

Laboratory 6

(Due date: **002**: April 10th, **003**: April 11th)

OBJECTIVES

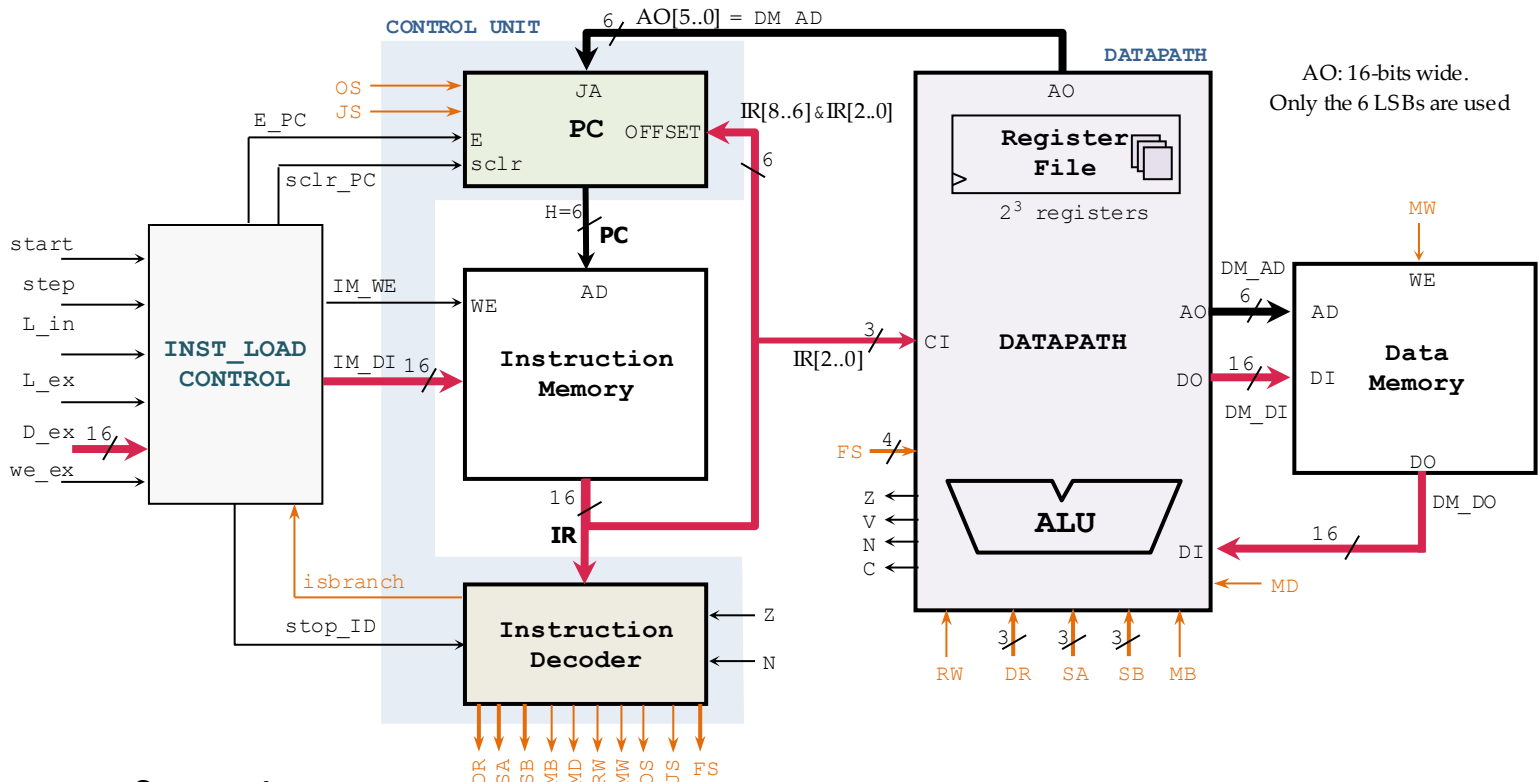
- ✓ Design a 16-bit microprocessor with Single-Cycle Hardwired Control.
- ✓ Implement an Instruction Set.

VHDL CODING

- ✓ Refer to the [Tutorial: VHDL for FPGAs](#) for a tutorial and a list of examples.

