

UM–SJTU Joint Institute VE370 Introduction to Computer Organization

Project 2 Report - Sample

Based on Tianze's report

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I Objective

Fill here

• The memory-reference instructions: Fill here

• The arithmetic-logical instructions: Fill here

• The jumping instructions: Fill here

II Top Level Block Diagram

(i) Single Cycle

We use exactly the same figure(Figure 1) for our design from textbook.

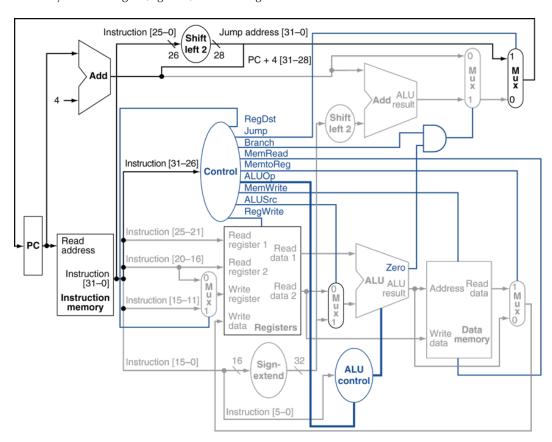


Figure 1: Single Cycle Diagram.

(ii) Pipeline

Since we cannot find a perfect diagram for pipeline, we draw a diagram by ourselves. Please see the next chapter for the figures corresponding to different stages.

III Design of Components

Since all the components used in Pipeline can be used in Single cycle, we'll only talk about the cases for pipeline.

(i) IF Stage

And the modules are given by:

1. PC MUX

This part is used to select PC source from branched address, jump address, or PC+4. The Verilog code for PC MUX is

```
module MUX_PC (PCp4, BranchPC, JumpPC, BNEorBEQ, JumpSignal, PC_in);
input [31:0] PCp4, BranchPC, JumpPC;
input BNEorBEQ, JumpSignal;
output reg [31:0] PC_in;

always @ ( * ) begin
   if (BNEorBEQ) begin
   PC_in = BranchPC;
end else if (JumpSignal) begin
   PC_in = JumpPC;
end else begin
   PC_in = PCp4;
end
end
```

- 2. PC Register
- 3. PC Adder 4

4. Instruction Memory

```
module InstructionMem(PCAddress, Instruction);
// Your code here
   memory[0] = 32'b0010000000001000000000000000000000; //addi $t0, $zero, 0x20
   memory[1] = 32'b001000000001001000000000110111; //addi $t1, $zero, 0x37
   memory[2] = 32'b0000000100001001100000000100100; //and $s0, $t0, $t1
   memory[3] = 32'b0000000100001001100000000100101; //or $s0, $t0, $t1
   memory[6] = 32'b0000000100010001000100000100000; //add $s1, $t0, $t1
   memory[7] = 32'b00000001000010011001000000100010; //sub $s2, $t0, $t1
   memory[8] = 32'b00010010001100100000000000001001; //beq $s1, $s2, error0
   memory[9] = 32'b1000110000010001000000000000100; //lw $s1, 4($zero)
   memory[10]= 32'b0011001000110010000000001001000; //andi $s2, $s1, 0x48
   memory[11] =32'b00010010001100100000000001001; //beq $s1, $s2, error1
   memory[12] =32'b1000110000010011000000000001000; //lw $s3, 8($zero)
   memory[13] =32'b0001001000010011000000000001010; //beq $s0, $s3, error2
   memory[14] =32'b000000100101000011010000000101010; //slt $s4, $s2, $s1 (Last)
   memory[15] =32'b0001001010000000000000000001111; //beq $s4, $0, EXIT
   memory[16] =32'b000000100010000010010000001, //add $s2, $s1, $0
   memory[17] =32'b0000100000000000000000000001110; //j Last
   memory[19] =32'b00100000000100100000000000000000; //addi $t1, $0, 0
   memory[20] =32'b00001000000000000000000000011111; //j EXIT
   memory[21] =32'b001000000001000000000000001; //addi $t0, $0, 1(error1)
   memory[22] =32'b001000000000100100000000000001; //addi $t1, $0, 1
   memory[23] =32'b0000100000000000000000000011111; //j EXIT
   memory[26] =32'b0000100000000000000000000011111; //j EXIT
   memory[27] =32'b0010000000010000000000000000011; //addi $t0, $0, 3(error3)
   memory[28] =32'b00100000000100100000000000011; //addi $t1, $0, 3
   memory[29] =32'b00001000000000000000000000011111; //j EXIT
```

(ii) ID Stage

- Register File
- 2. Control Unit
- 3. Hazard Detection Unit and ID Forwarding Unit
- 4. Comparator

- (iii) EX Stage
- 1. Forwarding Unit and MUX
- 2. ALU Control
- 3. ALU Unit
- (iv) Memory Stage and Write Back Stage
- 1. Data Memory

IV Control and Data Hazard

- (i) EX stage
- 1. Data Hazard

Forwarding Unit

Forwarding MUX EX

- (ii) ID stage
- 1. Control Hazard
- 2. Data Hazard

Hazard Detection Unit

Forwarding MUX ID

V Instruction Implementation

VI SSD and Top Module

VII RTL Schematic (Optional)

Please note that this part is not mandatory. Please zoom in to check the details.

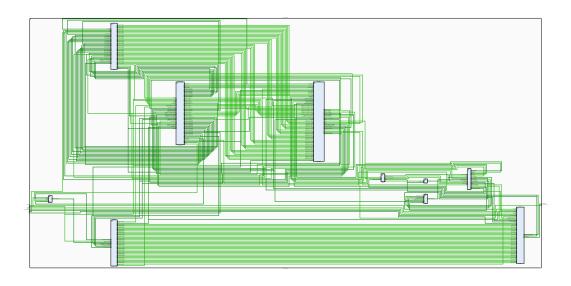


Figure 2: Schematic for Pipeline Main module.

