实验 6：单周期 CPU 设计与测试

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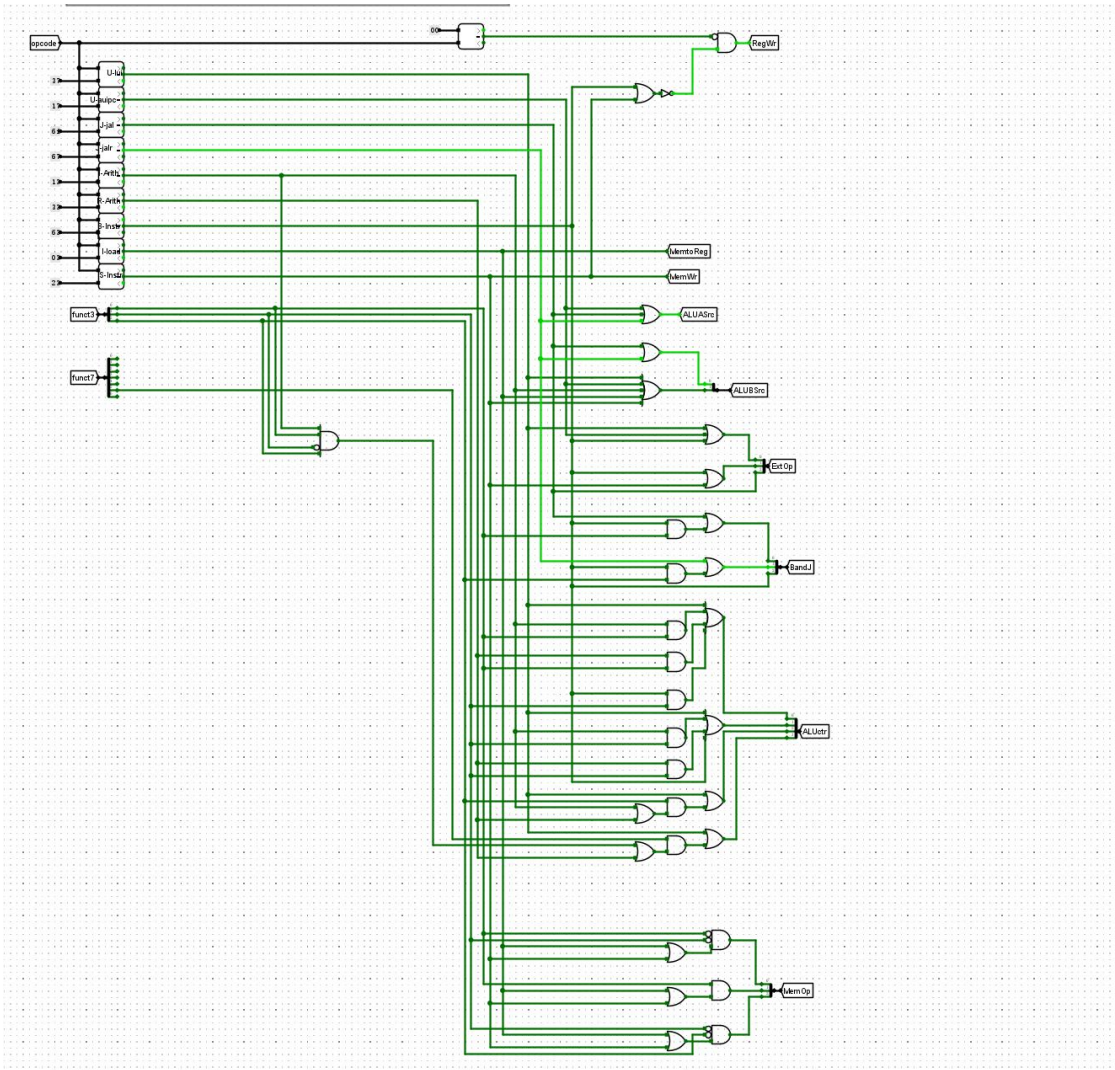
一、实验目的

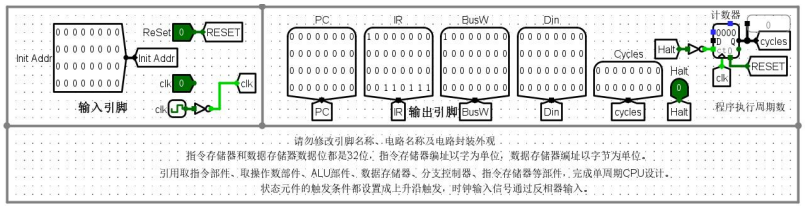
. 分析单周期 CPU 的控制信号，掌握 RV32I 控制器的设计方法。
2. 掌握 RISC-V 汇编语言程序的基本设计方法。
3. 运用 RARS 编译、生成二进制可执行文件。
4. 加载可执行文件、验证 CPU 设计。
5. 理解汇编语言程序与机器语言代码之间的对应关系。

