南京航空航天大学《计算机组成原理Ⅱ课程设计》报告

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- 报告阶段：PA2.2, PA2.3
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- 本次实验，我完成了所有内容。

目录

PA2.2 思考题

什么是API?

应用程序接口(`Application Programming Interface`,又称为应用编程接口)是软件系统不同组成部分衔接的约定. 接口本身指一种规范或者说约定,用于说明供需的具体情况.

AM属于硬件还是软件?

AM即不属于硬件也不属于软件,它只是一个抽象概念,描述了一个计算机应该具备的功能,或者说它描述的就是指令集体系本身.就像凶器没有具体所指,用于杀人的就是凶器.

堆和栈在哪里?

因为堆本身就是运行时分配的内存,而栈也是用来保存运行时环境变量和函数运行时栈帧的.程序运行时操作系统会在其进程空间通过对特定变量赋值来分配堆和栈.比如`Linux`中,堆为`start_brk`(堆起始,不变)和`brk`(堆结尾),栈为`rsp`(初始值即为栈底).AM带来了启示.

回忆运行过程

阅读当前目录`Makefile`之后大致了解`make ALL=xxx run`运行过程.

- 首先读取`$(AM_HOME)/Makefile.check`中的默认参数,包括之前设置的ARCH,由于已经修改文件中默认值,所以这里无需指定.
- 然后通过命令行指定的`ALL`寻找`tests`目录下对应的`*.c`文件.
- 根据AM中指定ARCH提供的编译链接规则编译生成可执行文件.
- 将可执行文件作为nemu的镜像启动nemu.控制权转交给nemu.

神奇的eflags（2)

```
+-----+-----+------------------------------------+
| SF  |  OF |                 实例                 |
+-----+-----+------------------------------------+
|  0  |  0  |               2 - 1                |
+-----+-----+------------------------------------+
|  0  |  1  |           (2 ^ 31) - 1             |
+-----+-----+------------------------------------+
|  1  |  0  |               1 - 2                |
+-----+-----+------------------------------------+
|  1  |  1  |        (2 ^ 31 - 1) - (-1)         |
+-----+-----+------------------------------------+
```

当`(OF || SF) == 0`,被减数大于减数.

这是巧合吗?

- `above`表示op2 `>` op1,无符号比较.
- `below`表示op2 `<` op1,无符号比较.
- `greater`表示op2 `>` op1,有符号比较.
- `less`表示op2 `<` op1,有符号比较.

NEMU的本质

IOE,图像处理模块等.

PA2.2 实验内容

任务1.1：实现更多的指令 && 任务 1.2：启用已实现指令 && 任务 1.3：逐个通过测试样例 && 任务 2：通过一键回归测试

在all-instr.h中声明新增函数.

```
make_EHelper(add);
make_EHelper(cmp);
make_EHelper(inc);
make_EHelper(dec);
make_EHelper(neg);
make_EHelper(adc);
make_EHelper(sbb);
make_EHelper(mul);
make_EHelper(imul1);
make_EHelper(imul2);
make_EHelper(imul3);
make_EHelper(div);
make_EHelper(idiv);
make_EHelper(jmp);
make_EHelper(jcc);
make_EHelper(jmp_rm);
make_EHelper(call_rm);
make_EHelper(pusha);
make_EHelper(popa);
make_EHelper(leave);
make_EHelper(cltd);
make_EHelper(cwtl);
make_EHelper(movsx);
make_EHelper(movzx);
make_EHelper(lea);
make_EHelper(test);
make_EHelper(and);
make_EHelper(or);
make_EHelper(sar);
make_EHelper(shl);
make_EHelper(shr);
make_EHelper(setcc);
make_EHelper(not);
make_EHelper(nop);
make_EHelper(lidt);
make_EHelper(mov_r2cr);
make_EHelper(mov_cr2r);
make_EHelper(int);
make_EHelper(iret);
make_EHelper(in);
make_EHelper(out);
```

