中国科学技术大学计算机学院

《计算机组成原理》报告

实验题目：汇编程序设计

学生姓名：刘恒远

学生学号：PB20111642

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计算机实验教学中心制

【实验目的】

- 熟悉 RISC-V 汇编指令的格式
- 熟悉 CPU 仿真软件 Ripes，理解汇编指令执行的基本原理（数据通路和控制器的协调工作过程）
- 熟悉汇编程序的基本结构，掌握简单汇编程序的设计
- 掌握汇编仿真软件 RARS(RISC-V Assembler & Runtime Simulator)的使用方法，会用该软件进行汇编程序的仿真、调试以及生成 CPU 测试需要的指令和数据文件（COE）
- 理解 CPU 调试模块 PDU 的使用方法

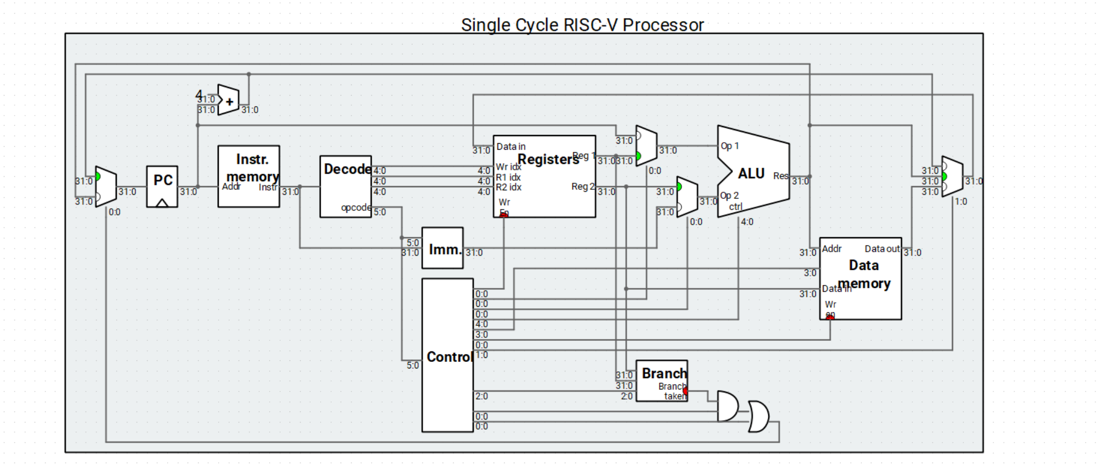
【实验环境】

Ripes,Rars

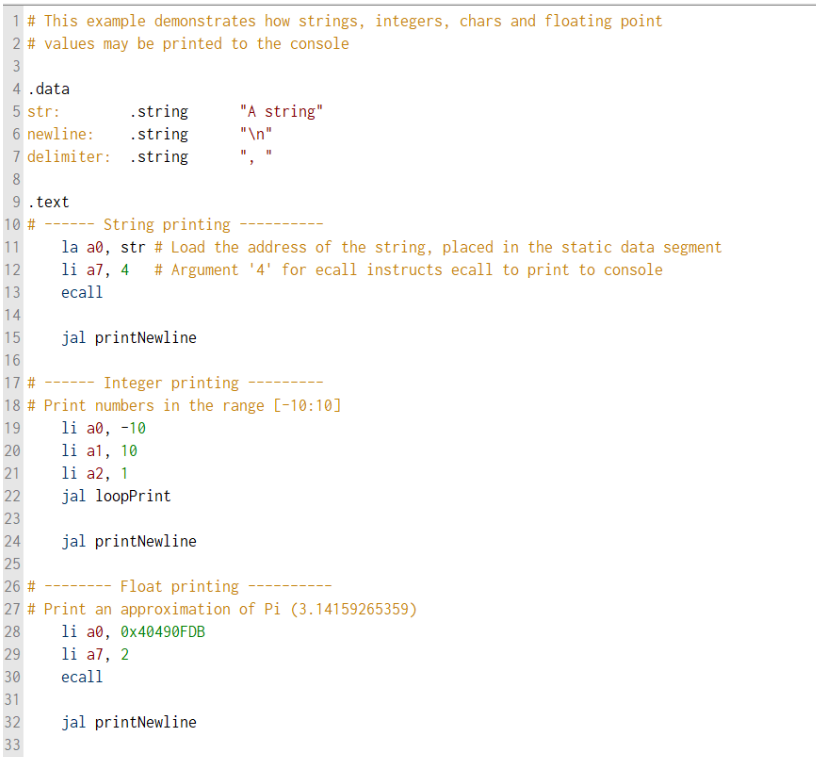
【实验过程】

题目一：

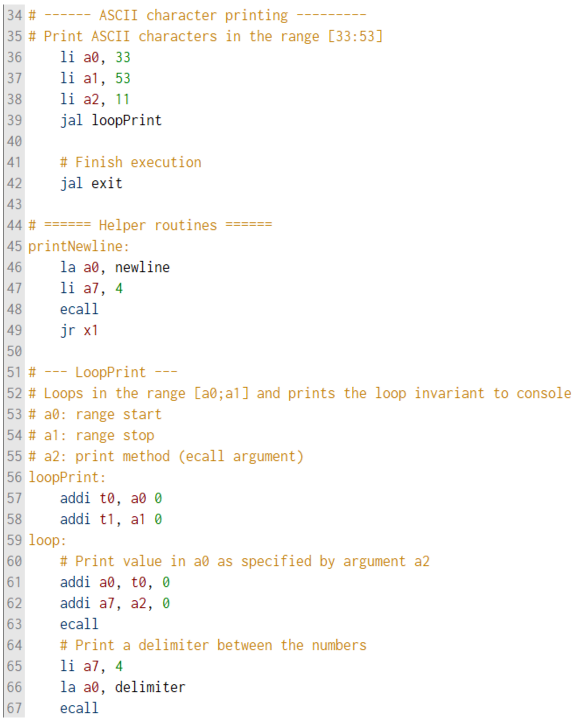
单周期 CPU 数据通路如图：



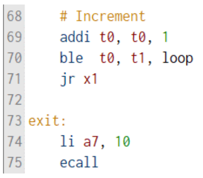
示例代码内容为输出一系列数字与字符。



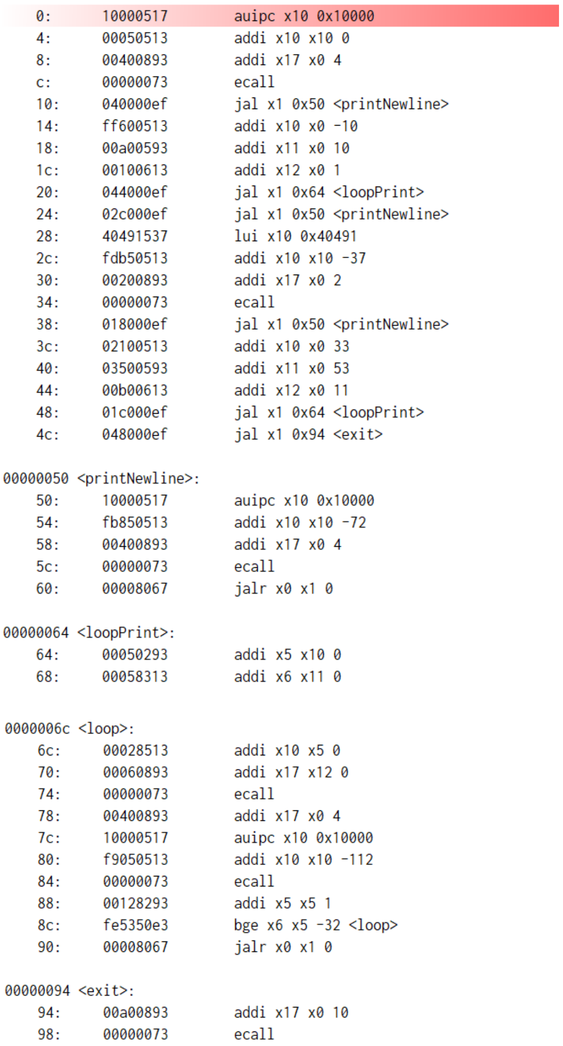
```
# This example demonstrates how strings, integers, chars and floating point
# values may be printed to the console

.data
str:        .string      "A string"
newline:    .string      "\n"
delimiter:  .string      ", "

.text
# ------ String printing ----------
    la a0, str # Load the address of the string, placed in the static data segment
    li a7, 4   # Argument '4' for ecall instructs ecall to print to console
    ecall

    jal printNewline

# ------ Integer printing ---------
# Print numbers in the range [-10:10]
    li a0, -10
    li a1, 10
    li a2, 1
    jal loopPrint

    jal printNewline

# -------- Float printing ----------
# Print an approximation of Pi (3.14159265359)
    li a0, 0x40490FDB
    li a7, 2
    ecall

    jal printNewline