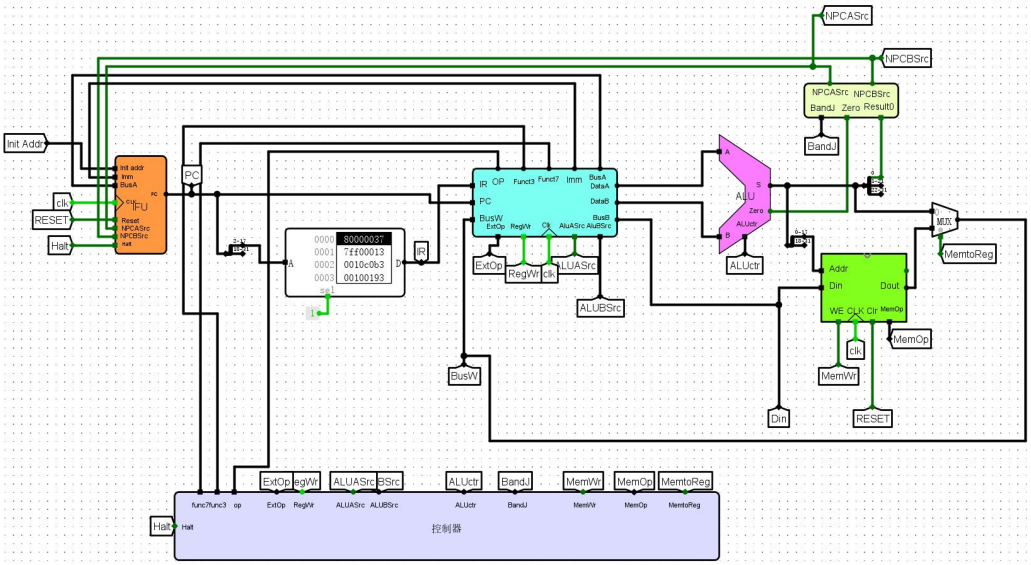
二、整体设计和原理电路图

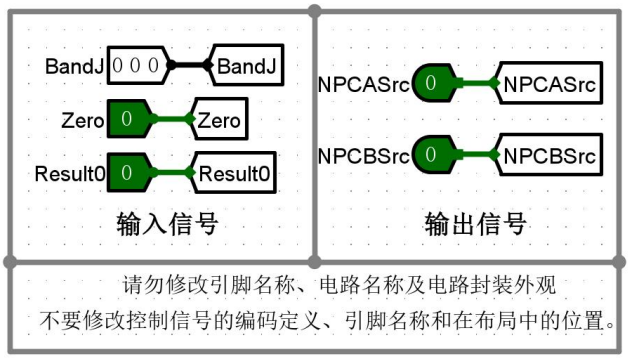
6.1

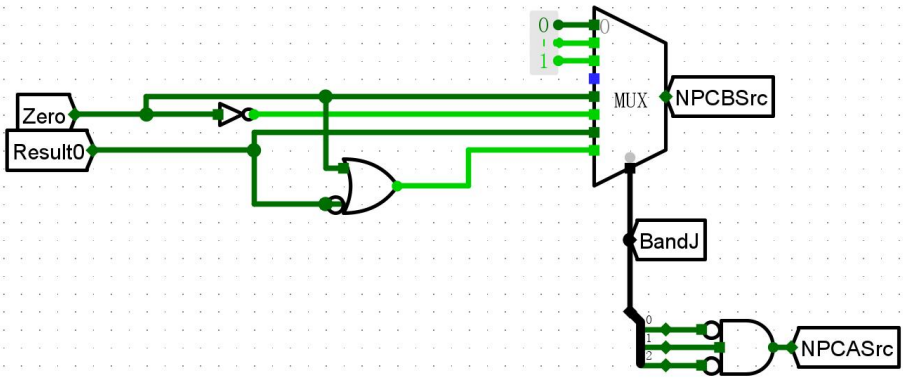


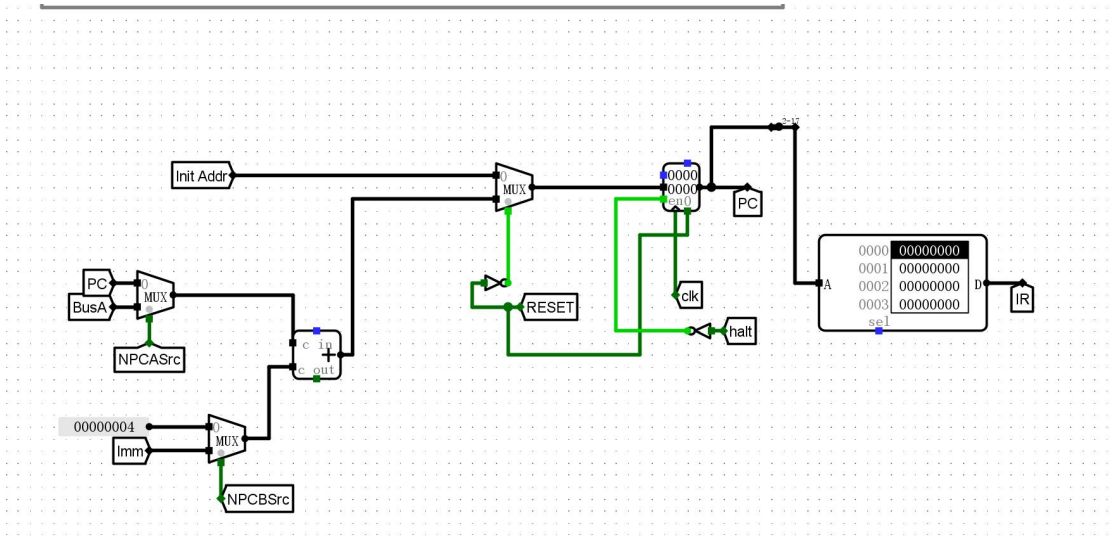
6.2


Init Addr
ReSet
RESET
Init Addr
clk
clk
输入引脚
PC
IR
BusW
Din
Cycles
Halt
计数器
cycles
RESET
PC
IR
输出引脚
BusW
Din
cycles
Halt
程序执行周期数
请勿修改引脚名称、电路名称及电路封装外观
指令存储器和数据存储器数据位都是32位，指令存储器编址以字为单位；数据存储器编址以字节为单位。
引用取指令部件、取操作数部件、ALU部件、数据存储器、分支控制器、指令存储器等部件，完成单周期CPU设计。
状态元件的触发条件都设置成上升沿触发，时钟输入信号通过反相器输入。