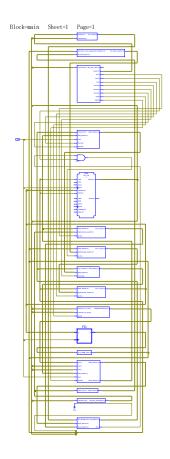


Figure 3: Schematic for Single Cycle.

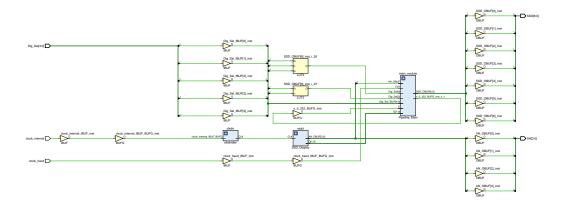


Figure 4: Schematic including SSD.

VIII Textual Result

By running the instruction memory, we can achieve the following Textual Result. (Too long so that we put it in the appendix part)

IX Conclusion and Discussion

Needn't be too long

X Reference

XI Appendix

(i) Textual Result

```
VCD info: dumpfile pipeline_test.vcd opened for output.
______
               0, CLK = 1, PC = 0x00000000
[\$s0] = 0x00000000, [\$s1] = 0x00000000, [\$s2] = 0x000000000
[\$t1] = 0x00000000, [\$t2] = 0x00000000, [\$t3] = 0x000000000
[\$t4] = 0x00000000, [\$t5] = 0x00000000, [\$t6] = 0x000000000
[\$t7] = 0x00000000, [\$t8] = 0x00000000, [\$t9] = 0x000000000
______
Time =
               1, CLK = 0, PC = 0x000000004
[\$s0] = 0x00000000, [\$s1] = 0x00000000, [\$s2] = 0x000000000
[\$s3] = 0x00000000, [\$s4] = 0x00000000, [\$s5] = 0x000000000
[\$56] = 0x000000000, [\$57] = 0x000000000, [\$t0] = 0x000000000
[\$t1] = 0x00000000, [\$t2] = 0x00000000, [\$t3] = 0x00000000
[\$t4] = 0x000000000, [\$t5] = 0x000000000, [\$t6] = 0x000000000
[\$t7] = 0x00000000, [\$t8] = 0x00000000, [\$t9] = 0x000000000
-----
Time =
               1, CLK = 1, PC = 0 \times 000000004
[\$s0] = 0x00000000, [\$s1] = 0x00000000, [\$s2] = 0x000000000
[\$s3] = 0x00000000, [\$s4] = 0x00000000, [\$s5] = 0x00000000
[\$56] = 0x00000000, [\$57] = 0x00000000, [\$t0] = 0x00000000
[\$t1] = 0x000000000, [\$t2] = 0x000000000, [\$t3] = 0x000000000
[\$t4] = 0x00000000, [\$t5] = 0x00000000, [\$t6] = 0x00000000
[\$t7] = 0x00000000, [\$t8] = 0x00000000, [\$t9] = 0x00000000
_____
               2, CLK = 0, PC = 0x00000008
Time =
[\$s0] = 0x00000000, [\$s1] = 0x00000000, [\$s2] = 0x000000000
[\$s3] = 0x00000000, [\$s4] = 0x00000000, [\$s5] = 0x000000000
[\$56] = 0x000000000, [\$57] = 0x000000000, [\$t0] = 0x000000000
[\$t1] = 0x00000000, [\$t2] = 0x00000000, [\$t3] = 0x00000000
[\$t4] = 0x00000000, [\$t5] = 0x00000000, [\$t6] = 0x00000000
[\$t7] = 0x00000000, [\$t8] = 0x00000000, [\$t9] = 0x000000000
_____
Time =
               2, CLK = 1, PC = 0x000000008
[\$s0] = 0x000000000, [\$s1] = 0x000000000, [\$s2] = 0x000000000
[\$s3] = 0x00000000, [\$s4] = 0x00000000, [\$s5] = 0x000000000
[\$56] = 0x000000000, [\$57] = 0x000000000, [\$t0] = 0x000000000
[\$t1] = 0x00000000, [\$t2] = 0x00000000, [\$t3] = 0x00000000
[\$t4] = 0x00000000, [\$t5] = 0x00000000, [\$t6] = 0x00000000
[\$t7] = 0x00000000, [\$t8] = 0x00000000, [\$t9] = 0x000000000
_____
               3, CLK = 0, PC = 0 \times 00000000 c
Time =
[\$50] = 0 \times 000000000, [\$51] = 0 \times 00000000, [\$52] = 0 \times 000000000
```

```
[\$s3] = 0x00000000, [\$s4] = 0x00000000, [\$s5] = 0x000000000
[\$s6] = 0x00000000, [\$s7] = 0x00000000, [\$t0] = 0x000000000
[\$t1] = 0x00000000, [\$t2] = 0x00000000, [\$t3] = 0x00000000
[\$t4] = 0x00000000, [\$t5] = 0x00000000, [\$t6] = 0x00000000
[\$t7] = 0x00000000, [\$t8] = 0x00000000, [\$t9] = 0x000000000
______
                3, CLK = 1, PC = 0x00000000c
[\$s0] = 0x00000000, [\$s1] = 0x00000000, [\$s2] = 0x000000000
[\$s3] = 0x00000000, [\$s4] = 0x00000000, [\$s5] = 0x000000000
[\$56] = 0x000000000, [\$57] = 0x000000000, [\$t0] = 0x000000000
[\$t1] = 0x00000000, [\$t2] = 0x00000000, [\$t3] = 0x00000000
[\$t4] = 0x00000000, [\$t5] = 0x00000000, [\$t6] = 0x00000000
[\$t7] = 0x00000000, [\$t8] = 0x00000000, [\$t9] = 0x000000000
______
Time =
                4, CLK = 0, PC = 0 \times 00000010
[\$s0] = 0x00000000, [\$s1] = 0x00000000, [\$s2] = 0x000000000
[\$s3] = 0x000000000, [\$s4] = 0x000000000, [\$s5] = 0x000000000
[\$56] = 0 \times 00000000, [\$57] = 0 \times 00000000, [\$t0] = 0 \times 000000000
[\$t1] = 0x00000000, [\$t2] = 0x00000000, [\$t3] = 0x00000000
[\$t4] = 0x00000000, [\$t5] = 0x00000000, [\$t6] = 0x00000000
[\$t7] = 0x00000000, [\$t8] = 0x00000000, [\$t9] = 0x000000000
-----
Time =
                4, CLK = 1, PC = 0 \times 00000010
[\$50] = 0x00000000, [\$51] = 0x00000000, [\$52] = 0x000000000
[\$s3] = 0x00000000, [\$s4] = 0x00000000, [\$s5] = 0x00000000
[\$56] = 0x00000000, [\$57] = 0x00000000, [\$t0] = 0x000000020
[\$t1] = 0x00000000, [\$t2] = 0x00000000, [\$t3] = 0x00000000
[\$t4] = 0x000000000, [\$t5] = 0x000000000, [\$t6] = 0x000000000
[\$t7] = 0x00000000, [\$t8] = 0x00000000, [\$t9] = 0x000000000
______
                5, CLK = 0, PC = 0 \times 00000014
Time =
[\$50] = 0 \times 000000000, [\$51] = 0 \times 000000000, [\$52] = 0 \times 000000000
[\$s3] = 0x000000000, [\$s4] = 0x000000000, [\$s5] = 0x000000000
[\$56] = 0x000000000, [\$57] = 0x000000000, [\$t0] = 0x000000020
[\$t1] = 0x00000000, [\$t2] = 0x00000000, [\$t3] = 0x000000000
[\$t4] = 0x00000000, [\$t5] = 0x00000000, [\$t6] = 0x000000000
[\$t7] = 0x00000000, [\$t8] = 0x00000000, [\$t9] = 0x000000000
______
Time =
                5, CLK = 1, PC = 0 \times 00000014
[\$s0] = 0x00000000, [\$s1] = 0x00000000, [\$s2] = 0x000000000
[\$s3] = 0x00000000, [\$s4] = 0x00000000, [\$s5] = 0x000000000
[\$56] = 0x000000000, [\$57] = 0x000000000, [\$t0] = 0x000000020
[\$t1] = 0x00000037, [\$t2] = 0x00000000, [\$t3] = 0x00000000
[\$t4] = 0x00000000, [\$t5] = 0x00000000, [\$t6] = 0x000000000
[\$t7] = 0x00000000, [\$t8] = 0x00000000, [\$t9] = 0x000000000
______
```

