::5054:ff:fe12:3456/64 Scope:Site
          inet6 addr: fe80::5054:ff:fe12:3456/64 Scope:Link
          UP BROADCAST RUNNING MULTICAST  MTU:1500  Metric:1
          RX packets:2 errors:0 dropped:0 overruns:0 frame:0
          TX packets:8 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:220 (220.0 B)  TX bytes:672 (672.0 B)

lo        Link encap:Local Loopback
          inet addr:127.0.0.1  Mask:255.0.0.0
          inet6 addr: ::1/128 Scope:Host
          UP LOOPBACK RUNNING  MTU:65536  Metric:1
          RX packets:0 errors:0 dropped:0 overruns:0 frame:0
          TX packets:0 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:0 (0.0 B)  TX bytes:0 (0.0 B)

~ #
```

- 禁用Linux默认的网卡驱动

  `Device Divers->Network device support->Ethernet driver support -> Intel (R) PRO/1000 Gigabit Ethernet support`

```
.config - Linux/x86 6.1.0-rc1 Kernel Configuration
> Device Drivers > Network device support > Ethernet driver support
                    Ethernet driver support
  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  [ ] excluded  <M> module  < > module capable

                    ^(-)
                    [*]   Intel (82586/82593/82596) devices
                    [*]   Intel devices
                    <*>     Intel(R) PRO/100+ support
                    < >     Intel(R) PRO/1000 Gigabit Ethernet support
                    <*>     Intel(R) PRO/1000 PCI-Express Gigabit Ethernet support
                    [*]       Support HW cross-timestamp on PCH devices
                    < >     Intel(R) 82575/82576 PCI-Express Gigabit Ethernet support
                    < >     Intel(R) 82576 Virtual Function Ethernet support
                    < >     Intel(R) PRO/10GbE support
                    < >     Intel(R) 10GbE PCI Express adapters support
                    < >     Intel(R) 10GbE PCI Express Virtual Function Ethernet support
                    < >     Intel(R) Ethernet Controller XL710 Family support
                    < >     Intel(R) Ethernet Adaptive Virtual Function support
                    < >     Intel(R) Ethernet Connection E800 Series Support
                    < >     Intel(R) FM10000 Ethernet Switch Host Interface Support
                    < >     Intel(R) Ethernet Controller I225-LM/I225-V support
                    v(+)

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

- 再次编译内核，并启动qemu，使用 `ifconfig` 命令，可以看到现在已经看不到网络接口了

```
[    1.567623] netconsole: network logging started
[    1.655241] ata2: found unknown device (class 0)
[    1.665564] ata2.00: ATAPI: QEMU DVD-ROM, 2.5+, max UDMA/100
[    1.676004] scsi 1:0:0:0: CD-ROM            QEMU     QEMU DVD-ROM     2.5+ PQ: 0 ANSI: 5
[    1.711254] sr 1:0:0:0: [sr0] scsi3-mmc drive: 4x/4x cd/rw xa/form2 tray
[    1.711659] cdrom: Uniform CD-ROM driver Revision: 3.20
[    1.731144] sr 1:0:0:0: Attached scsi generic sg0 type 5
[    2.142892] input: ImExPS/2 Generic Explorer Mouse as /devices/platform/i8042/serio1/input/input3
[    2.277780] tsc: Refined TSC clocksource calibration: 2903.978 MHz
[    2.278270] clocksource: tsc: mask: 0xffffffffffffffff max_cycles: 0x29dbf0ef31e, max_idle_ns: 440795267001 ns
[    2.278787] clocksource: Switched to clocksource tsc
[   14.437965] cfg80211: Loading compiled-in X.509 certificates for regulatory database
[   14.502573] modprobe (67) used greatest stack depth: 14272 bytes left
[   14.516902] cfg80211: Loaded X.509 cert 'sforshee: 00b28ddf47aef9cea7'
[   14.518901] platform regulatory.0: Direct firmware load for regulatory.db failed with error -2
[   14.519440] cfg80211: failed to load regulatory.db
[   14.520980] ALSA device list:
[   14.521479]   No soundcards found.
[   14.590973] Freeing unused kernel image (initmem) memory: 1328K
[   14.591690] Write protecting the kernel read-only data: 24576k
[   14.594974] Freeing unused kernel image (text/rodata gap) memory: 2032K
[   14.595987] Freeing unused kernel image (rodata/data gap) memory: 840K
[   14.744763] x86/mm: Checked W+X mappings: passed, no W+X pages found.
[   14.745314] Run sbin/init as init process
[   14.786749] mount (72) used greatest stack depth: 14160 bytes left
[   14.930148] mdev (74) used greatest stack depth: 13928 bytes left

Please press Enter to activate this console.
~ # ifconfig
~ #
```

