Computer Organization, Spring 2018

Lab 4: Single Cycle CPU II

Due : 2018/05/21

1. Goal

Based on Lab 3 (simple single-cycle CPU), add a memory unit to implement a complete single-cycle CPU which can run R-type, I-type and jump instructions.

2. Demands

A. Please use ModleSim as your HDL simulator.

B. **One person forms a group.** Please attach your names and student IDs as comments in the top of each file. (Ex. 0516001.zip) The type of compressed file must be “zip”. **Other form of file will get -10%**. The assignment you upload on E3 must have the form of "Lab4_student ID.zip".

C. Data Memory, and Test Bench are supplied.

D. Refer to Lab 3 for top module’s name and IO ports.
Initialize the stack pointer (i.e., Reg_File[29]) to 128, and other registers to 0
Decoder may add control signals:
-Branch_o
-Jump_o
-MemRead_o
-MemWrite_o
-MemtoReg_o

3. Requirement description

A. Basic instruction:

Lab 3 instruction + lw、sw、beq、bne、j

Format:

R-type

Op[31:26]	Rs[25:21]	Rt[20:16]	Rd[15:11]	Shamt[10:6]	Func[5:0]

I-type

Op[31:26]	Rs[25:21]	Rt[20:16]	Immediate[15:0]

Jump

Op[31:26]	Address[25:0]

Definition:

lw instruction :

memwrite is 0，memread is 1，regwrite is 1

Reg[rt] ← Mem[rs+imm]

sw instruction :

memwrite is 1，memread is 0

Mem[rs+imm] ← Reg[rt]

branch instruction :

branch is 1，and decide branch or not by do AND with the zero signal from ALU

beq:

if (rs==rt) then PC=PC+4+ (sign_Imm<<2)

bne:

if (rs!=rt) then PC=PC+4+ (sign_Imm<<2)

Jump instruction :

jump is 1

PC={PC[31:28], address<<2}

Op field:

instruction	Op[31:26]
lw	6’b100001
sw	6’b100011
beq	6’b111011
bne	6’b100101
jump	6’b100010

Extend ALUOp from 2-bit to 3-bit: (You can modify this if necessary)

instruction	ALUOp
R-type	010
addi	100
lui	101
lw、sw	000
beq	001
bne	110
jump	x

B. Advance set 1:

Jal: jump and link

In MIPS, 31th register is used to save return address for function call
Reg[31] save PC+4 and perform jump

Reg[31]=PC+4
PC={PC[31:28], address[25:0]<<2}

Op[31:26]	Address[25:0]
6’b100111	Address[25:0]

Jr: jump to the address in the register rs

PC=reg[rs]
e.g.：In MIPS, return could be used by jr r31 to jump to return address from JAL.

Op[31:26]	Rs[25:21]	Rt[20:16]	Rd[15:11]	Shamt[10:6]	Func[5:0]
6’b111111	rs	0	0	0	6’b001000

C. Advance set 2:

blt (branch on less than): if(rs<rt) then branch

Op[31:26]	Rs[25:21]	Rt[20:16]	Immediate[15:0]
6’b100110	rs	rt	offset

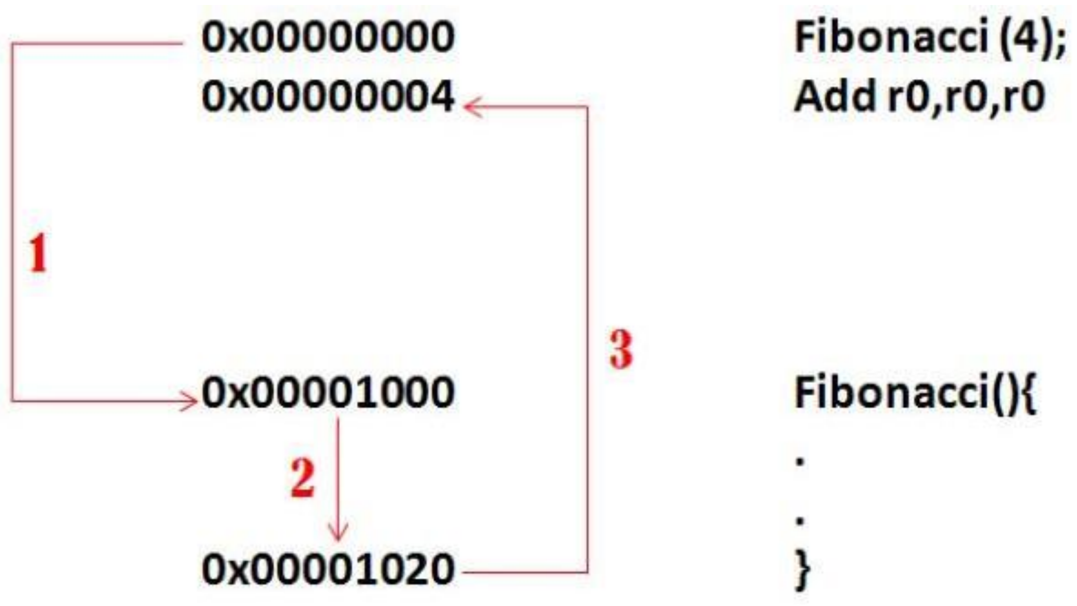
bnez (branch non equal zero): if(rs!=0) then branch (it is same as bne)