Time = 6, CLK = 0, PC = 0×00000018

```
[\$s0] = 0x00000000, [\$s1] = 0x00000000, [\$s2] = 0x000000000
[\$s3] = 0x00000000, [\$s4] = 0x00000000, [\$s5] = 0x000000000
[\$56] = 0x00000000, [\$57] = 0x00000000, [\$t0] = 0x00000020
[\$t1] = 0x00000037, [\$t2] = 0x000000000, [\$t3] = 0x000000000
[\$t4] = 0x00000000, [\$t5] = 0x00000000, [\$t6] = 0x00000000
[\$t7] = 0x00000000, [\$t8] = 0x00000000, [\$t9] = 0x000000000
______
                6, CLK = 1, PC = 0 \times 00000018
Time =
[\$50] = 0x00000020, [\$51] = 0x00000000, [\$52] = 0x000000000
[\$s3] = 0x00000000, [\$s4] = 0x00000000, [\$s5] = 0x000000000
[\$56] = 0 \times 000000000, [\$57] = 0 \times 000000000, [\$t0] = 0 \times 000000020
[\$t1] = 0x00000037, [\$t2] = 0x00000000, [\$t3] = 0x000000000
[\$t4] = 0x00000000, [\$t5] = 0x00000000, [\$t6] = 0x00000000
[$t7] = 0x00000000, [$t8] = 0x00000000, [$t9] = 0x00000000
______
                7, CLK = 0, PC = 0x0000001c
Time =
[\$s0] = 0x00000020, [\$s1] = 0x00000000, [\$s2] = 0x000000000
[\$s3] = 0x00000000, [\$s4] = 0x00000000, [\$s5] = 0x000000000
[\$56] = 0x00000000, [\$57] = 0x00000000, [\$t0] = 0x000000020
[\$t1] = 0x00000037, [\$t2] = 0x00000000, [\$t3] = 0x000000000
[\$t4] = 0x00000000, [\$t5] = 0x00000000, [\$t6] = 0x00000000
[\$t7] = 0x00000000, [\$t8] = 0x00000000, [\$t9] = 0x000000000
______
                7, CLK = 1, PC = 0 \times 00000001c
Time =
[\$s0] = 0x00000037, [\$s1] = 0x000000000, [\$s2] = 0x000000000
[\$s3] = 0x00000000, [\$s4] = 0x00000000, [\$s5] = 0x000000000
[\$56] = 0 \times 000000000, [\$57] = 0 \times 000000000, [\$t0] = 0 \times 000000020
[\$t1] = 0x00000037, [\$t2] = 0x00000000, [\$t3] = 0x00000000
[$t4] = 0x00000000, [$t5] = 0x00000000, [$t6] = 0x00000000
[$t7] = 0x00000000, [$t8] = 0x00000000, [$t9] = 0x00000000
_____
Time =
                 8, CLK = 0, PC = 0x000000020
[\$s0] = 0x00000037, [\$s1] = 0x000000000, [\$s2] = 0x000000000
[\$s3] = 0x00000000, [\$s4] = 0x00000000, [\$s5] = 0x00000000
[\$56] = 0x000000000, [\$57] = 0x000000000, [\$t0] = 0x000000020
[\$t1] = 0x00000037, [\$t2] = 0x00000000, [\$t3] = 0x00000000
[\$t4] = 0x00000000, [\$t5] = 0x00000000, [\$t6] = 0x00000000
[\$t7] = 0 \times 000000000, [\$t8] = 0 \times 000000000, [\$t9] = 0 \times 000000000
______
                8, CLK = 1, PC = 0 \times 000000020
Time =
[\$s0] = 0x00000037, [\$s1] = 0x00000000, [\$s2] = 0x000000000
[\$s3] = 0x000000000, [\$s4] = 0x000000000, [\$s5] = 0x000000000
[\$56] = 0x00000000, [\$57] = 0x00000000, [\$t0] = 0x00000020
[\$t1] = 0x00000037, [\$t2] = 0x00000000, [\$t3] = 0x000000000
[\$t4] = 0x00000000, [\$t5] = 0x00000000, [\$t6] = 0x00000000
[\$t7] = 0x00000000, [\$t8] = 0x00000000, [\$t9] = 0x000000000
______
```