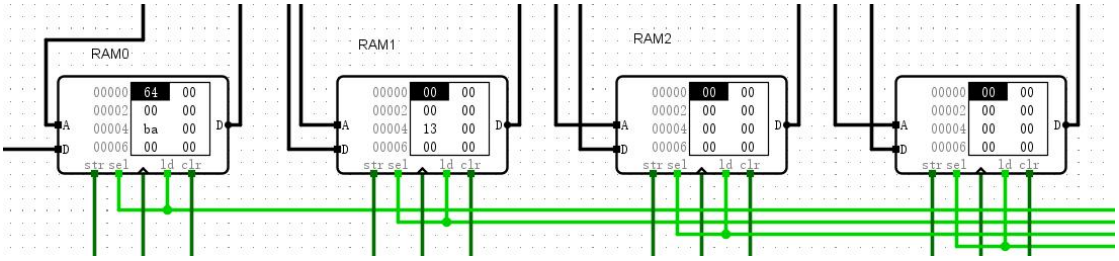

NPCASrc
NPCBSrc
NPCASrc NPCBSrc
BandJ Zero Result0
BandJ
Init Addr
clk
RESET
Halt
IFU
PC
IR
ALU
ALUctr
ExtOp
RegWr
ALUASrc
ALUBSrc
BusW
MemtoReg
Addr
Din
Dout
MemOp
MemWr
clk
Din
RESET
ExtOp
RegWr
ALUASrc
ALUBSrc
ALUctr
BandJ
MemWr
MemOp
MemtoReg
Halt
控制器


BandJ
BandJ
Zero
Zero
Result0
Result0
输入信号
NPCASrc
NPCASrc
NPCBSrc
NPCBSrc
输出信号
请勿修改引脚名称、电路名称及电路封装外观
不要修改控制信号的编码定义、引脚名称和在布局中的位置。