修改exec.c中的译码表.

```
/* 0x80, 0x81, 0x83 */
make_group(gp1,
    EX(add), EX(or), EX(adc), EX(sbb),
    EX(and), EX(sub), EX(xor), EX(cmp))

  /* 0xc0, 0xc1, 0xd0, 0xd1, 0xd2, 0xd3 */
make_group(gp2,
    EX(rol), EMPTY, EMPTY, EMPTY,
    EX(shl), EX(shr), EMPTY, EX(sar))

  /* 0xf6, 0xf7 */
make_group(gp3,
    IDEX(test_I, test), EMPTY, EX(not), EX(neg),
    EX(mul), EX(imul1), EX(div), EX(idiv))
  /* 0xfe */
make_group(gp4,
    EX(inc), EX(dec), EMPTY, EMPTY,
    EMPTY, EMPTY, EMPTY, EMPTY)

  /* 0xff */
make_group(gp5,
    EX(inc), EX(dec), EX(call_rm), EX(call),
    EX(jmp_rm), EX(jmp), EX(push), EMPTY)

  /* 0x0f 0x01*/
make_group(gp7,
    EMPTY, EMPTY, EMPTY, EMPTY,
    EMPTY, EMPTY, EMPTY, EMPTY)

/* TODO: Add more instructions!!! */

opcode_entry opcode_table [512] = {
  /* 0x00 */    IDEXW(G2E, add, 1), IDEX(G2E, add), IDEXW(E2G, add, 1), IDEX(E2G, add),
  /* 0x04 */    IDEXW(I2a, add, 1), IDEX(I2a, add), EMPTY, EMPTY,
  /* 0x08 */    IDEXW(G2E, or, 1), IDEX(G2E, or), IDEXW(E2G, or, 1), IDEX(E2G, or),
  /* 0x0c */    IDEXW(I2a, or, 1), IDEX(I2a, or), EMPTY, EX(2byte_esc),
  /* 0x10 */    IDEXW(G2E, adc, 1), IDEX(G2E, adc), IDEXW(E2G, adc, 1), IDEX(E2G, adc),
  /* 0x14 */    IDEXW(I2a, adc, 1), IDEX(I2a, adc), EMPTY, EMPTY,
  /* 0x18 */    IDEXW(G2E, sbb, 1), IDEX(G2E, sbb), IDEXW(E2G, sbb, 1), IDEX(E2G, sbb),
  /* 0x1c */    IDEXW(I2a, sbb, 1), IDEX(I2a, sbb), EMPTY, EMPTY,
  /* 0x20 */    IDEXW(G2E, and, 1), IDEX(G2E, and), IDEXW(E2G, and, 1), IDEX(E2G, and),
  /* 0x24 */    IDEXW(I2a, and, 1), IDEX(I2a, and), EMPTY, EMPTY,
  /* 0x28 */    IDEXW(G2E, sub, 1), IDEX(G2E, sub), IDEXW(E2G, sub, 1), IDEX(E2G, sub),
  /* 0x2c */    IDEXW(I2a, sub, 1), IDEX(I2a, sub), EMPTY, EMPTY,
  /* 0x30 */    IDEXW(G2E, xor, 1), IDEX(G2E, xor), IDEXW(E2G, xor, 1), IDEX(E2G, xor),
  /* 0x34 */    IDEXW(I2a, xor, 1), IDEX(I2a, xor), EMPTY, EMPTY,
  /* 0x38 */    IDEXW(G2E, cmp, 1), IDEX(G2E, cmp), IDEXW(E2G, cmp, 1), IDEX(E2G, cmp),
  /* 0x3c */    IDEXW(I2a, cmp, 1), IDEX(I2a, cmp), EMPTY, EMPTY,
  /* 0x40 */    IDEX(r, inc), IDEX(r, inc), IDEX(r, inc), IDEX(r, inc),
  /* 0x44 */    IDEX(r, inc), IDEX(r, inc), IDEX(r, inc), IDEX(r, inc),
  /* 0x48 */    IDEX(r, dec), IDEX(r, dec), IDEX(r, dec), IDEX(r, dec),
  /* 0x4c */    IDEX(r, dec), IDEX(r, dec), IDEX(r, dec), IDEX(r, dec),
  /* 0x50 */    IDEX(r, push), IDEX(r, push), IDEX(r, push), IDEX(r, push),
  /* 0x54 */    IDEX(r, push), IDEX(r, push), IDEX(r, push), IDEX(r, push),
  /* 0x58 */    IDEX(r, pop), IDEX(r, pop), IDEX(r, pop), IDEX(r, pop),
  /* 0x5c */    IDEX(r, pop), IDEX(r, pop), IDEX(r, pop), IDEX(r, pop),
  /* 0x60 */    EX(pusha), EX(popa), EMPTY, EMPTY,
  /* 0x64 */    EMPTY, EMPTY, EX(operand_size), EMPTY,
  /* 0x68 */    IDEX(push_SI, push), IDEX(I_E2G, imul3), IDEXW(push_SI, push, 1), IDEX(I_E2G,
imul3),
  /* 0x6c */    EMPTY, EMPTY, EMPTY, EMPTY,
  /* 0x70 */    IDEXW(J, jcc, 1), IDEXW(J, jcc, 1), IDEXW(J, jcc, 1), IDEXW(J, jcc, 1),
  /* 0x74 */    IDEXW(J, jcc, 1), IDEXW(J, jcc, 1), IDEXW(J, jcc, 1), IDEXW(J, jcc, 1),
  /* 0x78 */    IDEXW(J, jcc, 1), IDEXW(J, jcc, 1), IDEXW(J, jcc, 1), IDEXW(J, jcc, 1),
  /* 0x7c */    IDEXW(J, jcc, 1), IDEXW(J, jcc, 1), IDEXW(J, jcc, 1), IDEXW(J, jcc, 1),
  /* 0x80 */    IDEXW(I2E, gp1, 1), IDEX(I2E, gp1), EMPTY, IDEX(SI2E, gp1),
  /* 0x84 */    IDEXW(G2E, test, 1), IDEX(G2E, test), EMPTY, EMPTY,
  /* 0x88 */    IDEXW(mov_G2E, mov, 1), IDEX(mov_G2E, mov), IDEXW(mov_E2G, mov, 1),
IDEX(mov_E2G, mov),
  /* 0x8c */    EMPTY, IDEX(lea_M2G, lea), EMPTY, IDEX(E, pop),
  /* 0x90 */    EX(nop), EMPTY, EMPTY, EMPTY,
  /* 0x94 */    EMPTY, EMPTY, EMPTY, EMPTY,
  /* 0x98 */    EX(cwtl), EX(cltd), EMPTY, EMPTY,
  /* 0x9c */    EMPTY, EMPTY, EMPTY, EMPTY,
  /* 0xa0 */    IDEXW(O2a, mov, 1), IDEX(O2a, mov), IDEXW(a2O, mov, 1), IDEX(a2O, mov),
  /* 0xa4 */    EMPTY, EMPTY, EMPTY, EMPTY,
  /* 0xa8 */    IDEXW(I2a, test, 1), IDEX(I2a, test), EMPTY, EMPTY,
  /* 0xac */    EMPTY, EMPTY, EMPTY, EMPTY,
  /* 0xb0 */    IDEXW(mov_I2r, mov, 1), IDEXW(mov_I2r, mov, 1), IDEXW(mov_I2r, mov, 1),
IDEXW(mov_I2r, mov, 1),
  /* 0xb4 */    IDEXW(mov_I2r, mov, 1), IDEXW(mov_I2r, mov, 1), IDEXW(mov_I2r, mov, 1),
IDEXW(mov_I2r, mov, 1),
  /* 0xb8 */    IDEX(mov_I2r, mov), IDEX(mov_I2r, mov), IDEX(mov_I2r, mov), IDEX(mov_I2r,
mov),
  /* 0xbc */    IDEX(mov_I2r, mov), IDEX(mov_I2r, mov), IDEX(mov_I2r, mov), IDEX(mov_I2r,
mov),
  /* 0xc0 */    IDEXW(gp2_Ib2E, gp2, 1), IDEX(gp2_Ib2E, gp2), IDEXW(I, ret, 2), EX(ret),
  /* 0xc4 */    EMPTY, EMPTY, IDEXW(mov_I2E, mov, 1), IDEX(mov_I2E, mov),
  /* 0xc8 */    EMPTY, EX(leave), EMPTY, EMPTY,
  /* 0xcc */    EX(int3), IDEXW(I, int, 1), EMPTY, EX(iret),
  /* 0xd0 */    IDEXW(gp2_1_E, gp2, 1), IDEX(gp2_1_E, gp2), IDEXW(gp2_cl2E, gp2, 1),
IDEX(gp2_cl2E, gp2),
  /* 0xd4 */    EMPTY, EMPTY, EX(nemu_trap), EMPTY,
  /* 0xd8 */    EMPTY, EMPTY, EMPTY, EMPTY,
  /* 0xdc */    EMPTY, EMPTY, EMPTY, EMPTY,
  /* 0xe0 */    EMPTY, EMPTY, EMPTY, EMPTY,
  /* 0xe4 */    IDEXW(in_I2a, in, 1), IDEX(in_I2a, in), IDEXW(out_a2I, out, 1), IDEX(out_a2I,
out),
  /* 0xe8 */    IDEX(J, call), IDEX(J, jmp), EMPTY, IDEXW(J, jmp, 1),
  /* 0xec */    IDEXW(in_dx2a, in, 1), IDEX(in_dx2a, in), IDEXW(out_a2dx, out, 1),
IDEX(out_a2dx, out),
  /* 0xf0 */    EMPTY, EMPTY, EMPTY, EMPTY,
  /* 0xf4 */    EMPTY, EMPTY, IDEXW(E, gp3, 1), IDEX(E, gp3),
  /* 0xf8 */    EMPTY, EMPTY, EMPTY, EMPTY,
  /* 0xfc */    EMPTY, EMPTY, IDEXW(E, gp4, 1), IDEX(E, gp5),

  /*2 byte_opcode_table */

  ...
  /* 0x80 */    IDEX(J, jcc), IDEX(J, jcc), IDEX(J, jcc), IDEX(J, jcc),
  /* 0x84 */    IDEX(J, jcc), IDEX(J, jcc), IDEX(J, jcc), IDEX(J, jcc),
  /* 0x88 */    IDEX(J, jcc), IDEX(J, jcc), IDEX(J, jcc), IDEX(J, jcc),
  /* 0x8c */    IDEX(J, jcc), IDEX(J, jcc), IDEX(J, jcc), IDEX(J, jcc),
  /* 0x90 */    IDEXW(E, setcc, 1), IDEXW(E, setcc, 1), IDEXW(E, setcc, 1), IDEXW(E, setcc,
1),
  /* 0x94 */    IDEXW(E, setcc, 1), IDEXW(E, setcc, 1), IDEXW(E, setcc, 1), IDEXW(E, setcc,
1),
  /* 0x98 */    IDEXW(E, setcc, 1), IDEXW(E, setcc, 1), IDEXW(E, setcc, 1), IDEXW(E, setcc,
1),
  /* 0x9c */    IDEXW(E, setcc, 1), IDEXW(E, setcc, 1), IDEXW(E, setcc, 1), IDEXW(E, setcc,
1),
  /* 0xa0 */    EMPTY, EMPTY, EMPTY, EMPTY,
  /* 0xa4 */    EMPTY, EMPTY, EMPTY, EMPTY,
  /* 0xa8 */    EMPTY, EMPTY, EMPTY, EMPTY,
  /* 0xac */    EMPTY, EMPTY, EMPTY, IDEX(E2G, imul2),
  /* 0xb0 */    EMPTY, EMPTY, EMPTY, EMPTY,
  /* 0xb4 */    EMPTY, EMPTY, IDEXW(mov_E2G, movzx, 1), IDEXW(mov_E2G, movzx, 2),
  /* 0xb8 */    EMPTY, EMPTY, EMPTY, EMPTY,
  /* 0xbc */    EMPTY, EMPTY, IDEXW(mov_E2G, movsx, 1), IDEXW(mov_E2G, movsx, 2),
  ...
};
```

实现arith.c中未实现的函数.

```
make_EHelper(add) {
  rtlreg_t result, flag;

  rtl_add(&result, &id_dest->val, &id_src->val);

  flag = 0;
  if (result < id_src->val || result < id_dest->val) {
    //CF
    flag = 1;
  }
  rtl_set_CF(&flag);

  flag = 0;
  if (((int)id_dest->val > 0 && (int)id_src->val > 0 && (int)result < 0)
  || ((int)id_dest->val < 0 && (int)id_src->val < 0 && (int)result > 0)) {
    //OF
    flag = 1;
  }
  rtl_set_OF(&flag);

  rtl_update_ZFSF(&result, id_dest->width);
  //更新ZFSF

  operand_write(id_dest, &result);
  //将结果写入目标Operand

  print_asm_template2(add);
}

make_EHelper(cmp) {
  //即没有写入的sub
  rtlreg_t result, flag;

  if (id_src->width == 1 && id_dest->width >= 2)
  {
    rtl_sext(&id_src->val, &id_src->val, id_src->width);
  }
  //sign-extended

  rtl_sub(&result, &id_dest->val, &id_src->val);

  flag = 0;
  if (((int)id_dest->val >= 0 && (int)id_src->val < 0 && (int)result < 0)
  || ((int)id_dest->val < 0 && (int)id_src->val >= 0 && (int)result > 0)) {
    //OF
    flag = 1;
  }
  rtl_set_OF(&flag);

  flag = 0;
  if (id_dest->val < id_src->val) {
    //CF
    flag = 1;
  }
  rtl_set_CF(&flag);

  rtl_update_ZFSF(&result, id_dest->width);
  //更新ZFSF

  print_asm_template2(cmp);
```

```
}

make_EHelper(inc) {
  rtlreg_t result, flag;

  result = id_dest->val + 1;

  flag = 0;
  if ((1 << (8 * id_dest->width - 1)) == result) {
    //OF
    flag = 1;
  }
  rtl_set_OF(&flag);

  flag = 0;
  if (0 == result) {
    //CF
    flag = 1;
  }
  rtl_set_CF(&flag);

  rtl_update_ZFSF(&result, id_dest->width);
  //更新ZFSF

  operand_write(id_dest, &result);
  //将结果写入目标Operand

  print_asm_template1(inc);
}

make_EHelper(dec) {
  rtlreg_t result, flag;

  result = id_dest->val - 1;

  flag = 0;
  if ((~0 >> (32 - 8 * id_dest->width - 1)) == result) {
    //OF
    flag = 1;
  }
  rtl_set_OF(&flag);

  flag = 0;
  if ((~0 >> (32 - 8 * id_dest->width)) == result) {
    //CF
    flag = 1;
  }
  rtl_set_CF(&flag);

  rtl_update_ZFSF(&result, id_dest->width);
  //更新ZFSF

  operand_write(id_dest, &result);
  //将结果写入目标Operand

  print_asm_template1(dec);
}

make_EHelper(neg) {
  rtlreg_t result, flag;
  result = -id_dest->val;

  flag = 0;
  if (id_dest->val != 0) {
    //CF
    flag = 1;
  }
  rtl_set_CF(&flag);

  flag = 0;
  if ((1 << (8 * id_dest->width - 1)) == id_dest->val) {
    //OF
    flag = 1;
  }
  rtl_set_OF(&flag);

  rtl_update_ZFSF(&result, id_dest->width);
  //更新ZFSF

  operand_write(id_dest, &result);
  //将结果写入目标operand

  print_asm_template1(neg);
}
```