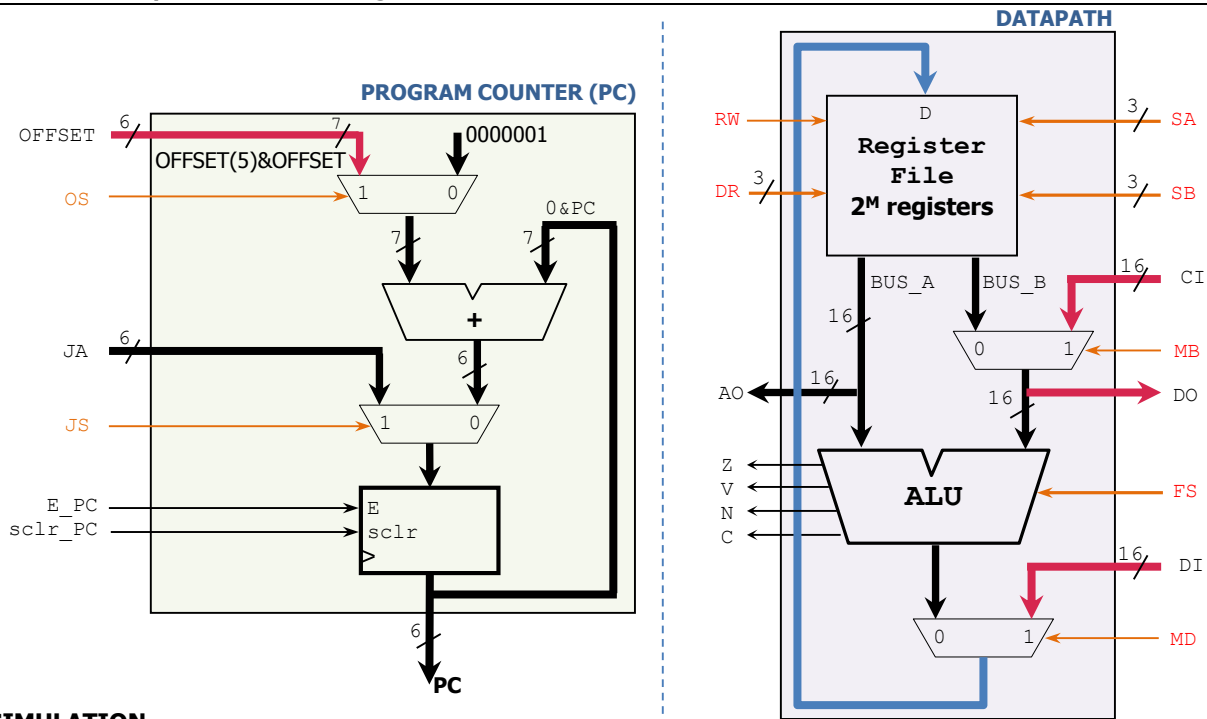
FIRST ACTIVITY: 16-BIT MICROPROCESSOR DESIGN AND SIMULATION (100/100)

- Implement the **Simple Computer** (see Notes – Unit 6): uP with 6-bit IM/DM address, 16-bit instructions, and 16-bit data.



Components:

- ✓ DM, IM: 64 words, 16 bits per word. Use the files RAM_emul.vhd, my_rege.vhd. (set the proper parameters).
- ✓ Datapath:
 - Register File: 8 registers (R0 – R7) are included. See Notes – Unit 6 for an example with 4 registers.
 - ALU: Use the files: alu.vhd, alu_arith.vhd, alu_logic.vhd, super_addsub.vhd, fulladd.vhd.
- ✓ PC: Note that OFFSET is a 6-bit signed number. The adder uses 7 bits, from which we only retrieve the 6 LSBs.
- ✓ Instruction Decoder (ID): This is a large combinational circuit. The outputs depend directly on the inputs.
 - The outputs are generated based on the instructions on IR (Instruction Register).
 - Instruction Set: For the list of instructions, refer to Notes – Unit 6. The Instruction Set does not include instructions that read the V and C bits. Thus, the ID does not consider these two bits.
 - stop_ID: This input signal causes all the ID outputs to be '0' if stop_ID=1.
 - isbranch: If the instruction in IR is a branch or jump instruction, this signal is set to '1'.
- ✓ Instruction Load Control: This component is required in order to write instructions on the IM, and then to trigger program execution. Use the file instload_ctrl.vhd. This circuit is a FSM that works as follows:
 - To store instructions on IM from an external port, assert L_ex and then use the inputs D_ex and we_ex.
 - To store instructions on IM using pre-stored hardwired data, assert L_in.
 - Once instructions are written on the IM, program execution is started by asserting start for a clock cycle. The step signal controls whether to enable program execution (step=1) or disable it (step=0).



SIMULATION

- We will execute the following pre-stored program (counter from 2 to 13): (see instload_ctrl.vhd). Note that the count appears on R0.

Address	Assembly Program	VHDL code snippet
000000	start: LDI R3,4	CD (0) <= "1001100011---100";
000001	LDI R0,2	CD (1) <= "1001100000---010";
000010	LDI R1,7	CD (2) <= "1001100001---111";
000011	ADI R1,R1,4	CD (3) <= "1000010001001100";
000100	loop: ADI R0,R0,1	CD (4) <= "1000010000000001";
000101	DEC R1,R1	CD (5) <= "0000110001001---";
000110	BRZ R1,-5	CD (6) <= "1100000111001011";
000111	JMP R3	CD (7) <= "1110000---011---";
001000		...
...		

- Tesbench:
 - ✓ Set L_in=1 for a clock cycle. Then wait about 70 cycles for the program to be written on the Instruction Memory.
 - ✓ Set start=1 for a clock cycle. Make sure that step = 1 during the execution of the program.
 - Circuit verification: To see if the instructions are processed in the right order, take a look at PC and IR. Then, to check the outputs, observe the R0-R7 values and then focus on other signals such as the ID outputs.
- Design Flow and verification:
 - ✓ Write the VHDL for the given circuit. Synthesize your circuit. (Run Synthesis).
 - ✓ Perform Functional Simulation (Run Simulation → Run Behavioral Simulation). **Demonstrate this to your TA.**
- Submit (as a .zip file) the generated files: VHDL code and VHDL testbench to Moodle (an assignment will be created). DO NOT submit the whole Vivado Project.

🌟 You can work in teams of up to two (2) students. Only one Moodle submission per team.

TA signature: _____

Date: _____