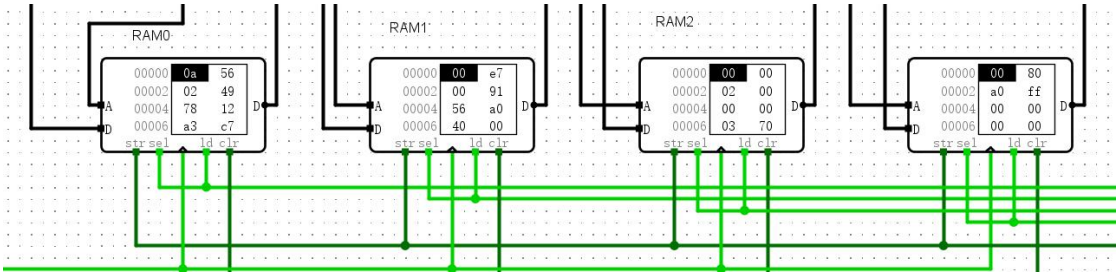

Zero
Result0
MUX
NPCBSrc
BandJ
NPCASrc



6.3 模拟结果：

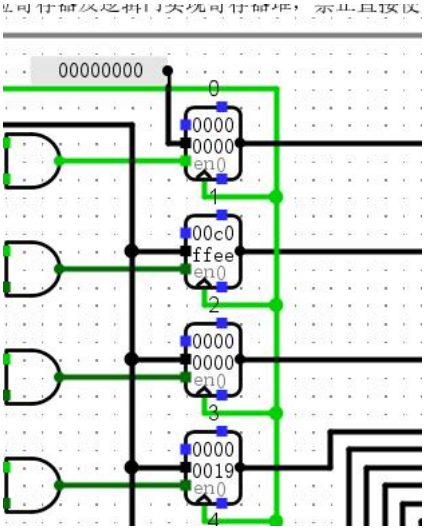


6.4模拟结果：

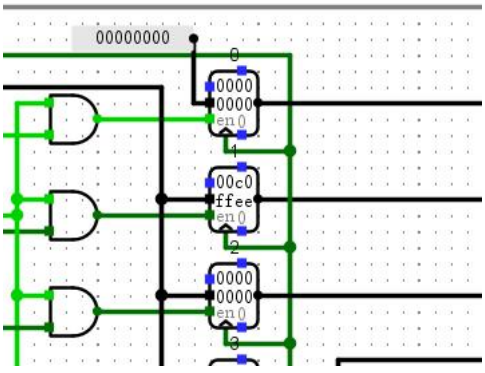


6.5 由于数据过多，挑选几个作为展示

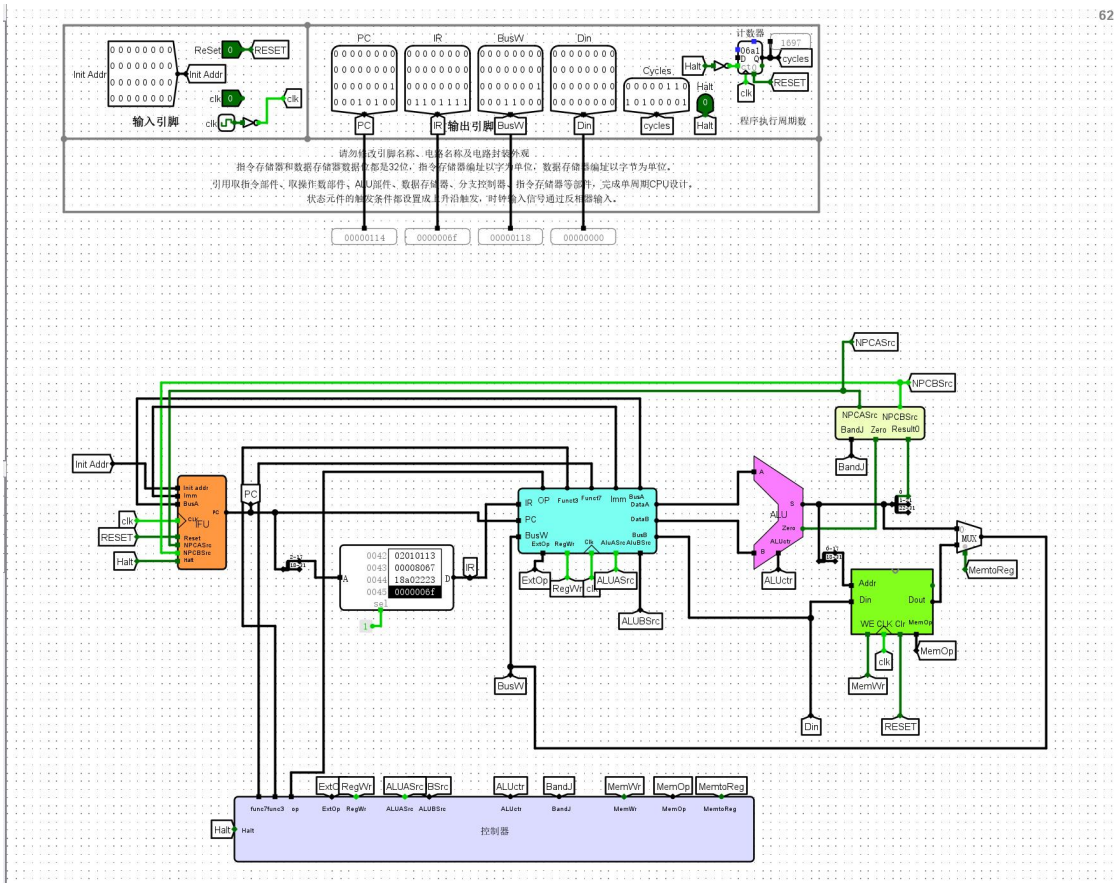
Add结果：



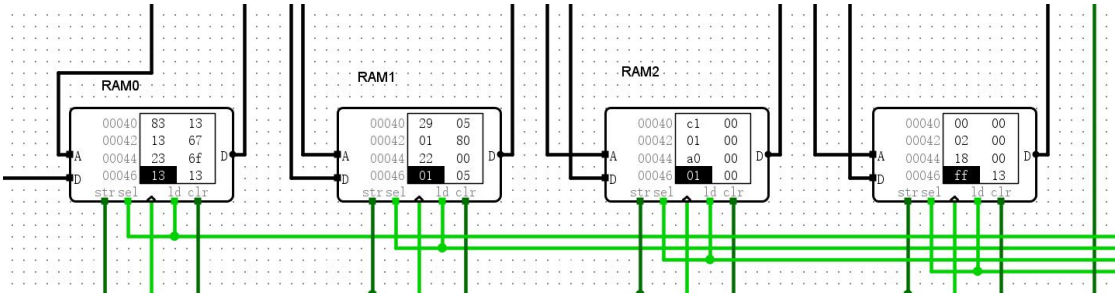
Beq：



6.6：执行bubble sort测试：

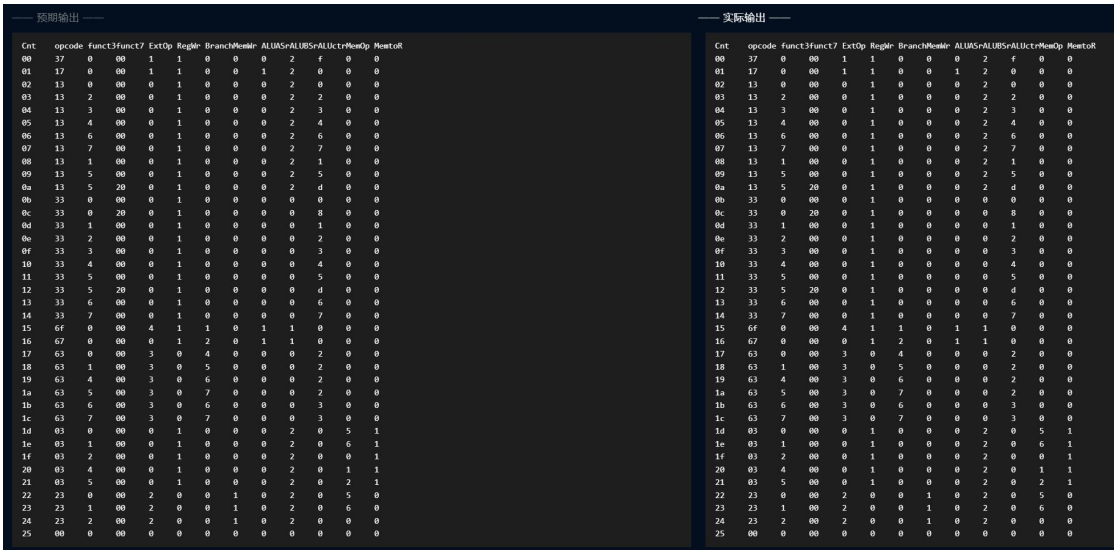


运行后，各个RAM的存储结果：

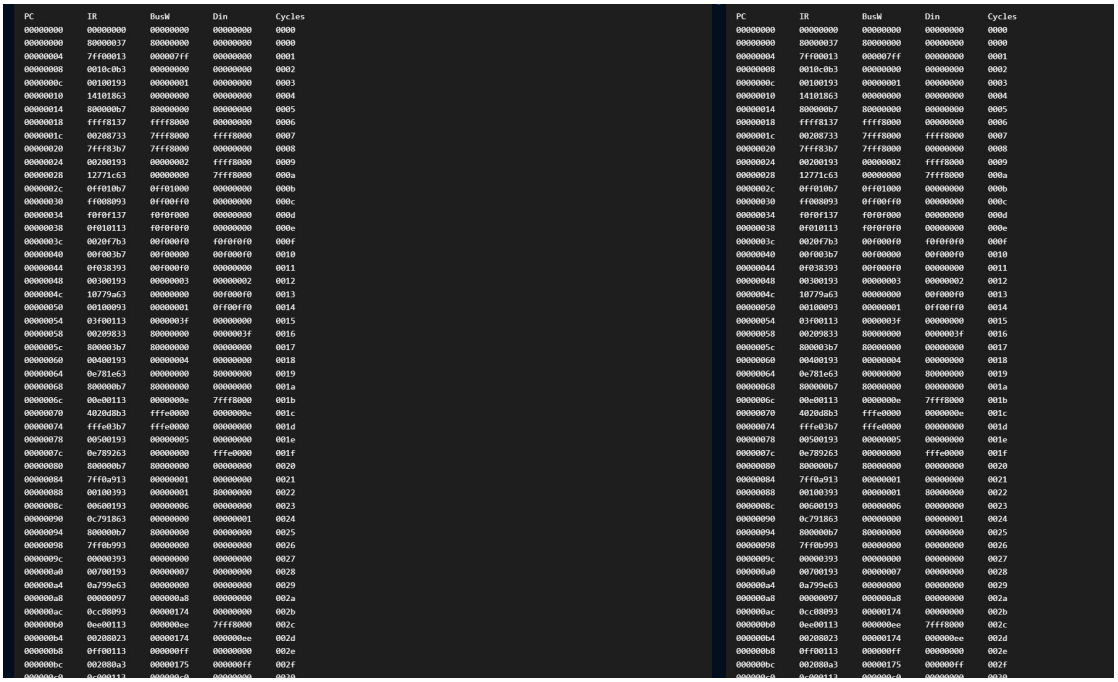


三、实验数据仿真测试图

6.1



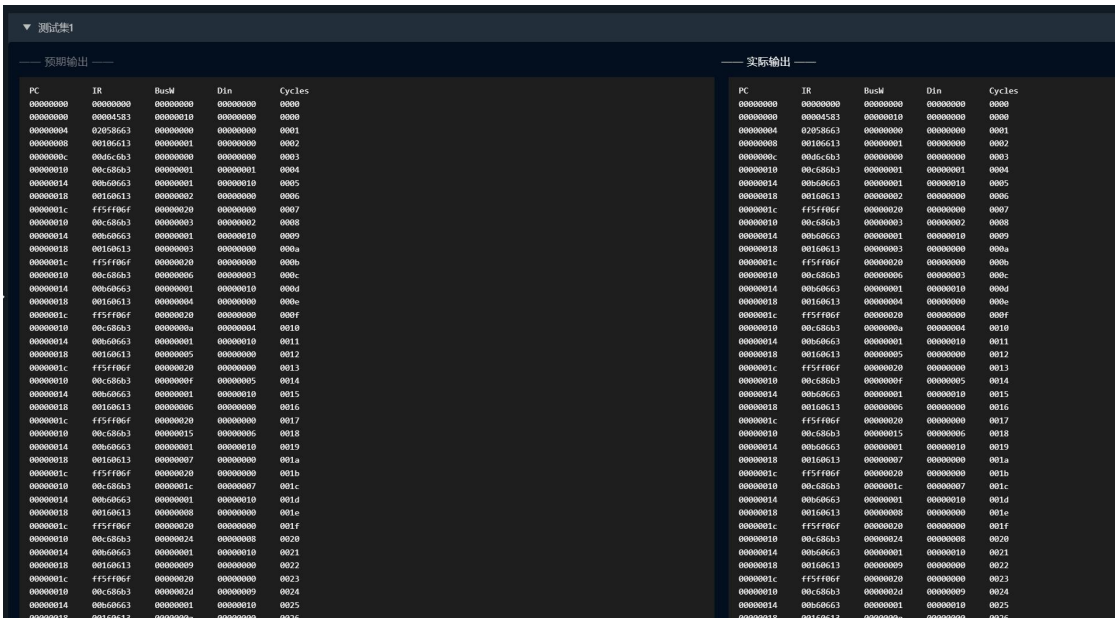
6.2



PC	IR	BusW	Din	Cycles
00000000	00000000	00000000	00000000	0000
00000000	80000037	80000000	00000000	0000
00000004	7ff00013	000007ff	00000000	0001
00000008	0010c0b3	00000000	00000000	0002
0000000c	00100193	00000001	00000000	0003
00000010	14101863	00000000	00000000	0004
00000014	800000b7	80000000	00000000	0005
00000018	ffff8137	ffff8000	00000000	0006
0000001c	00208733	7fff8000	ffff8000	0007
00000020	7fff83b7	7fff8000	00000000	0008
00000024	00200193	00000002	ffff8000	0009
00000028	12771c63	00000000	7fff8000	000a
0000002c	0ff010b7	0ff01000	00000000	000b
00000030	ff000093	0ff00ff0	00000000	000c
00000034	f0f0f137	f0f0f000	00000000	000d
00000038	0f010113	f0f0f0f0	00000000	000e
0000003c	0020f7b3	00f000f0	f0f0f0f0	000f
00000040	00f003b7	00f00000	00f000f0	0010
00000044	0f038393	00f000f0	00000000	0011
00000048	00300193	00000003	00000002	0012
0000004c	10779a63	00000000	00f000f0	0013
00000050	00100093	00000001	0ff00ff0	0014
00000054	03f00113	0000003f	00000000	0015
00000058	00209833	80000000	0000003f	0016