实现cc.c中未实现的函数.

```
void rtl_setcc(rtlreg_t* dest, uint8_t subcode) {
  bool invert = subcode & 0x1;
  rtlreg_t a, b, c;
  enum {
    CC_O, CC_NO, CC_B,  CC_NB,
    CC_E, CC_NE, CC_BE, CC_NBE,
    CC_S, CC_NS, CC_P,  CC_NP,
    CC_L, CC_NL, CC_LE, CC_NLE
  };

  // TODO: Query EFLAGS to determine whether the condition code is satisfied.
  // dest <- ( cc is satisfied ? 1 : 0)
  switch (subcode & 0xe) {
    case CC_O:
      rtl_get_OF(dest);
      break;
    case CC_B:
      rtl_get_CF(dest);
      break;
    case CC_E:
      rtl_get_ZF(dest);
      break;
    case CC_BE:
      rtl_get_CF(&a);
      rtl_get_ZF(&b);
      *dest = a || b;
      break;
    case CC_S:
      rtl_get_SF(dest);
      break;
    case CC_L:
      rtl_get_SF(&a);
      rtl_get_OF(&b);
      rtl_get_ZF(&c);
      *dest = (a != b ) && !c;
      break;
    case CC_LE:
      rtl_get_SF(&a);
      rtl_get_OF(&b);
      rtl_get_ZF(&c);
      *dest = (a != b ) || c;
      break;
    default: panic("should not reach here");
    case CC_P: panic("n86 does not have PF");
  }

  if (invert) {
    rtl_xori(dest, dest, 0x1);
  }
}
```

实现control.c中未实现的函数.

```
make_EHelper(call_rm) {
  rtl_push(&decoding.seq_eip);
  decoding.jmp_eip = id_dest->val;
  decoding.is_jmp = 1;

  print_asm("call *%s", id_dest->str);
}
```

实现data-mov.c中未实现的函数.

```
make_EHelper(pusha) {
  if (decoding.is_operand_size_16) {
    t0 = reg_w(R_SP);
    //保存当前sp
    rtl_push((rtlreg_t *)&reg_w(R_AX));
    rtl_push((rtlreg_t *)&reg_w(R_CX));
    rtl_push((rtlreg_t *)&reg_w(R_DX));
    rtl_push((rtlreg_t *)&reg_w(R_BX));
    rtl_push(&t0);
    rtl_push((rtlreg_t *)&reg_w(R_BP));
    rtl_push((rtlreg_t *)&reg_w(R_SI));
    rtl_push((rtlreg_t *)&reg_w(R_DI));
  }
  else {
    t0 = reg_w(R_ESP);
    //保存当前esp
    rtl_push((rtlreg_t *)&reg_w(R_EAX));
    rtl_push((rtlreg_t *)&reg_w(R_ECX));
    rtl_push((rtlreg_t *)&reg_w(R_EDX));
    rtl_push((rtlreg_t *)&reg_w(R_EBX));
    rtl_push(&t0);
    rtl_push((rtlreg_t *)&reg_w(R_EBP));
    rtl_push((rtlreg_t *)&reg_w(R_ESI));
    rtl_push((rtlreg_t *)&reg_w(R_EDI));
  }

  print_asm("pusha");
}

make_EHelper(popa) {
  if (decoding.is_operand_size_16) {
    rtl_pop((rtlreg_t *)&reg_w(R_AX));
    rtl_pop((rtlreg_t *)&reg_w(R_CX));
    rtl_pop((rtlreg_t *)&reg_w(R_DX));
    rtl_pop((rtlreg_t *)&reg_w(R_BX));
    rtl_pop(&t0);
    //pading
    rtl_pop((rtlreg_t *)&reg_w(R_BP));
    rtl_pop((rtlreg_t *)&reg_w(R_SI));
    rtl_pop((rtlreg_t *)&reg_w(R_DI));
  }
  else {
    rtl_pop((rtlreg_t *)&reg_w(R_EAX));
    rtl_pop((rtlreg_t *)&reg_w(R_ECX));
    rtl_pop((rtlreg_t *)&reg_w(R_EDX));
    rtl_pop((rtlreg_t *)&reg_w(R_EBX));
    rtl_pop(&t0);
    //pading
    rtl_pop((rtlreg_t *)&reg_w(R_EBP));
    rtl_pop((rtlreg_t *)&reg_w(R_ESI));
    rtl_pop((rtlreg_t *)&reg_w(R_EDI));
  }

  print_asm("popa");
}

make_EHelper(leave) {
  if (decoding.is_operand_size_16) {
    reg_w(R_SP) = reg_w(R_BP);
    rtl_pop((rtlreg_t *)&reg_w(R_BP));
  }
  else {
    reg_l(R_ESP) = reg_l(R_EBP);
    rtl_pop((rtlreg_t *)&reg_l(R_EBP));
  }

  print_asm("leave");
}

make_EHelper(cltd) {
  if (decoding.is_operand_size_16) {
    if (reg_w(R_AX) < 0) {
      reg_w(R_DX) = 0xffff;
    }
    else {
      reg_w(R_DX) = 0;
    }
  }
  else {
    if (reg_l(R_EAX) < 0) {
      reg_l(R_EDX) = 0xffffffff;
    }
    else {
      reg_l(R_EDX) = 0;
    }
  }

  print_asm(decoding.is_operand_size_16 ? "cwtl" : "cltd");
}
```

```
make_EHelper(cwtl) {
  if (decoding.is_operand_size_16) {
    rtl_sext((rtlreg_t *)&reg_w(R_AX), (rtlreg_t *)&reg_b(R_AL), 2);
  }
  else {
    rtl_sext((rtlreg_t *)&reg_l(R_EAX), (rtlreg_t *)&reg_w(R_AX), 4);
  }

  print_asm(decoding.is_operand_size_16 ? "cbtw" : "cwtl");
}
```

实现logic.c中未实现的函数.

```
make_EHelper(test) {
  rtlreg_t result, flag;

  rtl_and(&result, &id_dest->val, &id_src->val);

  flag = 0;
  rtl_set_CF(&flag);
  rtl_set_OF(&flag);
  //直接置0

  rtl_update_ZFSF(&result, id_dest->width);
  //更新ZFSF

  print_asm_template2(test);
}

make_EHelper(and) {
  rtlreg_t result, flag;

  rtl_and(&result, &id_dest->val, &id_src->val);

  flag = 0;
  rtl_set_CF(&flag);
  rtl_set_OF(&flag);
  //直接置0

  rtl_update_ZFSF(&result, id_dest->width);
  //更新ZFSF

  operand_write(id_dest, &result);
  //将结果写入目标operand

  print_asm_template2(and);
}

make_EHelper(or) {
  rtlreg_t result, flag;

  rtl_or(&result, &id_dest->val, &id_src->val);

  flag = 0;
  rtl_set_CF(&flag);
  rtl_set_OF(&flag);
  //直接置0

  rtl_update_ZFSF(&flag, id_dest->width);
  //更新ZFSF
  operand_write(id_dest, &result);
  //将结果写入目标Operand

  print_asm_template2(or);
}

make_EHelper(sar) {
  rtlreg_t result;

  rtl_sar(&result, &id_dest->val, &id_src->val);

  rtl_update_ZFSF(&flag, id_dest->width);
  //更新ZFSF

  operand_write(id_dest, &result);
  //将结果写入目标Operand

  print_asm_template2(sar);
}

make_EHelper(shl) {
  rtlreg_t result;

  rtl_sal(&result, &id_dest->val, &id_src->val);

  rtl_update_ZFSF(&flag, id_dest->width);
  //更新ZFSF

  operand_write(id_dest, &result);
  //将结果写入目标Operand

  print_asm_template2(shl);
}

make_EHelper(shr) {
  rtlreg_t result;

  rtl_shr(&result, &id_dest->val, &id_src->val);

  rtl_update_ZFSF(&flag, id_dest->width);
  //更新ZFSF

  operand_write(id_dest, &result);
  //将结果写入目标Operand

  print_asm_template2(shr);
}

make_EHelper(not) {
  rtlreg_t result;

  result = id_dest->val;
  rtl_not(&result);

  operand_write(id_dest, &result);
  //将结果写入目标Operand

  print_asm_template1(not);
}
```

```
make_EHelper(rol) {
  int i;

  for (i = 0; i < id_src->val; i++) {
    t0 = id_src->val & (0x8000 << ((id_src->width - 2) * 8));
    t0 = t0 >> (id_src->width * 8 - 1);
    t1 = id_dest->val << 1;
    t1 &= t0;
  }

  operand_write(id_dest, &t1);
  //将结果写入目标operand

  print_asm_template2(rol);
}
```

修改之前的bug.