```



```
# ------ ASCII character printing ---------
# Print ASCII characters in the range [33:53]
    li a0, 33
    li a1, 53
    li a2, 11
    jal loopPrint

    # Finish execution
    jal exit

# ====== Helper routines ======
printNewline:
    la a0, newline
    li a7, 4
    ecall
    jr x1

# --- LoopPrint ---
# Loops in the range [a0;a1] and prints the loop invariant to console
# a0: range start
# a1: range stop
# a2: print method (ecall argument)
loopPrint:
    addi t0, a0 0
    addi t1, a1 0
loop:
    # Print value in a0 as specified by argument a2
    addi a0, t0, 0
    addi a7, a2, 0
    ecall
    # Print a delimiter between the numbers
    li a7, 4
    la a0, delimiter
    ecall
```



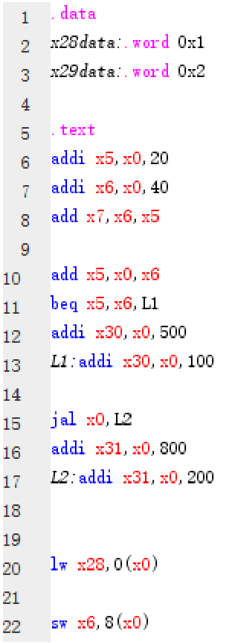
```
    # Increment
    addi t0, t0, 1
    ble  t0, t1, loop
    jr x1

exit:
    li a7, 10
    ecall
```



```
    0:      10000517        auipc x10 0x10000
    4:      00050513        addi x10 x10 0
    8:      00400893        addi x17 x0 4
    c:      00000073        ecall
    10:     040000ef        jal x1 0x50 <printNewline>
    14:     ff600513        addi x10 x0 -10
    18:     00a00593        addi x11 x0 10
    1c:     00100613        addi x12 x0 1
    20:     044000ef        jal x1 0x64 <loopPrint>
    24:     02c000ef        jal x1 0x50 <printNewline>
    28:     40491537        lui x10 0x40491
    2c:     fdb50513        addi x10 x10 -37
    30:     00200893        addi x17 x0 2
    34:     00000073        ecall
    38:     018000ef        jal x1 0x50 <printNewline>
    3c:     02100513        addi x10 x0 33
    40:     03500593        addi x11 x0 53
    44:     00b00613        addi x12 x0 11
    48:     01c000ef        jal x1 0x64 <loopPrint>
    4c:     048000ef        jal x1 0x94 <exit>

00000050 <printNewline>:
    50:     10000517        auipc x10 0x10000
    54:     fb850513        addi x10 x10 -72
    58:     00400893        addi x17 x0 4
    5c:     00000073        ecall
    60:     00008067        jalr x0 x1 0

00000064 <loopPrint>:
    64:     00050293        addi x5 x10 0
    68:     00058313        addi x6 x11 0


0000006c <loop>:
    6c:     00028513        addi x10 x5 0
    70:     00060893        addi x17 x12 0
    74:     00000073        ecall
    78:     00400893        addi x17 x0 4
    7c:     10000517        auipc x10 0x10000
    80:     f9050513        addi x10 x10 -112
    84:     00000073        ecall
    88:     00128293        addi x5 x5 1
    8c:     fe5350e3        bge x6 x5 -32 <loop>
    90:     00008067        jalr x0 x1 0

00000094 <exit>:
    94:     00a00893        addi x17 x0 10
    98:     00000073        ecall
```