0000005c	800003b7	80000000	00000000	0017
00000060	00400193	00000004	00000000	0018
00000064	0e781e63	00000000	80000000	0019
00000068	800000b7	80000000	00000000	001a
0000006c	00e00113	0000000e	7fff8000	001b
00000070	4020d8b3	fffe0000	0000000e	001c
00000074	fffe03b7	fffe0000	00000000	001d
00000078	00500193	00000005	0000000e	001e
0000007c	0e789263	00000000	fffe0000	001f
00000080	800000b7	80000000	00000000	0020
00000084	7ff0a913	00000001	00000000	0021
00000088	00100393	00000001	80000000	0022
0000008c	00600193	00000006	00000000	0023
00000090	0c791863	00000000	00000001	0024
00000094	800000b7	80000000	00000000	0025
00000098	7ff0b993	00000000	00000000	0026
0000009c	00000393	00000000	00000000	0027
000000a0	00700193	00000007	00000000	0028
000000a4	0a799e63	00000000	00000000	0029
000000a8	00000097	000000a8	00000000	002a
000000ac	0cc08093	00000174	00000000	002b
000000b0	0ee00113	000000ee	7fff8000	002c
000000b4	00208023	00000174	000000ee	002d
000000b8	0ff00113	000000ff	00000000	002e
000000bc	002080a3	00000175	000000ff	002f

PC	IR	BusW	Din	Cycles
00000000	00000000	00000000	00000000	0000
00000000	80000037	80000000	00000000	0000
00000004	7ff00013	000007ff	00000000	0001
00000008	0010c0b3	00000000	00000000	0002
0000000c	00100193	00000001	00000000	0003
00000010	14101863	00000000	00000000	0004
00000014	800000b7	80000000	00000000	0005
00000018	ffff8137	ffff8000	00000000	0006
0000001c	00208733	7fff8000	ffff8000	0007
00000020	7fff83b7	7fff8000	00000000	0008
00000024	00200193	00000002	ffff8000	0009
00000028	12771c63	00000000	7fff8000	000a