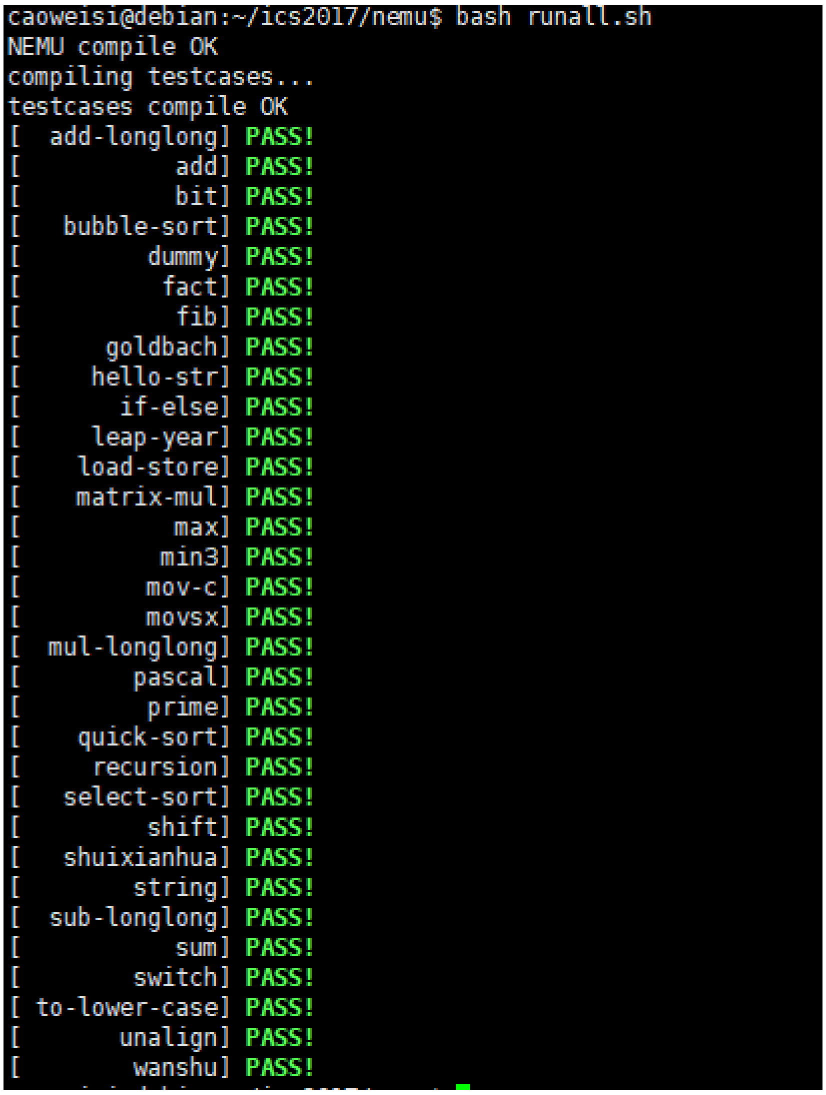
decode.c.

```
static inline make_DopHelper(SI) {
  assert(op->width == 1 || op->width == 4);

  op->type = OP_TYPE_IMM;
  t0 = instr_fetch(eip, op->width);
  rtl_sext((rtlreg_t *)&op->simm, &t0, op->width);
  rtl_li(&op->val, op->simm);

#ifdef DEBUG
  snprintf(op->str, OP_STR_SIZE, "$0x%x", op->simm);
#endif
}
```

rtl.h.

```
static inline void rtl_sext(rtlreg_t* dest, const rtlreg_t* src1, int width) {
  unsigned flag = *src1  & 0x1 << (width * 8 - 1);
  //判断符号位
  *dest = flag ? (width != 4 ? (~0 << (8 * width) | *src1) : *src1) : *src1;
}

static inline void rtl_update_ZF(const rtlreg_t* result, int width) {
  cpu.eflags.ZF = (*result << ((4 - width) * 8)) ? 0 : 1;
}
```

通过一键回归测试.



```
caoweisi@debian:~/ics2017/nemu$ bash runall.sh
NEMU compile OK
compiling testcases...
testcases compile OK
[  add-longlong] PASS!
[           add] PASS!
[           bit] PASS!
[   bubble-sort] PASS!
[         dummy] PASS!
[          fact] PASS!
[           fib] PASS!
[      goldbach] PASS!
[     hello-str] PASS!
[       if-else] PASS!
[     leap-year] PASS!
[    load-store] PASS!
[    matrix-mul] PASS!
[           max] PASS!
[          min3] PASS!
[         mov-c] PASS!
[         movsx] PASS!
[  mul-longlong] PASS!
[        pascal] PASS!
[         prime] PASS!
[    quick-sort] PASS!
[     recursion] PASS!
[   select-sort] PASS!
[         shift] PASS!
[   shuixianhua] PASS!
[        string] PASS!
[  sub-longlong] PASS!
[           sum] PASS!
[        switch] PASS!
[ to-lower-case] PASS!
[       unalign] PASS!
[        wanshu] PASS!
```

PA2.3 思考题

设备是如何工作的?

对与设备通信得分端口编号,然后通过特定指令向相应编号的端口发送数据从而与设备交互.

CPU需要知道设备是如何工作的吗?

不需要,这也是计算机系统中又一个接口的实例.

什么是驱动?

驱动是一个允许应用程序与硬件交互的程序,这种程序创建了一个硬件与硬件,或硬件与软件沟通的接口,经由主板上的总线或其它沟通子系统与硬件形成连接的机制,这样的机制使得硬件设备上的数据交换成为可能.

CPU知道吗?

不需要知道.

再次理解volatile关键字

如果0x8048000被映射到一个设备寄存器将检测不到设备寄存器的变化从而进入死循环.

Hello World运行在哪?

不一样,前者运行在真机上,后者运行在nemu上.

如何检测多个按键同时被按下?

相当于维护一个队列,每个按键有对应按下和松开的码数,按下加入队列,松开离开队列.

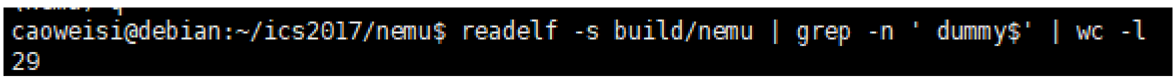
必答题

编译与链接 I

去掉`static`:无报错,但是产生可执行文件变大. 去掉`inline`:报错,在`special.c`中定义了但未使用相应`rtl`函数.这是因为`special.c`中`include`了`rtl.h`文件,所以预处理会将函数定义复制到源文件中,又因为没有使用所以报错. 去掉两者:报错,在所有目标文件中重复定义了相应`rtl`函数,同理是因为预处理.

编译与链接II

- 29.



```
caoweisi@debian:~/ics2017/nemu$ readelf -s build/nemu | grep -n ' dummy$' | wc -l
29
```

- 29.每个包含`common.h`和`debug.h`头文件的源文件都会有一个dummy变量实体.
- 报错原因是重复定义变量.此前没报错是因为只声明未初始化为弱符号,初始化了的为强符号,多个强符号会发生重复定义错误.

I/O端口与接口

系统`I/O`地址的范围是`0x0 ~ 0x399`.端口的地址范围是`0 ~ 0xffff`.`1k = 0x400`.

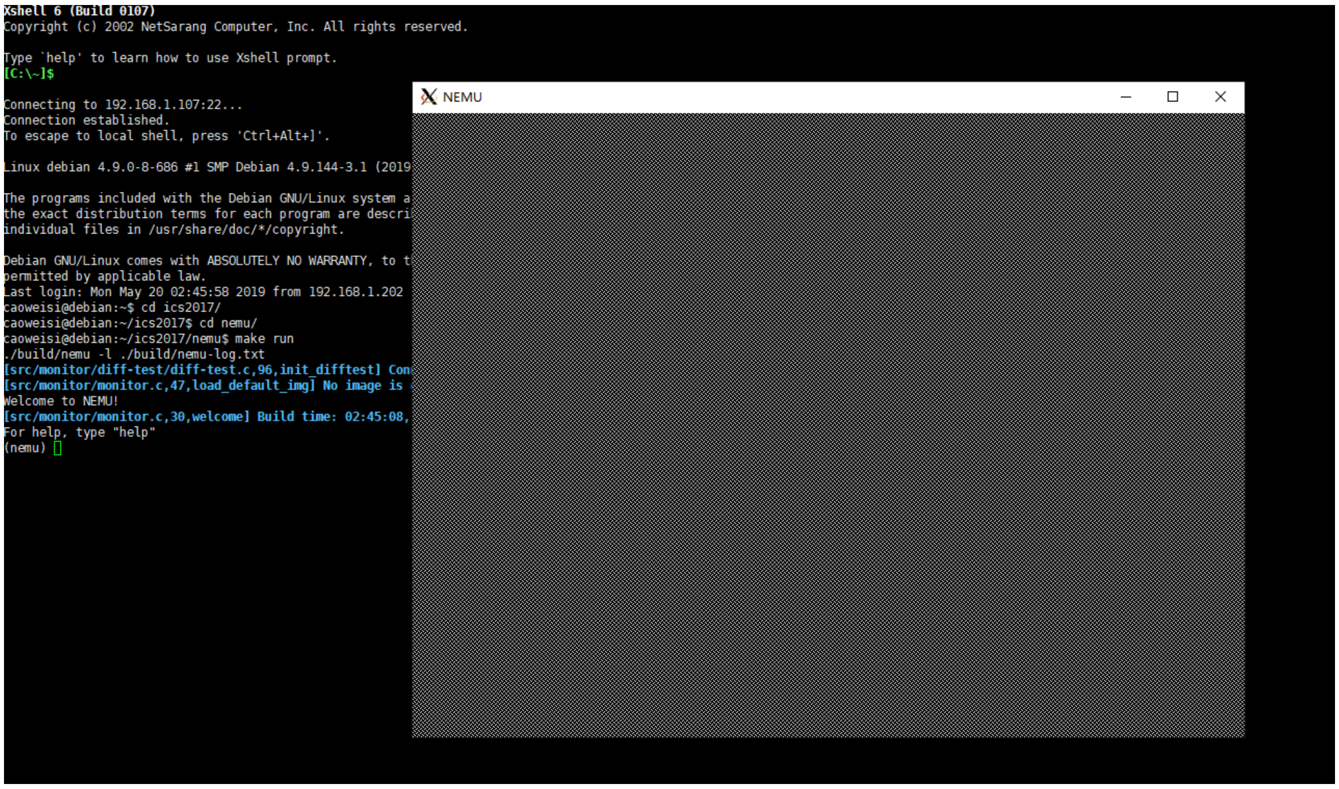
最常见的就是与显示器的通讯,CPU向显示器传输了数据和地址,而显示器向CPU返回状态信息.