9, CLK = 0, PC = 0×000000024

Time =

```
[\$s0] = 0x00000037, [\$s1] = 0x00000000, [\$s2] = 0x000000000
[\$s3] = 0x00000000, [\$s4] = 0x00000000, [\$s5] = 0x00000000
[\$56] = 0x000000000, [\$57] = 0x000000000, [\$t0] = 0x000000020
[\$t1] = 0x00000037, [\$t2] = 0x00000000, [\$t3] = 0x00000000
[\$t4] = 0x00000000, [\$t5] = 0x00000000, [\$t6] = 0x000000000
[\$t7] = 0x00000000, [\$t8] = 0x00000000, [\$t9] = 0x000000000
______
Time =
                 9, CLK = 1, PC = 0x00000024
[\$50] = 0x00000037, [\$51] = 0x00000000, [\$52] = 0x000000000
[\$s3] = 0x00000000, [\$s4] = 0x00000000, [\$s5] = 0x000000000
[\$56] = 0x00000000, [\$57] = 0x00000000, [\$t0] = 0x00000020
[\$t1] = 0x00000037, [\$t2] = 0x000000000, [\$t3] = 0x000000000
[$t4] = 0x00000000, [$t5] = 0x00000000, [$t6] = 0x00000000
[\$t7] = 0x00000000, [\$t8] = 0x00000000, [\$t9] = 0x000000000
_____
                10, CLK = 0, PC = 0 \times 000000024
Time =
[\$50] = 0 \times 00000037, [\$51] = 0 \times 00000000, [\$52] = 0 \times 000000000
[\$s3] = 0x00000000, [\$s4] = 0x00000000, [\$s5] = 0x000000000
[\$56] = 0x000000000, [\$57] = 0x000000000, [\$t0] = 0x000000020
[\$t1] = 0x00000037, [\$t2] = 0x00000000, [\$t3] = 0x00000000
[\$t4] = 0x00000000, [\$t5] = 0x00000000, [\$t6] = 0x000000000
[\$t7] = 0x00000000, [\$t8] = 0x00000000, [\$t9] = 0x000000000
______
                10, CLK = 1, PC = 0 \times 000000024
Time =
[\$s0] = 0x00000037, [\$s1] = 0x00000057, [\$s2] = 0x000000000
[\$s3] = 0x00000000, [\$s4] = 0x00000000, [\$s5] = 0x000000000
[\$56] = 0x000000000, [\$57] = 0x000000000, [\$t0] = 0x000000020
[$t1] = 0x00000037, [$t2] = 0x00000000, [$t3] = 0x00000000
[$t4] = 0x00000000, [$t5] = 0x00000000, [$t6] = 0x00000000
[\$t7] = 0x00000000, [\$t8] = 0x00000000, [\$t9] = 0x000000000
______
                11, CLK = 0, PC = 0 \times 000000024
Time =
[\$50] = 0 \times 000000037, [\$51] = 0 \times 000000057, [\$52] = 0 \times 0000000000
[\$s3] = 0x00000000, [\$s4] = 0x00000000, [\$s5] = 0x000000000
[\$56] = 0 \times 000000000, [\$57] = 0 \times 000000000, [\$t0] = 0 \times 000000020
[\$t1] = 0x00000037, [\$t2] = 0x00000000, [\$t3] = 0x00000000
[\$t4] = 0 \times 000000000, [\$t5] = 0 \times 000000000, [\$t6] = 0 \times 000000000
[\$t7] = 0x00000000, [\$t8] = 0x00000000, [\$t9] = 0x000000000
______
Time =
                11, CLK = 1, PC = 0 \times 000000024
[\$s0] = 0x00000037, [\$s1] = 0x00000057, [\$s2] = 0xffffffe9
[\$s3] = 0x00000000, [\$s4] = 0x00000000, [\$s5] = 0x00000000
[\$s6] = 0x000000000, [\$s7] = 0x000000000, [\$t0] = 0x000000020
[\$t1] = 0x00000037, [\$t2] = 0x00000000, [\$t3] = 0x00000000
[\$t4] = 0x00000000, [\$t5] = 0x00000000, [\$t6] = 0x00000000
[\$t7] = 0x00000000, [\$t8] = 0x00000000, [\$t9] = 0x000000000
```

```
Time =
                12, CLK = 0, PC = 0x000000028
[\$s0] = 0x00000037, [\$s1] = 0x00000057, [\$s2] = 0xffffffe9
[\$s3] = 0x00000000, [\$s4] = 0x000000000, [\$s5] = 0x000000000
[\$56] = 0x00000000, [\$57] = 0x00000000, [\$t0] = 0x00000020
[\$t1] = 0x00000037, [\$t2] = 0x00000000, [\$t3] = 0x00000000
[\$t4] = 0x00000000, [\$t5] = 0x00000000, [\$t6] = 0x000000000
[\$t7] = 0x00000000, [\$t8] = 0x00000000, [\$t9] = 0x000000000
______
Time =
                12, CLK = 1, PC = 0 \times 000000028
[\$s0] = 0x00000037, [\$s1] = 0x00000057, [\$s2] = 0xffffffe9
[\$s3] = 0x00000000, [\$s4] = 0x00000000, [\$s5] = 0x000000000
[\$56] = 0x000000000, [\$57] = 0x000000000, [\$t0] = 0x000000020
[\$t1] = 0x00000037, [\$t2] = 0x00000000, [\$t3] = 0x00000000
[\$t4] = 0x00000000, [\$t5] = 0x00000000, [\$t6] = 0x00000000
[\$t7] = 0x00000000, [\$t8] = 0x00000000, [\$t9] = 0x000000000
______
                13, CLK = 0, PC = 0 \times 00000002c
Time =
[\$s0] = 0x00000037, [\$s1] = 0x000000057, [\$s2] = 0xffffffe9
[\$s3] = 0x00000000, [\$s4] = 0x00000000, [\$s5] = 0x000000000
[\$56] = 0x000000000, [\$57] = 0x000000000, [\$t0] = 0x000000020