0000002c	0ff010b7	0ff01000	00000000	000b
00000030	ff000093	0ff00ff0	00000000	000c
00000034	f0f0f137	f0f0f000	00000000	000d
00000038	0f010113	f0f0f0f0	00000000	000e
0000003c	0020f7b3	00f000f0	f0f0f0f0	000f
00000040	00f003b7	00f00000	00f000f0	0010
00000044	0f038393	00f000f0	00000000	0011
00000048	00300193	00000003	00000002	0012
0000004c	10779a63	00000000	00f000f0	0013
00000050	00100093	00000001	0ff00ff0	0014
00000054	03f00113	0000003f	00000000	0015
00000058	00209833	80000000	0000003f	0016
0000005c	800003b7	80000000	00000000	0017
00000060	00400193	00000004	00000000	0018
00000064	0e781e63	00000000	80000000	0019
00000068	800000b7	80000000	00000000	001a
0000006c	00e00113	0000000e	7fff8000	001b
00000070	4020d8b3	fffe0000	0000000e	001c
00000074	fffe03b7	fffe0000	00000000	001d
00000078	00500193	00000005	0000000e	001e
0000007c	0e789263	00000000	fffe0000	001f
00000080	800000b7	80000000	00000000	0020
00000084	7ff0a913	00000001	00000000	0021
00000088	00100393	00000001	80000000	0022
0000008c	00600193	00000006	00000000	0023
00000090	0c791863	00000000	00000001	0024
00000094	800000b7	80000000	00000000	0025
00000098	7ff0b993	00000000	00000000	0026
0000009c	00000393	00000000	00000000	0027
000000a0	00700193	00000007	00000000	0028
000000a4	0a799e63	00000000	00000000	0029
000000a8	00000097	000000a8	00000000	002a
000000ac	0cc08093	00000174	00000000	002b
000000b0	0ee00113	000000ee	7fff8000	002c
000000b4	00208023	00000174	000000ee	002d
000000b8	0ff00113	000000ff	00000000	002e
000000bc	002080a3	00000175	000000ff	002f