PA2.3 实验内容

任务 1：加入IOE

修改`nemu/include/common.h`.

```
/* You will define this macro in PA2 */
#define HAS_IOE
```



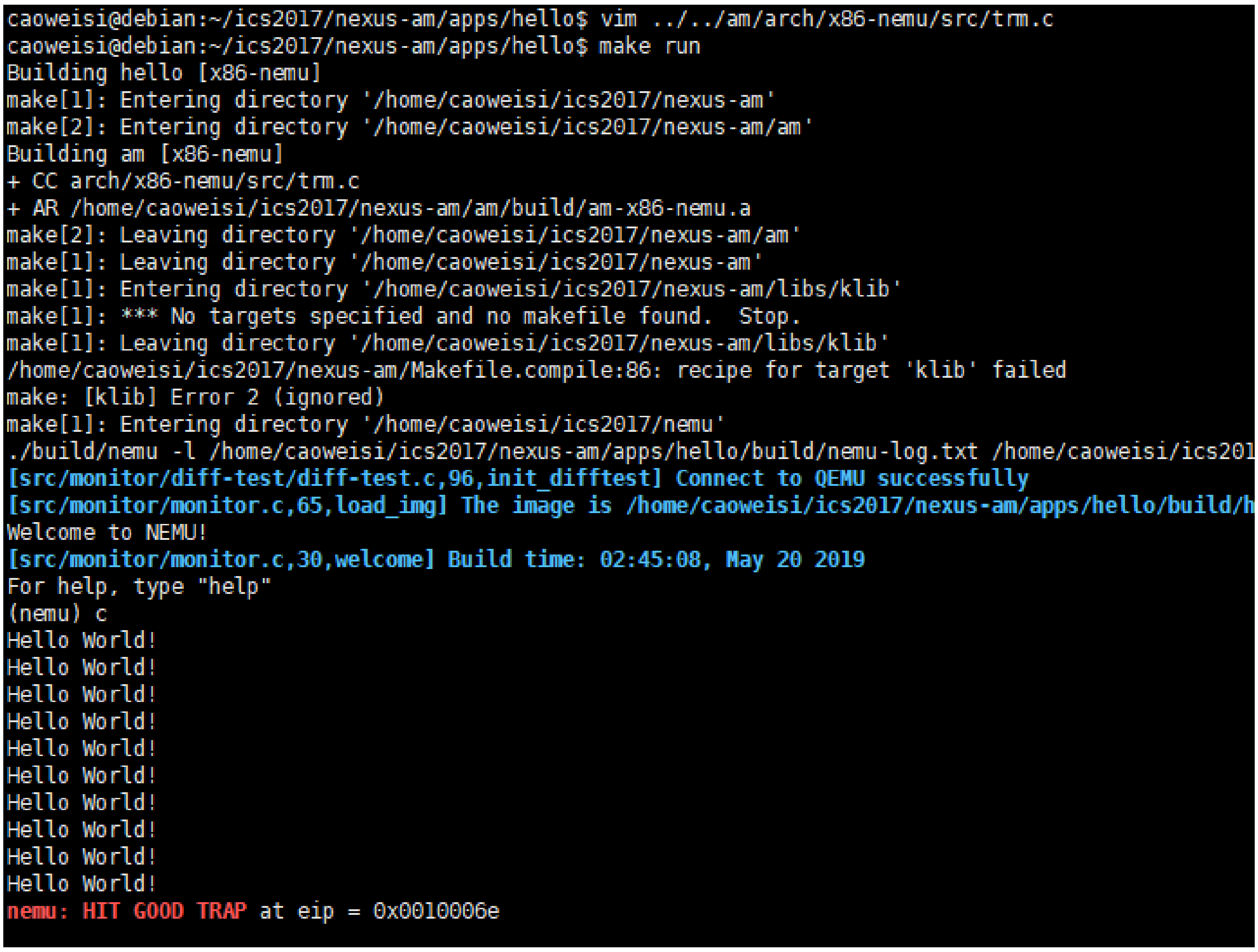
```
Xshell 6 (Build 0107)
Copyright (c) 2002 NetSarang Computer, Inc. All rights reserved.

Type `help' to learn how to use Xshell prompt.
[C:\~]$

Connecting to 192.168.1.107:22...
Connection established.
To escape to local shell, press 'Ctrl+Alt+]'.

Linux debian 4.9.0-8-686 #1 SMP Debian 4.9.144-3.1 (2019

The programs included with the Debian GNU/Linux system a
the exact distribution terms for each program are descri
individual files in /usr/share/doc/*/copyright.

Debian GNU/Linux comes with ABSOLUTELY NO WARRANTY, to t
permitted by applicable law.
Last login: Mon May 20 02:45:58 2019 from 192.168.1.202
caoweisi@debian:~$ cd ics2017/
caoweisi@debian:~/ics2017$ cd nemu/
caoweisi@debian:~/ics2017/nemu$ make run
./build/nemu -l ./build/nemu-log.txt
[src/monitor/diff-test/diff-test.c,96,init_difftest] Con
[src/monitor/monitor.c,47,load_default_img] No image is
Welcome to NEMU!
[src/monitor/monitor.c,30,welcome] Build time: 02:45:08,
For help, type "help"
(nemu) 
```

任务2：实现输入输出指令，运行Hello World

修改并声明nemu/src/cpu/exec/system.c中的in,out.

```
make_EHelper(in) {
  t0 = pio_read(id_src->val, id_src->width);
  operand_write(id_dest, &t0);

  print_asm_template2(in);

#ifdef DIFF_TEST
  diff_test_skip_qemu();
#endif
}

make_EHelper(out) {
  pio_write(id_dest->val, id_dest->width, id_src->val);

  print_asm_template2(out);

#ifdef DIFF_TEST
  diff_test_skip_qemu();
#endif
}
```

定义宏HAS_SERIAL后运行hello.