[$t1] = 0x00000037, [$t2] = 0x00000000, [$t3] = 0x00000000
[$t4] = 0x00000000, [$t5] = 0x00000000, [$t6] = 0x00000000
[\$t7] = 0 \times 000000000, [\$t8] = 0 \times 000000000, [\$t9] = 0 \times 000000000
______
Time =
                13, CLK = 1, PC = 0 \times 00000002c
[\$s0] = 0x00000037, [\$s1] = 0x00000057, [\$s2] = 0xffffffe9
[\$s3] = 0x00000000, [\$s4] = 0x00000000, [\$s5] = 0x000000000
[$s6] = 0x00000000, [$s7] = 0x00000000, [$t0] = 0x00000020
[$t1] = 0x00000037, [$t2] = 0x00000000, [$t3] = 0x00000000
[\$t4] = 0x00000000, [\$t5] = 0x00000000, [\$t6] = 0x00000000
[\$t7] = 0x00000000, [\$t8] = 0x00000000, [\$t9] = 0x000000000
______
Time =
                14, CLK = 0, PC = 0x00000002c
[\$s0] = 0x00000037, [\$s1] = 0x00000057, [\$s2] = 0xffffffe9
[\$s3] = 0x00000000, [\$s4] = 0x00000000, [\$s5] = 0x000000000
[\$56] = 0x00000000, [\$57] = 0x00000000, [\$t0] = 0x00000020
[\$t1] = 0x00000037, [\$t2] = 0x00000000, [\$t3] = 0x000000000
[\$t4] = 0x00000000, [\$t5] = 0x00000000, [\$t6] = 0x00000000
[\$t7] = 0 \times 000000000, [\$t8] = 0 \times 000000000, [\$t9] = 0 \times 000000000
______
Time =
                14, CLK = 1, PC = 0x0000002c
[\$s0] = 0x00000037, [\$s1] = 0x00000057, [\$s2] = 0xffffffe9
[\$s3] = 0x00000000, [\$s4] = 0x00000000, [\$s5] = 0x000000000
[\$56] = 0 \times 000000000, [\$57] = 0 \times 000000000, [\$t0] = 0 \times 000000020
[\$t1] = 0x00000037, [\$t2] = 0x00000000, [\$t3] = 0x00000000
[\$t4] = 0x00000000, [\$t5] = 0x00000000, [\$t6] = 0x00000000
[\$t7] = 0x00000000, [\$t8] = 0x00000000, [\$t9] = 0x000000000
```

```
Time =
               15, CLK = 0, PC = 0x00000030
[\$s0] = 0x00000037, [\$s1] = 0x00000057, [\$s2] = 0xffffffe9
[\$s3] = 0x00000000, [\$s4] = 0x00000000, [\$s5] = 0x00000000
[\$56] = 0x00000000, [\$57] = 0x00000000, [\$t0] = 0x00000020
[\$t1] = 0x00000037, [\$t2] = 0x00000000, [\$t3] = 0x00000000
[\$t4] = 0x00000000, [\$t5] = 0x00000000, [\$t6] = 0x00000000
[\$t7] = 0x00000000, [\$t8] = 0x00000000, [\$t9] = 0x000000000
______
Time =
               15, CLK = 1, PC = 0x00000030
[\$s0] = 0x00000037, [\$s1] = 0x00000037, [\$s2] = 0xffffffe9
[\$s3] = 0x00000000, [\$s4] = 0x00000000, [\$s5] = 0x000000000
[\$56] = 0x00000000, [\$57] = 0x00000000, [\$t0] = 0x00000020
[\$t1] = 0x00000037, [\$t2] = 0x000000000, [\$t3] = 0x000000000
[\$t4] = 0x00000000, [\$t5] = 0x00000000, [\$t6] = 0x00000000
[\$t7] = 0x00000000, [\$t8] = 0x00000000, [\$t9] = 0x000000000
______
Time =
               16, CLK = 0, PC = 0 \times 000000030
[\$s0] = 0x00000037, [\$s1] = 0x00000037, [\$s2] = 0xffffffe9
[\$s3] = 0x000000000, [\$s4] = 0x000000000, [\$s5] = 0x000000000
[\$56] = 0x000000000, [\$57] = 0x000000000, [\$t0] = 0x000000020
[\$t1] = 0x00000037, [\$t2] = 0x00000000, [\$t3] = 0x000000000
[\$t4] = 0x00000000, [\$t5] = 0x00000000, [\$t6] = 0x000000000
[\$t7] = 0x00000000, [\$t8] = 0x00000000, [\$t9] = 0x000000000
______
Time =
               16, CLK = 1, PC = 0 \times 000000030
[\$s0] = 0x000000037, [\$s1] = 0x000000037, [\$s2] = 0xffffffe9
[\$t1] = 0x00000037, [\$t2] = 0x00000000, [\$t3] = 0x00000000
[\$t4] = 0x00000000, [\$t5] = 0x00000000, [\$t6] = 0x00000000
[\$t7] = 0x00000000, [\$t8] = 0x00000000, [\$t9] = 0x000000000
______
               17, CLK = 0, PC = 0 \times 000000030
Time =
[\$s0] = 0x00000037, [\$s1] = 0x00000037, [\$s2] = 0xffffffe9
[\$s3] = 0x00000000, [\$s4] = 0x00000000, [\$s5] = 0x000000000
[\$56] = 0 \times 000000000, [\$57] = 0 \times 000000000, [\$t0] = 0 \times 000000020
[\$t1] = 0x00000037, [\$t2] = 0x000000000, [\$t3] = 0x000000000
[\$t4] = 0x000000000, [\$t5] = 0x000000000, [\$t6] = 0x000000000
[\$t7] = 0 \times 000000000, [\$t8] = 0 \times 00000000, [\$t9] = 0 \times 000000000
-----
Time =
               17, CLK = 1, PC = 0 \times 000000030
[\$s0] = 0x00000037, [\$s1] = 0x00000037, [\$s2] = 0x000000000