6.3



▼ 测试集1

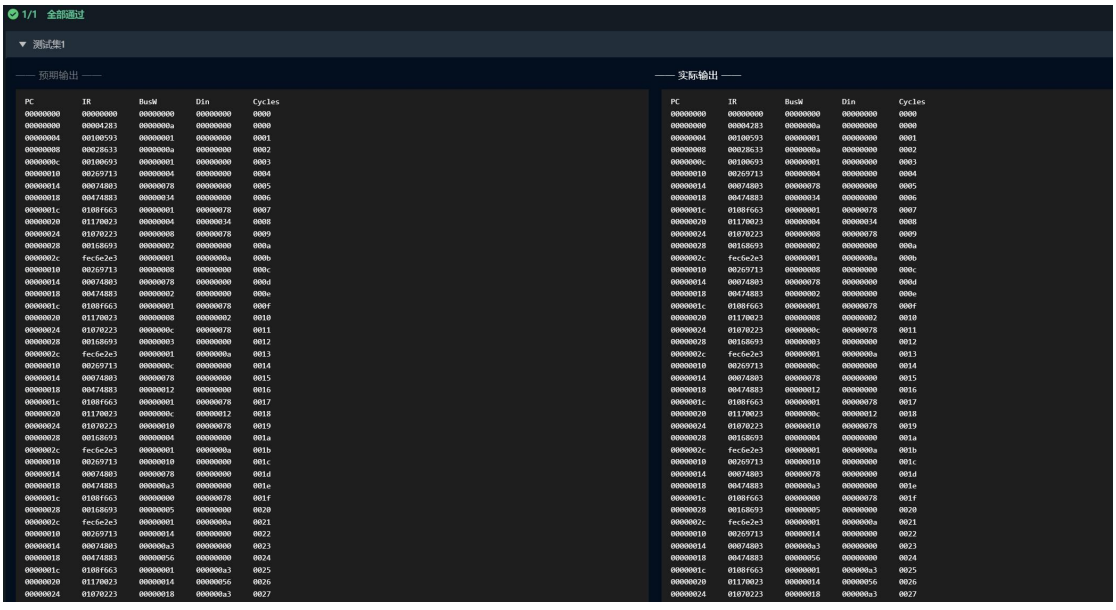
—— 预期输出 ——

PC	IR	BusW	Din	Cycles
00000000	00000000	00000000	00000000	0000
00000000	00004583	00000010	00000000	0000
00000004	02058663	00000000	00000000	0001
00000008	00106613	00000001	00000000	0002
0000000c	00d6c6b3	00000000	00000000	0003
00000010	00c686b3	00000001	00000001	0004
00000014	00b60663	00000001	00000010	0005
00000018	00160613	00000002	00000000	0006
0000001c	ff5ff06f	00000020	00000000	0007
00000010	00c686b3	00000003	00000002	0008
00000014	00b60663	00000001	00000010	0009
00000018	00160613	00000003	00000000	000a
0000001c	ff5ff06f	00000020	00000000	000b
00000010	00c686b3	00000006	00000003	000c
00000014	00b60663	00000001	00000010	000d
00000018	00160613	00000004	00000000	000e
0000001c	ff5ff06f	00000020	00000000	000f
00000010	00c686b3	0000000a	00000004	0010
00000014	00b60663	00000001	00000010	0011
00000018	00160613	00000005	00000000	0012
0000001c	ff5ff06f	00000020	00000000	0013
00000010	00c686b3	0000000f	00000005	0014
00000014	00b60663	00000001	00000010	0015
00000018	00160613	00000006	00000000	0016
0000001c	ff5ff06f	00000020	00000000	0017
00000010	00c686b3	00000015	00000006	0018
00000014	00b60663	00000001	00000010	0019
00000018	00160613	00000007	00000000	001a
0000001c	ff5ff06f	00000020	00000000	001b
00000010	00c686b3	0000001c	00000007	001c
00000014	00b60663	00000001	00000010	001d
00000018	00160613	00000008	00000000	001e
0000001c	ff5ff06f	00000020	00000000	001f
00000010	00c686b3	00000024	00000008	0020
00000014	00b60663	00000001	00000010	0021
00000018	00160613	00000009	00000000	0022
0000001c	ff5ff06f	00000020	00000000	0023
00000010	00c686b3	0000002d	00000009	0024
00000014	00b60663	00000001	00000010	0025

—— 实际输出 ——

PC	IR	BusW	Din	Cycles
00000000	00000000	00000000	00000000	0000
00000000	00004583	00000010	00000000	0000
00000004	02058663	00000000	00000000	0001
00000008	00106613	00000001	00000000	0002
0000000c	00d6c6b3	00000000	00000000	0003
00000010	00c686b3	00000001	00000001	0004
00000014	00b60663	00000001	00000010	0005
00000018	00160613	00000002	00000000	0006
0000001c	ff5ff06f	00000020	00000000	0007
00000010	00c686b3	00000003	00000002	0008
00000014	00b60663	00000001	00000010	0009
00000018	00160613	00000003	00000000	000a
0000001c	ff5ff06f	00000020	00000000	000b
00000010	00c686b3	00000006	00000003	000c
00000014	00b60663	00000001	00000010	000d
00000018	00160613	00000004	00000000	000e
0000001c	ff5ff06f	00000020	00000000	000f
00000010	00c686b3	0000000a	00000004	0010
00000014	00b60663	00000001	00000010	0011
00000018	00160613	00000005	00000000	0012
0000001c	ff5ff06f	00000020	00000000	0013
00000010	00c686b3	0000000f	00000005	0014
00000014	00b60663	00000001	00000010	0015
00000018	00160613	00000006	00000000	0016
0000001c	ff5ff06f	00000020	00000000	0017
00000010	00c686b3	00000015	00000006	0018
00000014	00b60663	00000001	00000010	0019
00000018	00160613	00000007	00000000	001a
0000001c	ff5ff06f	00000020	00000000	001b
00000010	00c686b3	0000001c	00000007	001c
00000014	00b60663	00000001	00000010	001d
00000018	00160613	00000008	00000000	001e
0000001c	ff5ff06f	00000020	00000000	001f
00000010	00c686b3	00000024	00000008	0020
00000014	00b60663	00000001	00000010	0021
00000018	00160613	00000009	00000000	0022
0000001c	ff5ff06f	00000020	00000000	0023
00000010	00c686b3	0000002d	00000009	0024
00000014	00b60663	00000001	00000010	0025