- 加载 `r4l_e1000_demo.ko` 模块，并配置网卡，在qemu启动的系统中输入：

```bash
# 加载内核模块
insmod r4l_e1000_demo.ko
# 启动名为eth0的网络接口
ip link set eth0 up
# 添加广播地址
ip addr add broadcast 10.0.2.255 dev eth0
#将 10.0.2.15 IP 地址分配给 eth0 网络接口，并将子网掩码设置为 255.255.255.0
ip addr add 10.0.2.15/255.255.255.0 dev eth0
# 添加默认路由网关
ip route add default via 10.0.2.1
```

```
~ # insmod r4l_e1000_demo.ko
[  356.457789] r4l_e1000_demo: loading out-of-tree module taints kernel.
[  356.466078] r4l_e1000_demo: Rust for linux e1000 driver demo (init)
[  356.467537] r4l_e1000_demo: Rust for linux e1000 driver demo (probe): None
[  356.675422] ACPI: \_SB_.LNKC: Enabled at IRQ 11
[  356.697562] r4l_e1000_demo: Rust for linux e1000 driver demo (net device get_stats64)
[  356.699658] insmod (82) used greatest stack depth: 11144 bytes left
```

`ping 10.0.2.2`

```
~ # ping 10.0.2.2
PING 10.0.2.2 (10.0.2.2): 56 data bytes
[  817.704911] r4l_e1000_demo: Rust for linux e1000 driver demo (net device start_xmit) tdt=4, tdh=4, rdt=7, rdh=0
[  817.705472] r4l_e1000_demo: Rust for linux e1000 driver demo (handle_irq)
[  817.705766] r4l_e1000_demo: pending_irqs: 131
[  817.706322] r4l_e1000_demo: Rust for linux e1000 driver demo (napi poll)
[  817.708476] r4l_e1000_demo: Rust for linux e1000 driver demo (net device start_xmit) tdt=5, tdh=5, rdt=0, rdh=1
[  817.708811] r4l_e1000_demo: Rust for linux e1000 driver demo (handle_irq)
[  817.709412] r4l_e1000_demo: pending_irqs: 131
[  817.710384] r4l_e1000_demo: Rust for linux e1000 driver demo (napi poll)
64 bytes from 10.0.2.2: seq=0 ttl=255 time=12.940 ms
[  818.714380] r4l_e1000_demo: Rust for linux e1000 driver demo (net device start_xmit) tdt=6, tdh=6, rdt=1, rdh=2
[  818.714801] r4l_e1000_demo: Rust for linux e1000 driver demo (handle_irq)
[  818.714933] r4l_e1000_demo: pending_irqs: 131
[  818.715063] r4l_e1000_demo: Rust for linux e1000 driver demo (napi poll)
64 bytes from 10.0.2.2: seq=1 ttl=255 time=1.747 ms
[  819.716636] r4l_e1000_demo: Rust for linux e1000 driver demo (net device start_xmit) tdt=7, tdh=7, rdt=2, rdh=3
[  819.717491] r4l_e1000_demo: Rust for linux e1000 driver demo (handle_irq)
[  819.717867] r4l_e1000_demo: pending_irqs: 131
[  819.718405] r4l_e1000_demo: Rust for linux e1000 driver demo (napi poll)
64 bytes from 10.0.2.2: seq=2 ttl=255 time=2.709 ms
^C
--- 10.0.2.2 ping statistics ---
3 packets transmitted, 3 packets received, 0% packet loss
round-trip min/avg/max = 1.747/5.798/12.940 ms
```

1. **编译成内核模块，是在哪个文件中以哪条语句定义的?**
   在src_e1000的目录中的Kbuild文件中的声明 `obj-m := r4l_e1000_demo.o` 告知构建系统要编译一个模块，构建系统会自动生成一个对应的 `.ko` 文件
2. **该模块位于独立的文件夹内，却能编译成Linux内核模块，这叫做out-of-tree module，请分析它是如何与内核代码产生联系的**
   `obj-m := r4l_e1000_demo.o` 声明了要构建的模块
   Makefile中的 `$(MAKE) -C $(KDIR) M=$$PWD`
   a. **-C** 选项告诉构建系统到内核源代码的路径去查找内核头文件和构建规则。
   b. **M=$$PWD** 选项告诉构建系统去当前模块源代码目录中查找Makefile