# Computer Organization Lab 2

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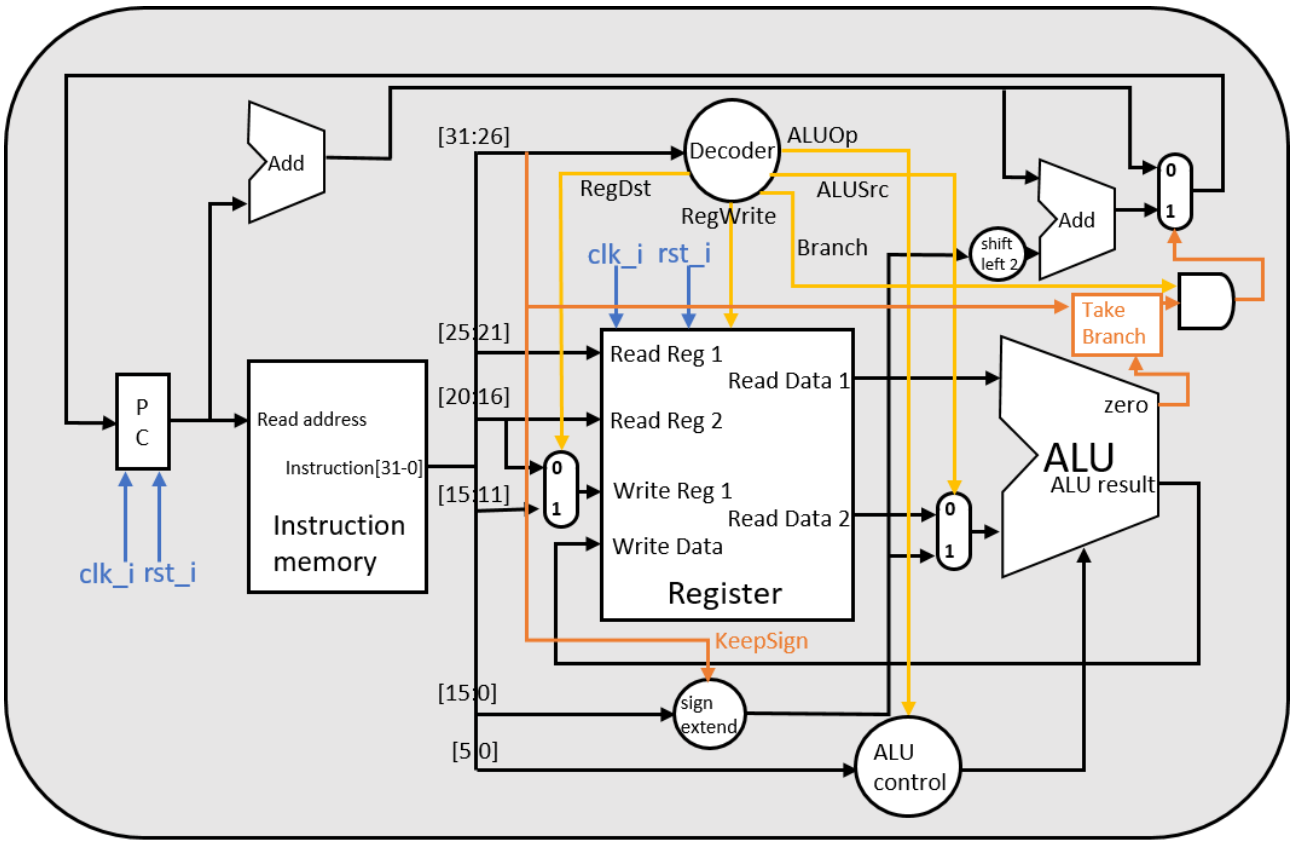
## Architecture Diagram




Top module: Simple_Single_CPU

## Detailed Description of the Implementation

- ALU Operations (input [3:0] ALU_op_i)
  Case (ALU_op_i)
  - 0: src1_i & src2_i
  - 1: src1_i | src2_i
  - 2: src1_i + src2_i
  - 6: src1_i - src2_i
  - 7: src1_i < src2_i
  - 12: ~(src1_i | src2_i)
  - 14: src2_i_signed >>> src1_i_signed
  - 15: src2_i << 16

- ALU Control (input [5:0] funct_i)
  Case (funct_i)
    - 3: ALUCtrl_o = 14; // SRA
    - 7: ALUCtrl_o = 14; // SRAV
    - 32: ALUCtrl_o = 2; // ADD
    - 34: ALUCtrl_o = 6; // SUB
    - 36: ALUCtrl_o = 0; // AND
    - 37: ALUCtrl_o = 1; // OR
    - 42: ALUCtrl_o = 7; // SLT
- Decoder Output Signals (input [4:0] instr_op_i;)
    - *RegWrite* = 1, if instr_op_i ∈ {0, 35, 8, 9, 15, 13}
      R-type, Load, ADDI, SLTIU, LUI, ORI
      -> Need to write result to some register
    - *ALU_op* =
      (instr_op_i == 35 || instr_op_i == 43) ? 2 : // Load or Store -> add
      (instr_op_i == 4 ? 6 : // Branch -> sub
      (instr_op_i == 8 ? 2 : // ADDI -> add
      (instr_op_i == 9 ? 7 : // SLTIU -> lt
      (instr_op_i == 13 ? 1 : // ORI -> or
      (instr_op_i == 15 ? 15: // LUI -> Left shift immediate by 16
      4'b1111))))); // Else -> check with funct in instruction
    - *ALUSrc* = 1, if instr_op_i ∈ {35, 43, 8, 9, 15, 13}
      Load, Store, ADDI, SLTIU, LUI, ORI
      -> Multiplexer selects [15:0] as the second ALU source
    - *RegDst* = 1, if instr_op_i == 0
      R-type
      -> Multiplexer selects [15:11] as the register to write to
    - *Branch* = 1, if instr_op_i ∈ {4, 5}
      BEQ, BNE
- Simple_Single_CPU
    - *keep_sign* (*KeepSign*) = 1, if inst[31:26] ∈ {9, 13}
      Keep sign (Zero-extend) if op is SLTIU, ORI
    - Assign shamt ([10:6]) as the first ALU source if op is SRA

- *TakeBranch* =
  BEQ -> Zero
  BNE -> !Zero

## Problems Encountered and Solutions

- Errors related to timing (eg. results come 1 clock cycle later)
  Solution: Change all nonblocking assignments to blocking assignments.

- General debugging difficulties
  Debugging is a pain throughout the implementation.
  Solution: Declare an always block and use $display to see the contents in the variables during simulation (evaluation).

```
always @(*) begin
   $display("%b", inst);
   // $display("addr_nxt1 = %d, addr_nxt2 = %d, addr = %d, addr_nxt = %d", addr_nxt1,
addr_nxt2, addr, addr_nxt);
   $display("%b", RegWrite);
   // $display("%b %b", RegRead1, reg_read1);
   $display("%d %d => %d ", reg_data1, reg_data2, res_alu);
end
```

## Lesson Learned (If Any)

- Debugging is surprisingly difficult with so many modules in 1 place.
  Next time it's probably wise to test individual components first, but even that would be kind of troublesome.

- Read the samples first to make sure that I truly understand the MIPS operations.