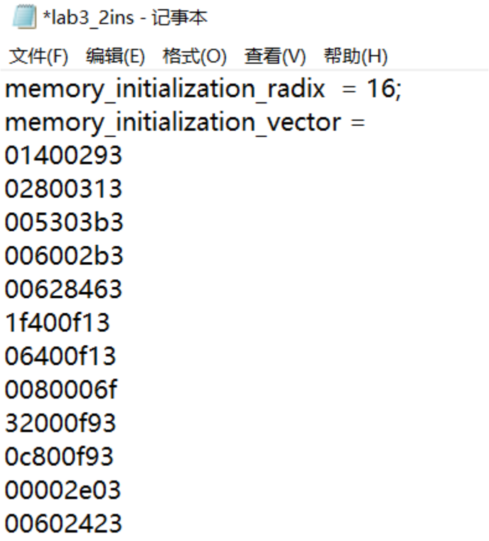
题目二：

设计汇编程序检查指令功能，汇编程序如图：

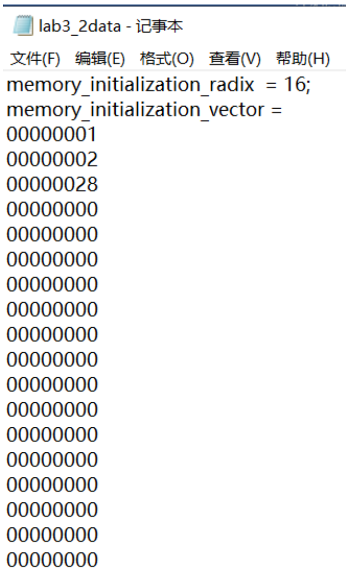


```
.data
x28data:.word 0x1
x29data:.word 0x2

.text
addi x5,x0,20
addi x6,x0,40
add x7,x6,x5

add x5,x0,x6
beq x5,x6,L1
addi x30,x0,500
L1:addi x30,x0,100

jal x0,L2
addi x31,x0,800
L2:addi x31,x0,200


lw x28,0(x0)

sw x6,8(x0)
```

最终生成的 coe 文件为：



```
memory_initialization_radix  = 16;
memory_initialization_vector =
01400293
02800313
005303b3
006002b3
00628463
1f400f13
06400f13
0080006f
32000f93
0c800f93
00002e03
00602423
```

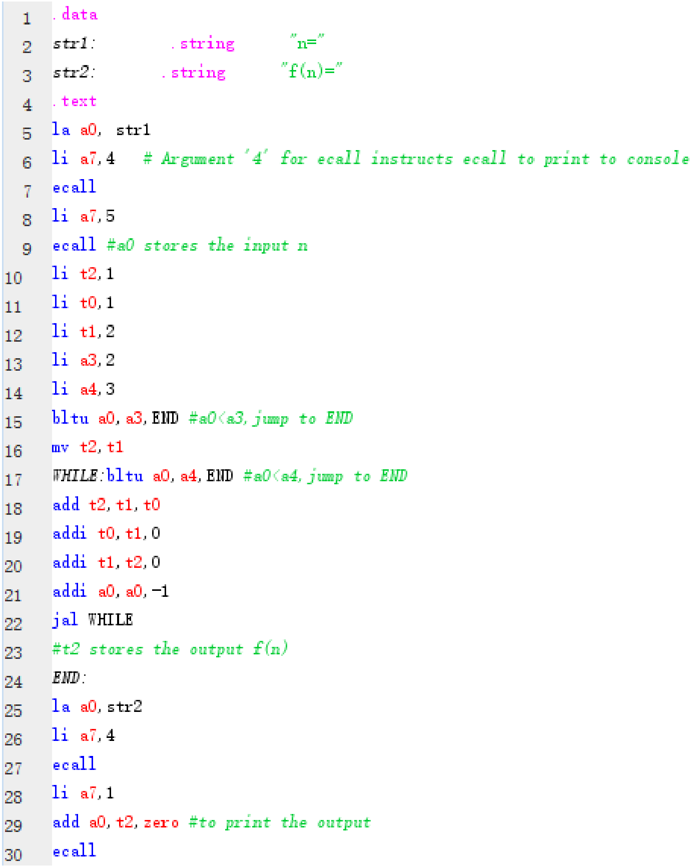


```
memory_initialization_radix  = 16;
memory_initialization_vector =
00000001
00000002
00000028
00000000
00000000
00000000
00000000
00000000
00000000
00000000
00000000
00000000
00000000
00000000
00000000
00000000
00000000
00000000
```