Op[31:26]	Rs[25:21]	Rt[20:16]	Immediate[15:0]
6’b101101	rs	0	offset

bgez (branch greater equal zero): if(rs>=0) then branch

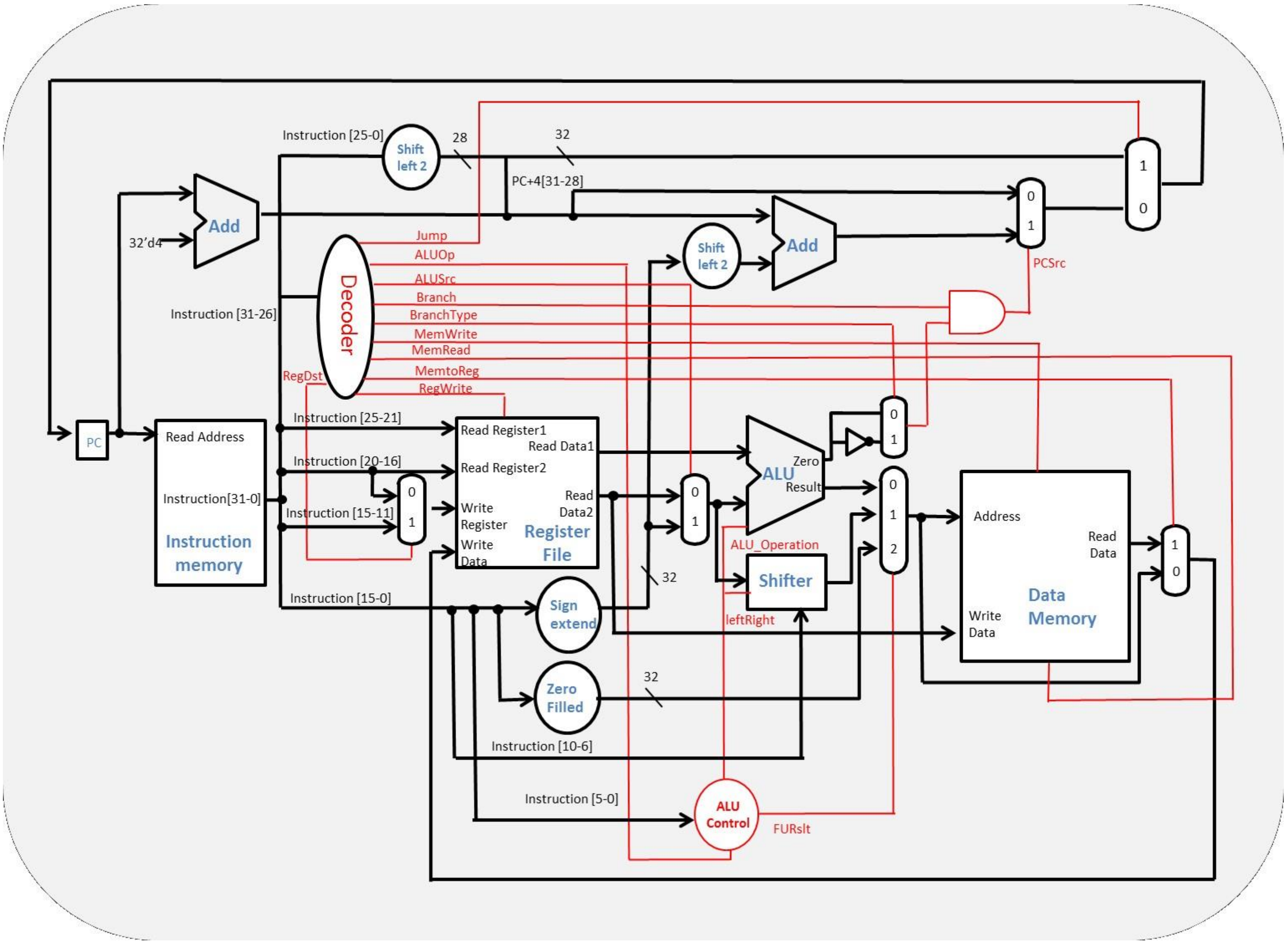
Op[31:26]	Rs[25:21]	Rt[20:16]	Immediate[15:0]
6’b110001	rs	1	offset

Example: when CPU executes function call:



if you want to execute recursive function, you must use the stack point (REGISTER_BANK [29]). First, store the register to memory and load back after function call has been finished.

4. Architecture Diagram



5. Test

Modify line 125 of TestBench.v to read different data.

CO_P4_test_data1.txt tests the basic instructions.

CO_P4_test_data2.txt tests the advanced set.

6. Bonus

Use the instructions defined in Lab3 and Lab4 to write a bubble sort program and translate it into binary code named as CO_P4_test_data3.txt.

First, use addi and sw to set memory[0]~ memory[4] in Data_Memory with values 5,4,3,2,1. After sorting, the values of memory[0]~memory[4] should be reordered from small to big.

The pseudo code of the bubble sort is given as follows:

```
function sort(list)
    for i = 0 to list.length - 1
        for j = 0 to list.length - i - 1
            if list[j] > list[j+1]
                swap (list[j], list[j+1])
            end if
        end for
    end for
end function
```

You don’t need to write the function type and may only accomplish the loop part.

7. Grade

a. Total score: 120pts. COPY WILL GET A 0 POINT!

b. Instruction score: Total 80 pts –

   basic instructions: 65 pts

   advanced set 1: 10 pts

   advanced set 2: 5 pts

c. Report: 20 pts – format is in CO_document. (up to 2 pages)

d. Bonus: 20 pts

8. Hand in your assignment

Please upload the assignment to the E3.

Put all files (includes CO_P4_test_data3.txt if you have done it) and report into same compressed file.

(Use Lab4_student ID.zip to be the name of your compressed file)

9. Q&A

If you have any question, just send email to TAs.