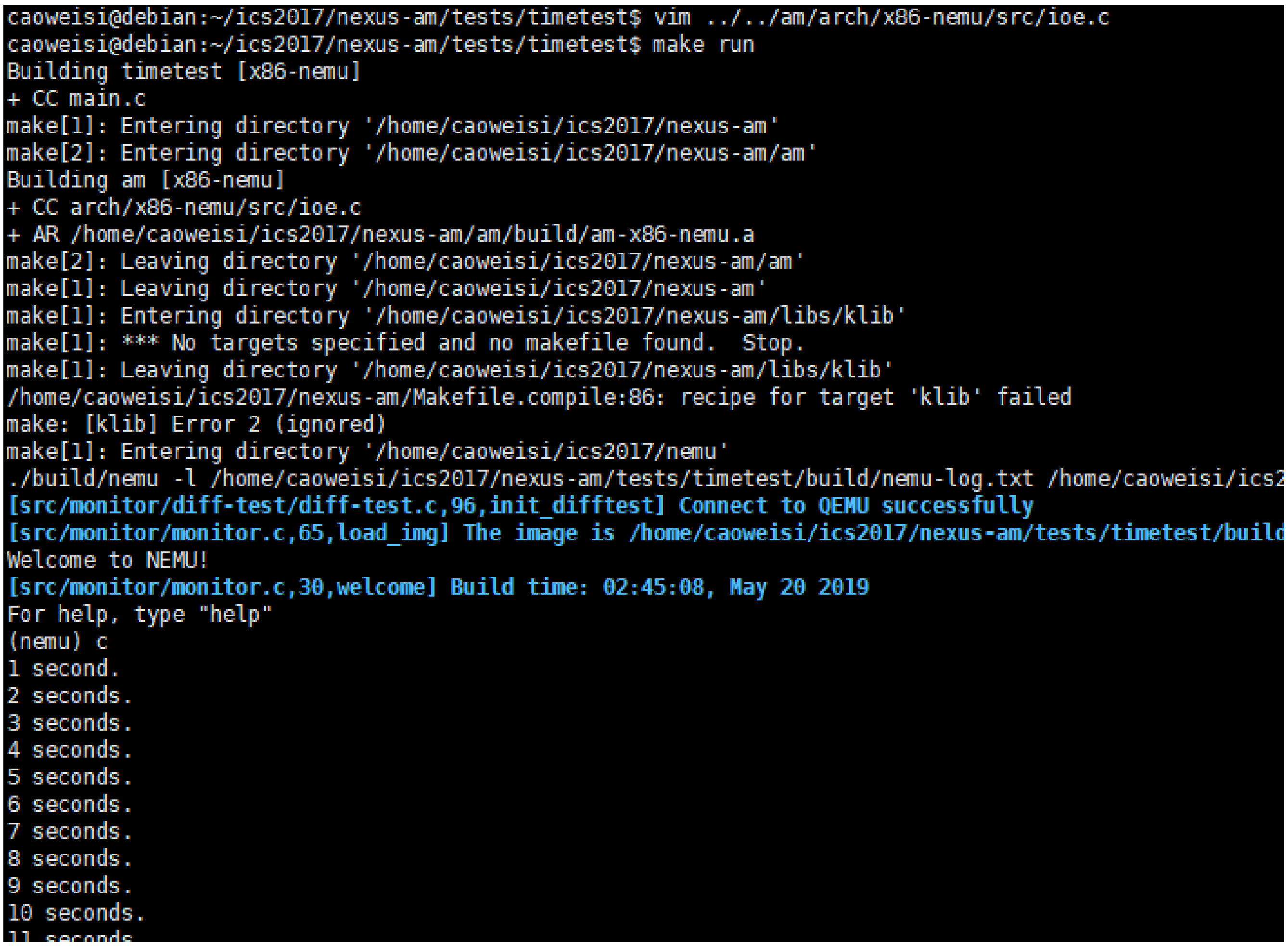


```
caoweisi@debian:~/ics2017/nexus-am/apps/hello$ vim ../../am/arch/x86-nemu/src/trm.c
caoweisi@debian:~/ics2017/nexus-am/apps/hello$ make run
Building hello [x86-nemu]
make[1]: Entering directory '/home/caoweisi/ics2017/nexus-am'
make[2]: Entering directory '/home/caoweisi/ics2017/nexus-am/am'
Building am [x86-nemu]
+ CC arch/x86-nemu/src/trm.c
+ AR /home/caoweisi/ics2017/nexus-am/am/build/am-x86-nemu.a
make[2]: Leaving directory '/home/caoweisi/ics2017/nexus-am/am'
make[1]: Leaving directory '/home/caoweisi/ics2017/nexus-am'
make[1]: Entering directory '/home/caoweisi/ics2017/nexus-am/libs/klib'
make[1]: *** No targets specified and no makefile found.  Stop.
make[1]: Leaving directory '/home/caoweisi/ics2017/nexus-am/libs/klib'
/home/caoweisi/ics2017/nexus-am/Makefile.compile:86: recipe for target 'klib' failed
make: [klib] Error 2 (ignored)
make[1]: Entering directory '/home/caoweisi/ics2017/nemu'
./build/nemu -l /home/caoweisi/ics2017/nexus-am/apps/hello/build/nemu-log.txt /home/caoweisi/ics201
[src/monitor/diff-test/diff-test.c,96,init_difftest] Connect to QEMU successfully
[src/monitor/monitor.c,65,load_img] The image is /home/caoweisi/ics2017/nexus-am/apps/hello/build/h
Welcome to NEMU!
[src/monitor/monitor.c,30,welcome] Build time: 02:45:08, May 20 2019
For help, type "help"
(nemu) c
Hello World!
Hello World!
Hello World!
Hello World!
Hello World!
Hello World!
Hello World!
Hello World!
Hello World!
Hello World!
nemu: HIT GOOD TRAP at eip = 0x0010006e
```

任务2.1：实现IOE抽象 && 任务3：运行timetest

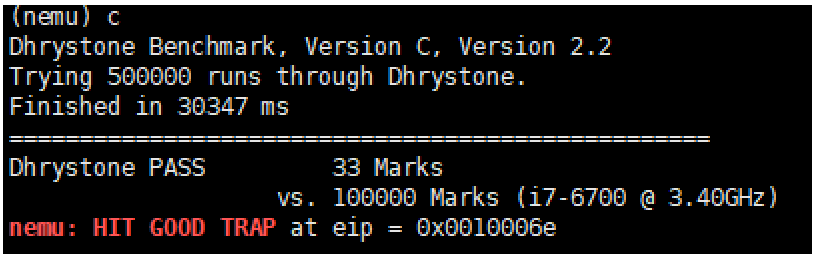
实现_uptime().

```
unsigned long _uptime() {
  return inl(RTC_PORT) - boot_time;
}
```

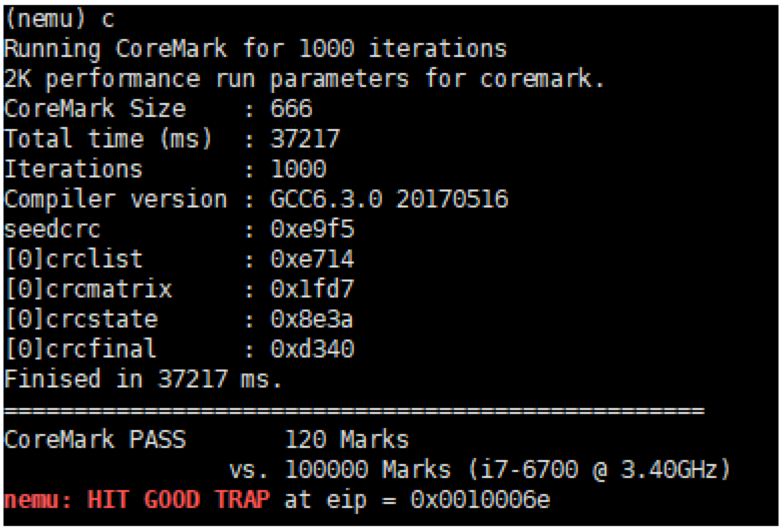

```
caoweisi@debian:~/ics2017/nexus-am/tests/timetest$ vim ../../am/arch/x86-nemu/src/ioe.c
caoweisi@debian:~/ics2017/nexus-am/tests/timetest$ make run
Building timetest [x86-nemu]
+ CC main.c
make[1]: Entering directory '/home/caoweisi/ics2017/nexus-am'
make[2]: Entering directory '/home/caoweisi/ics2017/nexus-am/am'
Building am [x86-nemu]
+ CC arch/x86-nemu/src/ioe.c
+ AR /home/caoweisi/ics2017/nexus-am/am/build/am-x86-nemu.a
make[2]: Leaving directory '/home/caoweisi/ics2017/nexus-am/am'
make[1]: Leaving directory '/home/caoweisi/ics2017/nexus-am'
make[1]: Entering directory '/home/caoweisi/ics2017/nexus-am/libs/klib'
make[1]: *** No targets specified and no makefile found.  Stop.
make[1]: Leaving directory '/home/caoweisi/ics2017/nexus-am/libs/klib'
/home/caoweisi/ics2017/nexus-am/Makefile.compile:86: recipe for target 'klib' failed
make: [klib] Error 2 (ignored)
make[1]: Entering directory '/home/caoweisi/ics2017/nemu'
./build/nemu -l /home/caoweisi/ics2017/nexus-am/tests/timetest/build/nemu-log.txt /home/caoweisi/ics2
[src/monitor/diff-test/diff-test.c,96,init_difftest] Connect to QEMU successfully
[src/monitor/monitor.c,65,load_img] The image is /home/caoweisi/ics2017/nexus-am/tests/timetest/build
Welcome to NEMU!
[src/monitor/monitor.c,30,welcome] Build time: 02:45:08, May 20 2019
For help, type "help"
(nemu) c
1 second.
2 seconds.
3 seconds.
4 seconds.
5 seconds.
6 seconds.
7 seconds.
8 seconds.
9 seconds.
10 seconds.
11 seconds.
```