（代码段）　　　　（数据段：省略的均为 00000000，全部共计 1024 行）

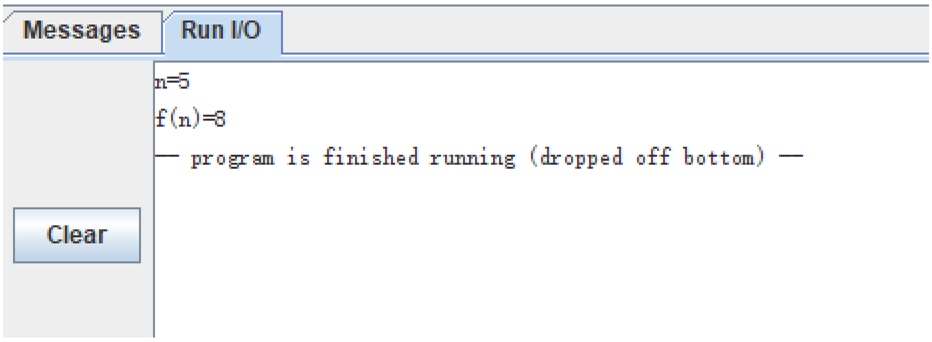
题目三：

斐波那契-卢卡斯数列的汇编程序如图所示：



```
.data
str1:        .string     "n="
str2:        .string     "f(n)="
.text
la a0, str1
li a7,4   # Argument '4' for ecall instructs ecall to print to console
ecall
li a7,5
ecall #a0 stores the input n
li t2,1
li t0,1
li t1,2
li a3,2
li a4,3
bltu a0,a3,END #a0<a3,jump to END
mv t2,t1
WHILE:bltu a0,a4,END #a0<a4,jump to END
add t2,t1,t0
addi t0,t1,0
addi t1,t2,0
addi a0,a0,-1
jal WHILE
#t2 stores the output f(n)
END:
la a0,str2
li a7,4
ecall
li a7,1
add a0,t2,zero #to print the output
ecall
```

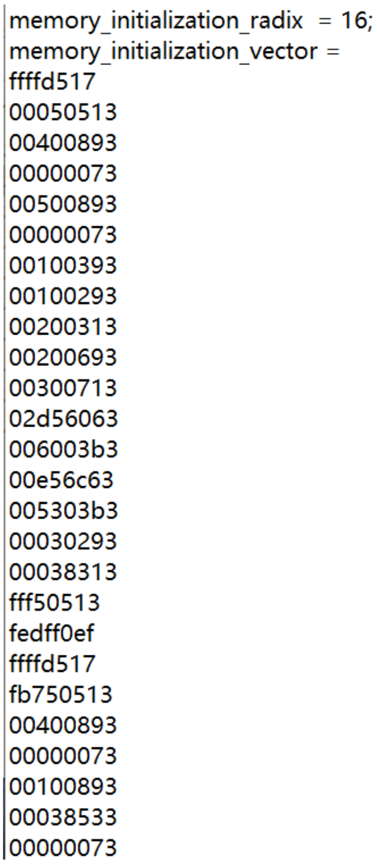
输出结果如图所示：



```
n=5
f(n)=8
— program is finished running (dropped off bottom) —
```

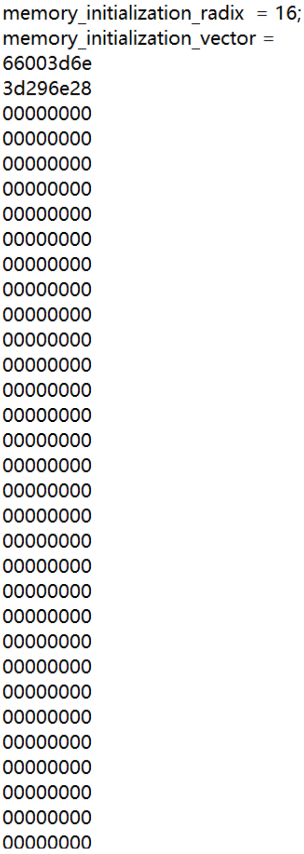
结果验证正确。

生成 coe 文件：



```
memory_initialization_radix  = 16;
memory_initialization_vector =
ffffd517
00050513
00400893
00000073
00500893
00000073
00100393
00100293
00200313
00200693
00300713
02d56063
006003b3
00e56c63
005303b3
00030293
00038313
fff50513
fedff0ef
ffffd517
fb750513
00400893
00000073
00100893
00038533
00000073
```

（代码段）



```
memory_initialization_radix  = 16;
memory_initialization_vector =
66003d6e
3d296e28
00000000
00000000
00000000
00000000
00000000
00000000
00000000
00000000
00000000
00000000
00000000
00000000
00000000
00000000
00000000
00000000
00000000
00000000
00000000
00000000
00000000
00000000
00000000
00000000
00000000
00000000
00000000
00000000
00000000
00000000
```

（数据段：省略的均为 00000000，全部共计 1024 行）

【总结与思考】

可以完善一下 PPT，便于理解与应用。