[\$s3] = 0x00000000, [\$s4] = 0x00000000, [\$s5] = 0x000000000
[\$56] = 0x000000000, [\$57] = 0x000000000, [\$t0] = 0x000000020
[\$t1] = 0x00000037, [\$t2] = 0x000000000, [\$t3] = 0x000000000
[\$t4] = 0x00000000, [\$t5] = 0x00000000, [\$t6] = 0x00000000
[\$t7] = 0x00000000, [\$t8] = 0x00000000, [\$t9] = 0x000000000
```

```
______
Time =
                 18, CLK = 0, PC = 0 \times 000000034
[\$s0] = 0x00000037, [\$s1] = 0x00000037, [\$s2] = 0x000000000
[\$s3] = 0x00000000, [\$s4] = 0x00000000, [\$s5] = 0x000000000
[\$56] = 0 \times 000000000, [\$57] = 0 \times 000000000, [\$t0] = 0 \times 000000020
[\$t1] = 0x00000037, [\$t2] = 0x00000000, [\$t3] = 0x00000000
[$t4] = 0x00000000, [$t5] = 0x00000000, [$t6] = 0x00000000
[$t7] = 0x00000000, [$t8] = 0x00000000, [$t9] = 0x00000000
______
                 18, CLK = 1, PC = 0 \times 000000034
Time =
[\$s0] = 0x00000037, [\$s1] = 0x00000037, [\$s2] = 0x000000000
[\$s3] = 0x00000000, [\$s4] = 0x00000000, [\$s5] = 0x00000000
[\$56] = 0 \times 000000000, [\$57] = 0 \times 000000000, [\$t0] = 0 \times 000000020
[\$t1] = 0x00000037, [\$t2] = 0x00000000, [\$t3] = 0x000000000
[\$t4] = 0 \times 000000000, \ [\$t5] = 0 \times 00000000, \ [\$t6] = 0 \times 000000000
[\$t7] = 0 \times 000000000, [\$t8] = 0 \times 000000000, [\$t9] = 0 \times 000000000
______
                19, CLK = 0, PC = 0 \times 000000038
Time =
[\$s0] = 0x00000037, [\$s1] = 0x00000037, [\$s2] = 0x000000000
[\$s3] = 0x000000000, [\$s4] = 0x000000000, [\$s5] = 0x000000000
[\$56] = 0 \times 000000000, [\$57] = 0 \times 000000000, [\$t0] = 0 \times 000000020
[\$t1] = 0x00000037, [\$t2] = 0x00000000, [\$t3] = 0x000000000
[\$t4] = 0 \times 000000000, [\$t5] = 0 \times 000000000, [\$t6] = 0 \times 000000000
[\$t7] = 0x00000000, [\$t8] = 0x00000000, [\$t9] = 0x00000000
______
                 19, CLK = 1, PC = 0 \times 000000038
Time =
[\$s0] = 0x00000037, [\$s1] = 0x00000037, [\$s2] = 0x000000000
[\$s3] = 0x00000000, [\$s4] = 0x00000000, [\$s5] = 0x000000000
[\$56] = 0x000000000, [\$57] = 0x000000000, [\$t0] = 0x000000020
[\$t1] = 0x00000037, [\$t2] = 0x00000000, [\$t3] = 0x00000000
[\$t4] = 0x00000000, [\$t5] = 0x00000000, [\$t6] = 0x000000000
[\$t7] = 0 \times 000000000, [\$t8] = 0 \times 000000000, [\$t9] = 0 \times 000000000
______
                 20, CLK = 0, PC = 0 \times 000000038
Time =
[\$s0] = 0x00000037, [\$s1] = 0x00000037, [\$s2] = 0x000000000
[\$s3] = 0x00000000, [\$s4] = 0x00000000, [\$s5] = 0x00000000
[\$56] = 0x000000000, [\$57] = 0x000000000, [\$t0] = 0x000000020
[\$t1] = 0x00000037, [\$t2] = 0x00000000, [\$t3] = 0x00000000
[\$t4] = 0 \times 00000000, [\$t5] = 0 \times 00000000, [\$t6] = 0 \times 000000000
[\$t7] = 0x000000000, [\$t8] = 0x000000000, [\$t9] = 0x000000000
______
Time =
                 20, CLK = 1, PC = 0 \times 000000038
[\$50] = 0 \times 000000037, [\$51] = 0 \times 000000037, [\$52] = 0 \times 0000000000
[\$s3] = 0x00000000, [\$s4] = 0x00000000, [\$s5] = 0x00000000
[\$56] = 0x000000000, [\$57] = 0x000000000, [\$t0] = 0x000000020
[\$t1] = 0x00000037, [\$t2] = 0x00000000, [\$t3] = 0x00000000
[\$t4] = 0x00000000, [\$t5] = 0x00000000, [\$t6] = 0x000000000
[\$t7] = 0x00000000, [\$t8] = 0x00000000, [\$t9] = 0x000000000
```

```
______
Time =
                21, CLK = 0, PC = 0 \times 000000038
[\$s0] = 0x00000037, [\$s1] = 0x00000037, [\$s2] = 0x000000000
[\$s3] = 0x00000000, [\$s4] = 0x00000000, [\$s5] = 0x000000000
[\$56] = 0x00000000, [\$57] = 0x00000000, [\$t0] = 0x00000020
[$t1] = 0x00000037, [$t2] = 0x00000000, [$t3] = 0x00000000
[$t4] = 0x00000000, [$t5] = 0x00000000, [$t6] = 0x00000000
[\$t7] = 0x00000000, [\$t8] = 0x00000000, [\$t9] = 0x000000000
______
                21, CLK = 1, PC = 0 \times 000000038
Time =
[\$50] = 0x00000037, [\$51] = 0x00000037, [\$52] = 0x000000000