任务4：看看NEMU跑多快

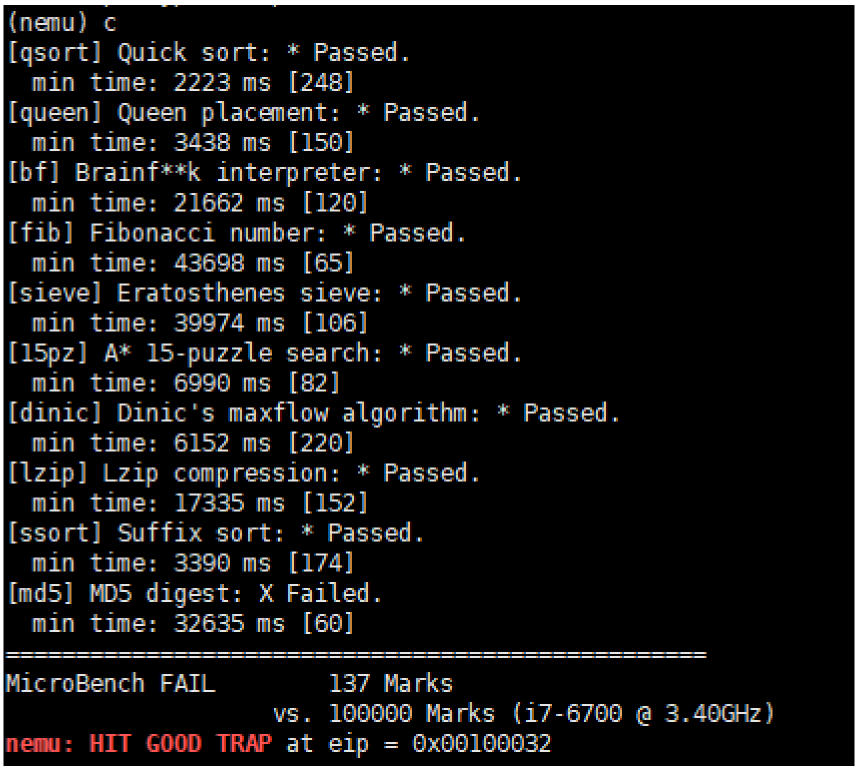
dhrystone.


```
(nemu) c
Dhrystone Benchmark, Version C, Version 2.2
Trying 500000 runs through Dhrystone.
Finished in 30347 ms
==================================================
Dhrystone PASS         33 Marks
                   vs. 100000 Marks (i7-6700 @ 3.40GHz)
nemu: HIT GOOD TRAP at eip = 0x0010006e
```

coremark.


```
(nemu) c
Running CoreMark for 1000 iterations
2K performance run parameters for coremark.
CoreMark Size     : 666
Total time (ms)   : 37217
Iterations        : 1000
Compiler version : GCC6.3.0 20170516
seedcrc           : 0xe9f5
[0]crclist        : 0xe714
[0]crcmatrix      : 0x1fd7
[0]crcstate       : 0x8e3a
[0]crcfinal       : 0xd340
Finised in 37217 ms.
==================================================
CoreMark PASS       120 Marks
                vs. 100000 Marks (i7-6700 @ 3.40GHz)
nemu: HIT GOOD TRAP at eip = 0x0010006e
```

microbench.

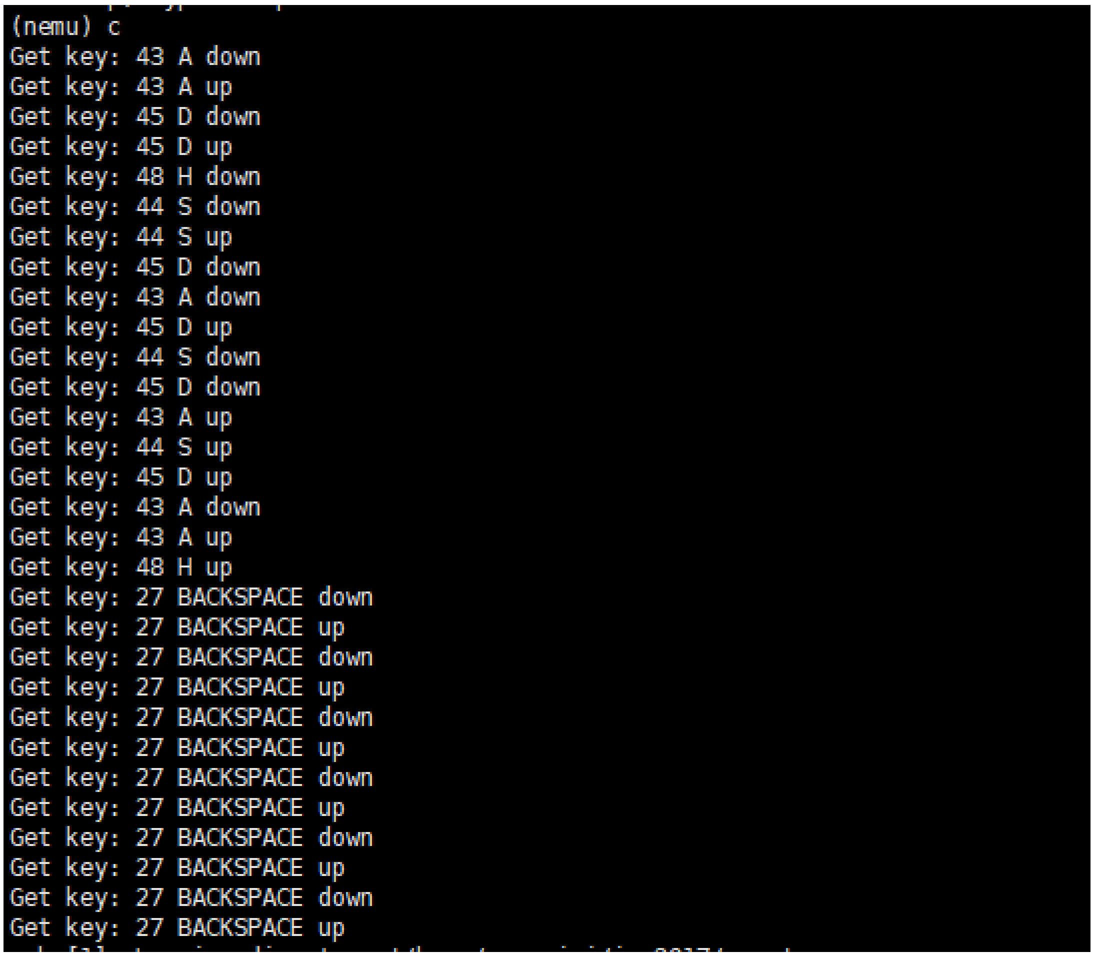

```
(nemu) c
[qsort] Quick sort: * Passed.
  min time: 2223 ms [248]
[queen] Queen placement: * Passed.
  min time: 3438 ms [150]
[bf] Brainf**k interpreter: * Passed.
  min time: 21662 ms [120]
[fib] Fibonacci number: * Passed.
  min time: 43698 ms [65]
[sieve] Eratosthenes sieve: * Passed.
  min time: 39974 ms [106]
[15pz] A* 15-puzzle search: * Passed.
  min time: 6990 ms [82]
[dinic] Dinic's maxflow algorithm: * Passed.
  min time: 6152 ms [220]
[lzip] Lzip compression: * Passed.
  min time: 17335 ms [152]
[ssort] Suffix sort: * Passed.
  min time: 3390 ms [174]
[md5] MD5 digest: X Failed.
  min time: 32635 ms [60]
==================================================
MicroBench FAIL         137 Marks
                   vs. 100000 Marks (i7-6700 @ 3.40GHz)
nemu: HIT GOOD TRAP at eip = 0x00100032
```

任务2.2：实现IOE抽象 && 任务5：运行keytest

实现_read_key().

```
#define I8042_DATA_PORT 0x60

#define I8042_STATUS_PORT 0x64

int _read_key() {
  if (inb(I8042_STATUS_PORT) == 1) {
    return inl(I8042_DATA_PORT);
  }
  return _KEY_NONE;
}
```

keytest.