6.4



✓ 1/1 全部通过

▼ 测试集1

—— 预期输出 ——

PC	IR	BusW	Din	Cycles
00000000	00000000	00000000	00000000	0000
00000000	00004283	0000000a	00000000	0000
00000004	00100593	00000001	00000000	0001
00000008	00028633	0000000a	00000000	0002
0000000c	00100693	00000001	00000000	0003
00000010	00269713	00000004	00000000	0004
00000014	00074803	00000078	00000000	0005
00000018	00474883	00000034	00000000	0006
0000001c	0108f663	00000001	00000078	0007
00000020	01170023	00000004	00000034	0008
00000024	01070223	00000008	00000078	0009
00000028	00168693	00000002	00000000	000a
0000002c	fec6e2e3	00000001	0000000a	000b
00000010	00269713	00000008	00000000	000c
00000014	00074803	00000078	00000000	000d
00000018	00474883	00000002	00000000	000e
0000001c	0108f663	00000001	00000078	000f
00000020	01170023	00000008	00000002	0010
00000024	01070223	0000000c	00000078	0011
00000028	00168693	00000003	00000000	0012
0000002c	fec6e2e3	00000001	0000000a	0013
00000010	00269713	0000000c	00000000	0014
00000014	00074803	00000078	00000000	0015
00000018	00474883	00000012	00000000	0016
0000001c	0108f663	00000001	00000078	0017
00000020	01170023	0000000c	00000012	0018
00000024	01070223	00000010	00000078	0019
00000028	00168693	00000004	00000000	001a
0000002c	fec6e2e3	00000001	0000000a	001b
00000010	00269713	00000010	00000000	001c
00000014	00074803	00000078	00000000	001d
00000018	00474883	000000a3	00000000	001e
0000001c	0108f663	00000000	00000078	001f
00000028	00168693	00000005	00000000	0020
0000002c	fec6e2e3	00000001	0000000a	0021
00000010	00269713	00000014	00000000	0022
00000014	00074803	000000a3	00000000	0023
00000018	00474883	00000056	00000000	0024
0000001c	0108f663	00000001	000000a3	0025
00000020	01170023	00000014	00000056	0026
00000024	01070223	00000018	000000a3	0027

—— 实际输出 ——

PC	IR	BusW	Din	Cycles
00000000	00000000	00000000	00000000	0000
00000000	00004283	0000000a	00000000	0000
00000004	00100593	00000001	00000000	0001
00000008	00028633	0000000a	00000000	0002
0000000c	00100693	00000001	00000000	0003
00000010	00269713	00000004	00000000	0004
00000014	00074803	00000078	00000000	0005
00000018	00474883	00000034	00000000	0006
0000001c	0108f663	00000001	00000078	0007
00000020	01170023	00000004	00000034	0008
00000024	01070223	00000008	00000078	0009
00000028	00168693	00000002	00000000	000a
0000002c	fec6e2e3	00000001	0000000a	000b
00000010	00269713	00000008	00000000	000c
00000014	00074803	00000078	00000000	000d
00000018	00474883	00000002	00000000	000e
0000001c	0108f663	00000001	00000078	000f
00000020	01170023	00000008	00000002	0010
00000024	01070223	0000000c	00000078	0011
00000028	00168693	00000003	00000000	0012
0000002c	fec6e2e3	00000001	0000000a	0013
00000010	00269713	0000000c	00000000	0014
00000014	00074803	00000078	00000000	0015
00000018	00474883	00000012	00000000	0016
0000001c	0108f663	00000001	00000078	0017
00000020	01170023	0000000c	00000012	0018
00000024	01070223	00000010	00000078	0019
00000028	00168693	00000004	00000000	001a
0000002c	fec6e2e3	00000001	0000000a	001b
00000010	00269713	00000010	00000000	001c
00000014	00074803	00000078	00000000	001d
00000018	00474883	000000a3	00000000	001e
0000001c	0108f663	00000000	00000078	001f
00000028	00168693	00000005	00000000	0020
0000002c	fec6e2e3	00000001	0000000a	0021
00000010	00269713	00000014	00000000	0022
00000014	00074803	000000a3	00000000	0023
00000018	00474883	00000056	00000000	0024
0000001c	0108f663	00000001	000000a3	0025
00000020	01170023	00000014	00000056	0026
00000024	01070223	00000018	000000a3	0027

四、错误现象及分析

6.1无

6.2 无

6.3 无
6.4 无
6.5 6.6 无。

五、思考题

1. 可以给进程限定一段时间的时间片，到时间片后，就把进程的上下文数据保存下来，然后切换到另一个进程。回到原先的进程后，恢复上下文数据，继续执行。

2. 我们可能需要一些驱动程序，用来规定与硬件的交互信息。另外，cpu 可能需要一些 IO 指令，从而方便处理这些格式。

3. 可能需要多一些寄存器存储中间结果。可能需要增加更多的控制信号，可能需要更复杂的时序控制逻辑，可能需要更复杂地考虑冒险等。