[\$s3] = 0x00000020, [\$s4] = 0x00000000, [\$s5] = 0x00000000
[\$56] = 0x000000000, [\$57] = 0x000000000, [\$t0] = 0x000000020
[\$t1] = 0x00000037, [\$t2] = 0x00000000, [\$t3] = 0x00000000
[\$t4] = 0x00000000, [\$t5] = 0x00000000, [\$t6] = 0x00000000
[$t7] = 0x00000000, [$t8] = 0x00000000, [$t9] = 0x00000000
______
                22, CLK = 0, PC = 0x0000003c
Time =
[\$s0] = 0x00000037, [\$s1] = 0x00000037, [\$s2] = 0x000000000
[\$s3] = 0x00000020, [\$s4] = 0x00000000, [\$s5] = 0x000000000
[\$s6] = 0x000000000, [\$s7] = 0x000000000, [\$t0] = 0x000000020
[\$t1] = 0x00000037, [\$t2] = 0x00000000, [\$t3] = 0x00000000
[\$t4] = 0x00000000, [\$t5] = 0x00000000, [\$t6] = 0x00000000
[\$t7] = 0x00000000, [\$t8] = 0x00000000, [\$t9] = 0x000000000
                22, CLK = 1, PC = 0 \times 00000003c
Time =
[\$50] = 0 \times 000000037, [\$51] = 0 \times 000000037, [\$52] = 0 \times 0000000000
[\$s3] = 0x00000020, [\$s4] = 0x00000000, [\$s5] = 0x000000000
[\$56] = 0x00000000, [\$57] = 0x00000000, [\$t0] = 0x00000020
[\$t1] = 0x00000037, [\$t2] = 0x00000000, [\$t3] = 0x00000000
[\$t4] = 0 \times 000000000, [\$t5] = 0 \times 000000000, [\$t6] = 0 \times 000000000
[\$t7] = 0x00000000, [\$t8] = 0x00000000, [\$t9] = 0x000000000
______
                23, CLK = 0, PC = 0x00000040
Time =
[\$s0] = 0x00000037, [\$s1] = 0x00000037, [\$s2] = 0x000000000
[$s3] = 0x00000020, [$s4] = 0x00000000, [$s5] = 0x00000000
[\$56] = 0x000000000, [\$57] = 0x000000000, [\$t0] = 0x000000020
[\$t1] = 0 \times 00000037, [\$t2] = 0 \times 00000000, [\$t3] = 0 \times 000000000
[\$t4] = 0x00000000, [\$t5] = 0x00000000, [\$t6] = 0x00000000
[\$t7] = 0x00000000, [\$t8] = 0x00000000, [\$t9] = 0x000000000
______
Time =
                23, CLK = 1, PC = 0x000000040
[\$50] = 0x00000037, [\$51] = 0x00000037, [\$52] = 0x000000000
[\$s3] = 0x00000020, [\$s4] = 0x000000000, [\$s5] = 0x000000000
[\$56] = 0x00000000, [\$57] = 0x00000000, [\$t0] = 0x00000020
[\$t1] = 0x00000037, [\$t2] = 0x00000000, [\$t3] = 0x000000000
[\$t4] = 0x00000000, [\$t5] = 0x00000000, [\$t6] = 0x000000000
```

```
[\$t7] = 0x00000000, [\$t8] = 0x00000000, [\$t9] = 0x000000000
______
                24, CLK = 0, PC = 0 \times 000000040
Time =
[\$s0] = 0x00000037, [\$s1] = 0x00000037, [\$s2] = 0x000000000
[\$s3] = 0x00000020, [\$s4] = 0x00000000, [\$s5] = 0x00000000
[\$s6] = 0 \times 000000000, [\$s7] = 0 \times 000000000, [\$t0] = 0 \times 000000020 [\$t1] = 0 \times 000000037, [\$t2] = 0 \times 000000000, [\$t3] = 0 \times 000000000
[\$t4] = 0x00000000, [\$t5] = 0x00000000, [\$t6] = 0x00000000
[\$t7] = 0x00000000, [\$t8] = 0x00000000, [\$t9] = 0x000000000
Time =
                24, CLK = 1, PC = 0 \times 000000040
[\$s0] = 0x00000037, [\$s1] = 0x00000037, [\$s2] = 0x00000000
[\$s3] = 0x00000020, [\$s4] = 0x00000000, [\$s5] = 0x000000000
[\$56] = 0x00000000, [\$57] = 0x00000000, [\$t0] = 0x00000020
[\$t1] = 0x00000037, [\$t2] = 0x00000000, [\$t3] = 0x00000000
[$t4] = 0x00000000, [$t5] = 0x00000000, [$t6] = 0x00000000
[\$t7] = 0x000000000, [\$t8] = 0x000000000, [\$t9] = 0x000000000
______
Time =
                25, CLK = 0, PC = 0 \times 000000040
[\$50] = 0 \times 000000037, [\$51] = 0 \times 000000037, [\$52] = 0 \times 0000000000
[\$s3] = 0x00000020, [\$s4] = 0x00000000, [\$s5] = 0x000000000
[\$56] = 0 \times 000000000, [\$57] = 0 \times 000000000, [\$t0] = 0 \times 000000020
[\$t1] = 0x00000037, [\$t2] = 0x00000000, [\$t3] = 0x00000000
[\$t4] = 0x00000000, [\$t5] = 0x00000000, [\$t6] = 0x000000000
[\$t7] = 0x00000000, [\$t8] = 0x00000000, [\$t9] = 0x000000000
______
                25, CLK = 1, PC = 0 \times 000000040
[\$s0] = 0x00000037, [\$s1] = 0x00000037, [\$s2] = 0x000000000
[\$s3] = 0x00000020, [\$s4] = 0x00000001, [\$s5] = 0x00000000
[\$56] = 0x000000000, [\$57] = 0x000000000, [\$t0] = 0x000000020
[\$t1] = 0x00000037, [\$t2] = 0x00000000, [\$t3] = 0x000000000