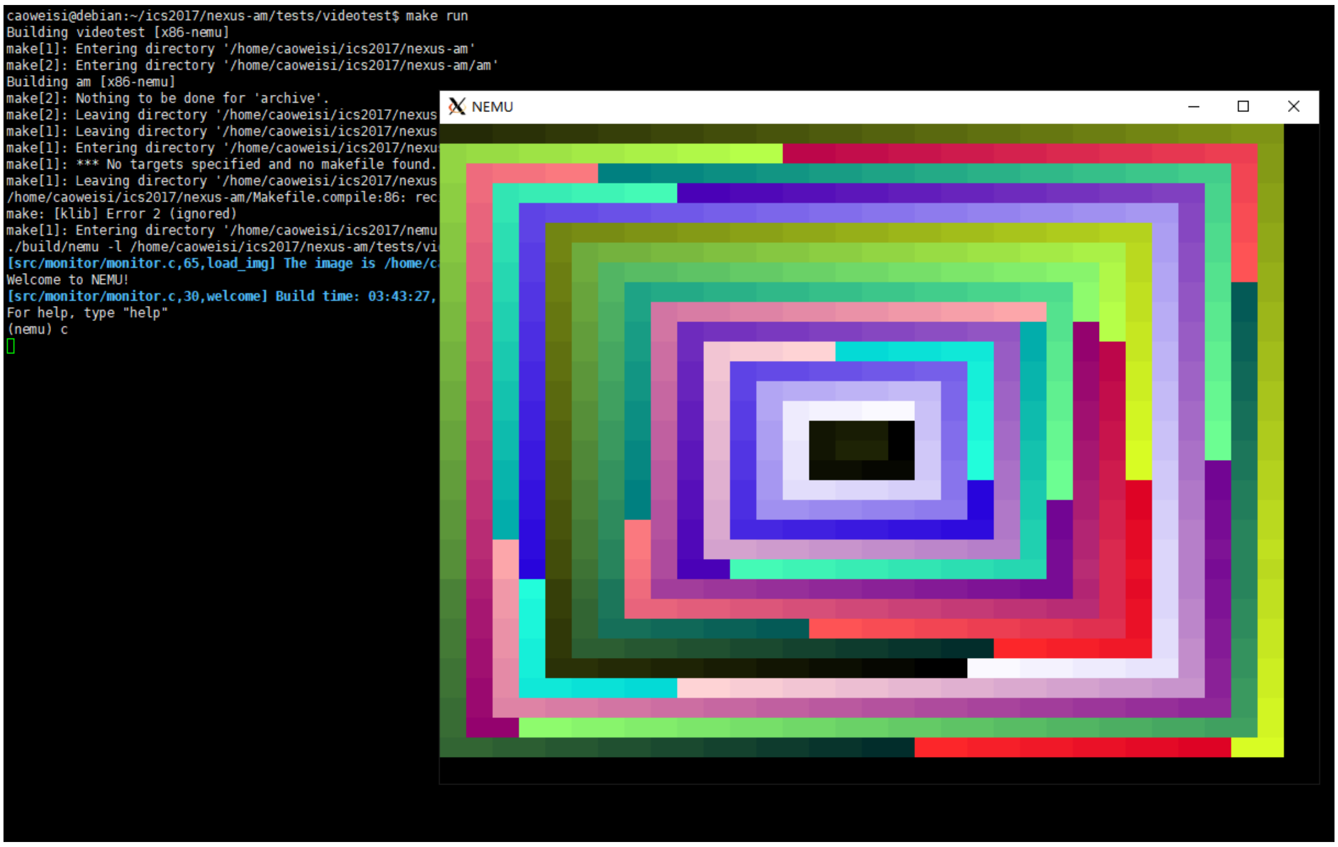
```
(nemu) c
Get key: 43 A down
Get key: 43 A up
Get key: 45 D down
Get key: 45 D up
Get key: 48 H down
Get key: 44 S down
Get key: 44 S up
Get key: 45 D down
Get key: 43 A down
Get key: 45 D up
Get key: 44 S down
Get key: 45 D down
Get key: 43 A up
Get key: 44 S up
Get key: 45 D up
Get key: 43 A down
Get key: 43 A up
Get key: 48 H up
Get key: 27 BACKSPACE down
Get key: 27 BACKSPACE up
Get key: 27 BACKSPACE down
Get key: 27 BACKSPACE up
Get key: 27 BACKSPACE down
Get key: 27 BACKSPACE up
Get key: 27 BACKSPACE down
Get key: 27 BACKSPACE up
Get key: 27 BACKSPACE down
Get key: 27 BACKSPACE up
Get key: 27 BACKSPACE down
Get key: 27 BACKSPACE up
```

任务2.3：实现IOE抽象 && 任务6：添加内存映射I/O && 任务7：运行videotest

修改nemu/src/memory/memory.c的paddr_read()和paddr_write()函数.

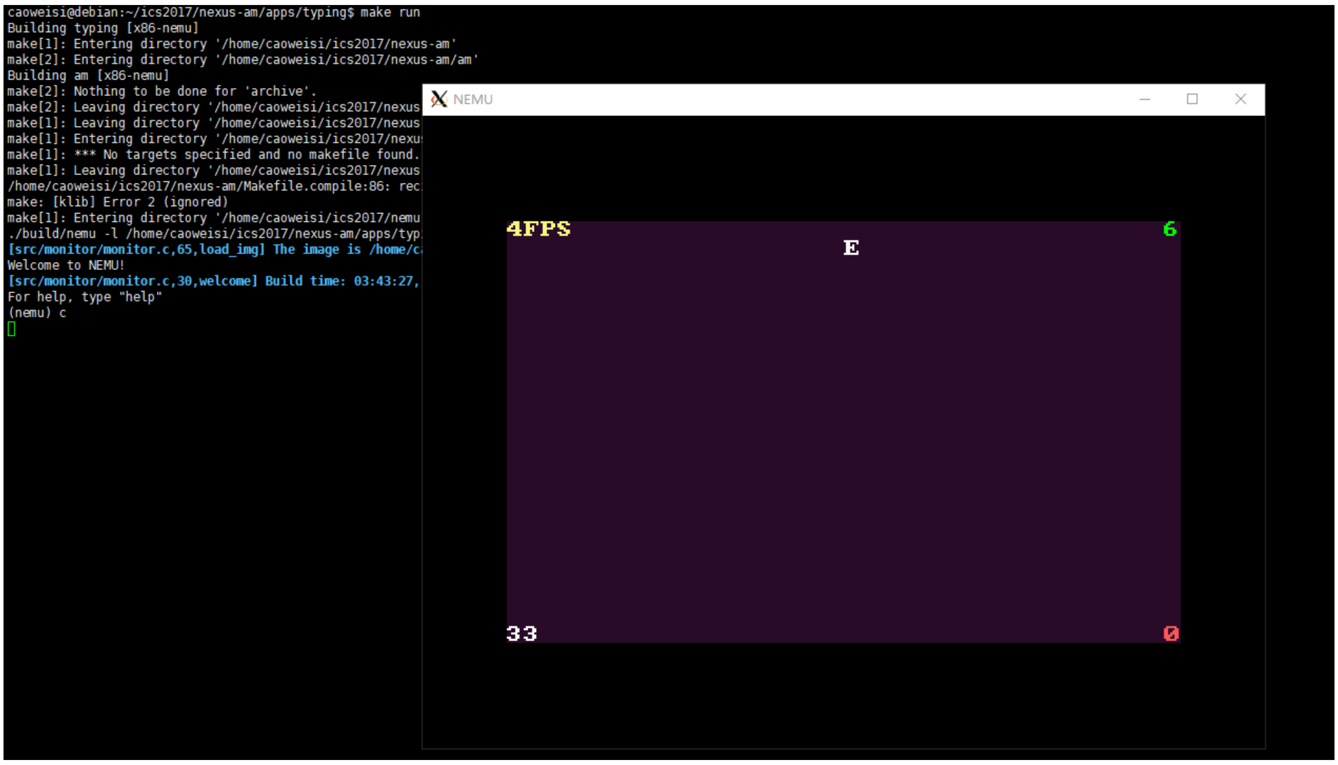
```
#include "device/mmio.h"

uint32_t paddr_read(paddr_t addr, int len) {
  int mmio_id = is_mmio(addr);
    if (mmio_id != -1) {
    return mmio_read(addr, len, mmio_id);
  }
  return pmem_rw(addr, uint32_t) & (~0u >> ((4 - len) << 3));
}

void paddr_write(paddr_t addr, int len, uint32_t data) {
  int mmio_id = is_mmio(addr);
  if (mmio_id != -1) {
    mmio_write(addr, len, data, mmio_id);
  }
  else {
    memcpy(guest_to_host(addr), &data, len);
  }
}
```

videotest.



```
caoweisi@debian:~/ics2017/nexus-am/tests/videotest$ make run
Building videotest [x86-nemu]
make[1]: Entering directory '/home/caoweisi/ics2017/nexus-am'
make[2]: Entering directory '/home/caoweisi/ics2017/nexus-am/am'
Building am [x86-nemu]
make[2]: Nothing to be done for 'archive'.
make[2]: Leaving directory '/home/caoweisi/ics2017/nexus
make[1]: Leaving directory '/home/caoweisi/ics2017/nexus
make[1]: Entering directory '/home/caoweisi/ics2017/nexu
make[1]: *** No targets specified and no makefile found.
make[1]: Leaving directory '/home/caoweisi/ics2017/nexus
/home/caoweisi/ics2017/nexus-am/Makefile.compile:86: rec
make: [klib] Error 2 (ignored)
make[1]: Entering directory '/home/caoweisi/ics2017/nemu
./build/nemu -l /home/caoweisi/ics2017/nexus-am/tests/vi
[src/monitor/monitor.c,65,load_img] The image is /home/c
Welcome to NEMU!
[src/monitor/monitor.c,30,welcome] Build time: 03:43:27,
For help, type "help"
(nemu) c
```

终极任务：运行打字小游戏



```
caoweisi@debian:~/ics2017/nexus-am/apps/typing$ make run
Building typing [x86-nemu]
make[1]: Entering directory '/home/caoweisi/ics2017/nexus-am'
make[2]: Entering directory '/home/caoweisi/ics2017/nexus-am/am'
Building am [x86-nemu]
make[2]: Nothing to be done for 'archive'.
make[2]: Leaving directory '/home/caoweisi/ics2017/nexus
make[1]: Leaving directory '/home/caoweisi/ics2017/nexus
make[1]: Entering directory '/home/caoweisi/ics2017/nexu
make[1]: *** No targets specified and no makefile found.
make[1]: Leaving directory '/home/caoweisi/ics2017/nexus
/home/caoweisi/ics2017/nexus-am/Makefile.compile:86: rec
make: [klib] Error 2 (ignored)
make[1]: Entering directory '/home/caoweisi/ics2017/nemu
./build/nemu -l /home/caoweisi/ics2017/nexus-am/apps/typ
[src/monitor/monitor.c,65,load_img] The image is /home/c
Welcome to NEMU!
[src/monitor/monitor.c,30,welcome] Build time: 03:43:27,
For help, type "help"
(nemu) c
```

遇到的问题及解决办法

查阅i386手册十分繁琐,忽略了width == 4时移位操作产生的问题等.

实验心得

机器永远是对的.

其他备注

由于去天津参加比赛,大电脑不好操作使用了另外一台电脑(只有`Linux`)写代码,后复制到大电脑上调试提交.