[\$t4] = 0x00000000, [\$t5] = 0x00000000, [\$t6] = 0x000000000
[\$t7] = 0x00000000, [\$t8] = 0x00000000, [\$t9] = 0x000000000
______
                26, CLK = 0, PC = 0 \times 000000044
[\$50] = 0x00000037, [\$51] = 0x00000037, [\$52] = 0x00000000
[\$s3] = 0x00000020, [\$s4] = 0x00000001, [\$s5] = 0x00000000
[\$56] = 0 \times 000000000, [\$57] = 0 \times 000000000, [\$t0] = 0 \times 000000020
[\$t1] = 0x00000037, [\$t2] = 0x00000000, [\$t3] = 0x00000000
[\$t4] = 0x00000000, [\$t5] = 0x00000000, [\$t6] = 0x000000000
[\$t7] = 0x00000000, [\$t8] = 0x00000000, [\$t9] = 0x000000000
-----
                26, CLK = 1, PC = 0 \times 000000044
Time =
[\$s0] = 0x00000037, [\$s1] = 0x00000037, [\$s2] = 0x000000000
[\$s3] = 0x00000020, [\$s4] = 0x00000001, [\$s5] = 0x00000000
[\$56] = 0 \times 000000000, [\$57] = 0 \times 000000000, [\$t0] = 0 \times 000000020
[\$t1] = 0x00000037, [\$t2] = 0x00000000, [\$t3] = 0x000000000
```

```
[\$t4] = 0x00000000, [\$t5] = 0x00000000, [\$t6] = 0x000000000
[\$t7] = 0 \times 000000000, [\$t8] = 0 \times 000000000, [\$t9] = 0 \times 000000000
Time =
                27, CLK = 0, PC = 0 \times 000000048
[\$s0] = 0x00000037, [\$s1] = 0x00000037, [\$s2] = 0x00000000
[$s3] = 0x00000020, [$s4] = 0x00000001, [$s5] = 0x00000000
[$s6] = 0x00000000, [$s7] = 0x00000000, [$t0] = 0x00000020
[$t1] = 0x00000037, [$t2] = 0x00000000, [$t3] = 0x00000000
[\$t4] = 0x00000000, [\$t5] = 0x00000000, [\$t6] = 0x00000000
[\$t7] = 0x00000000, [\$t8] = 0x00000000, [\$t9] = 0x00000000
______
                27, CLK = 1, PC = 0 \times 000000048
Time =
[\$s0] = 0x00000037, [\$s1] = 0x00000037, [\$s2] = 0x00000000
[\$s3] = 0x00000020, [\$s4] = 0x00000001, [\$s5] = 0x000000000
[\$56] = 0x00000000, [\$57] = 0x00000000, [\$t0] = 0x000000020
[\$t1] = 0x00000037, [\$t2] = 0x00000000, [\$t3] = 0x00000000
[\$t4] = 0x00000000, [\$t5] = 0x00000000, [\$t6] = 0x000000000
[\$t7] = 0 \times 000000000, [\$t8] = 0 \times 000000000, [\$t9] = 0 \times 000000000
______
Time =
                28, CLK = 0, PC = 0 \times 000000038
[\$s0] = 0x00000037, [\$s1] = 0x00000037, [\$s2] = 0x00000000
[\$s3] = 0x00000020, [\$s4] = 0x00000001, [\$s5] = 0x000000000
[\$56] = 0x00000000, [\$57] = 0x00000000, [\$t0] = 0x00000020
[\$t1] = 0x00000037, [\$t2] = 0x000000000, [\$t3] = 0x000000000
[\$t4] = 0x00000000, [\$t5] = 0x00000000, [\$t6] = 0x00000000
[\$t7] = 0x00000000, [\$t8] = 0x00000000, [\$t9] = 0x000000000
______
                28, CLK = 1, PC = 0x00000038
Time =
[\$50] = 0x00000037, [\$51] = 0x00000037, [\$52] = 0x000000000
[\$s3] = 0x00000020, [\$s4] = 0x00000001, [\$s5] = 0x000000000
[\$56] = 0 \times 000000000, [\$57] = 0 \times 000000000, [\$t0] = 0 \times 000000020
[\$t1] = 0x00000037, [\$t2] = 0x00000000, [\$t3] = 0x00000000
[\$t4] = 0x00000000, [\$t5] = 0x00000000, [\$t6] = 0x000000000
[\$t7] = 0 \times 00000000, [\$t8] = 0 \times 00000000, [\$t9] = 0 \times 00000000
______
                29, CLK = 0, PC = 0x0000003c
[\$s0] = 0x00000037, [\$s1] = 0x00000037, [\$s2] = 0x000000000
[\$s3] = 0x00000020, [\$s4] = 0x00000001, [\$s5] = 0x000000000
[\$56] = 0 \times 000000000, [\$57] = 0 \times 000000000, [\$t0] = 0 \times 000000020
[\$t1] = 0x00000037, [\$t2] = 0x00000000, [\$t3] = 0x000000000
[\$t4] = 0x00000000, [\$t5] = 0x00000000, [\$t6] = 0x00000000
[\$t7] = 0x00000000, [\$t8] = 0x00000000, [\$t9] = 0x000000000
______
                29, CLK = 1, PC = 0 \times 00000003c
Time =
[\$s0] = 0x00000037, [\$s1] = 0x00000037, [\$s2] = 0x00000037
[\$s3] = 0x00000020, [\$s4] = 0x00000001, [\$s5] = 0x000000000
[\$56] = 0 \times 000000000, [\$57] = 0 \times 000000000, [\$t0] = 0 \times 000000020
```

```
[$t1] = 0x00000037, [$t2] = 0x00000000, [$t3] = 0x000000000
[$t4] = 0x000000000, [$t5] = 0x00000000, [$t6] = 0x000000000
[$t7] = 0x000000000, [$t8] = 0x000000000, [$t9] = 0x000000000
```
