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**ECE-111 Advanced Digital Design Projects**

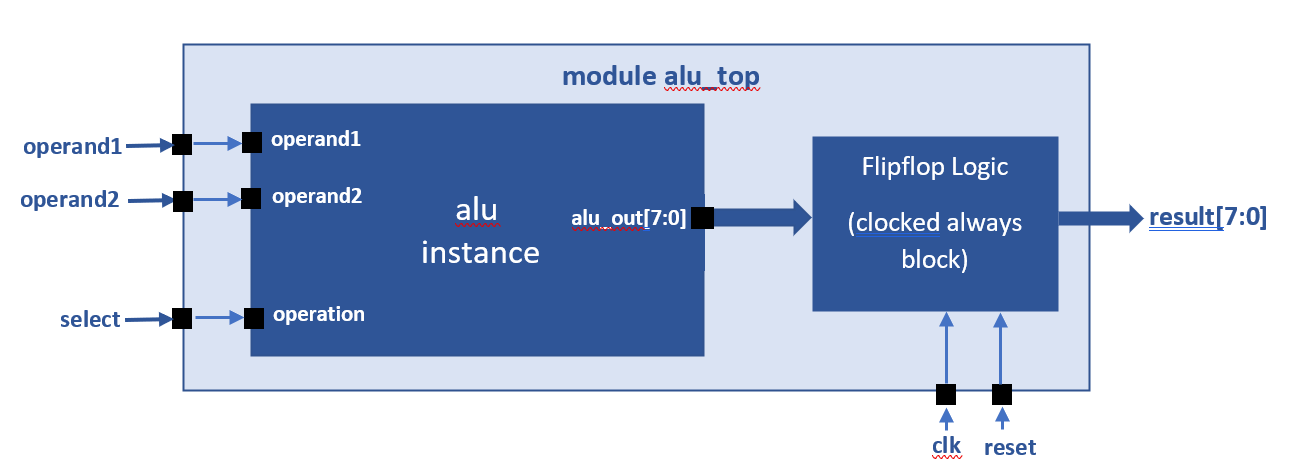
* **Objective of Homework-2:** Learn how to create parameterized modules, how to instantiate a module in another module, how to connect primary ports of two modules using explicit name based binding approach. Learn functional behavior of SystemVerilog arithmetic and logical operators and understand hardware generated for each of the operator post synthesis. Observe change in value of signals in sensitivity list of always block how it impacts the behavior of the circuit.

**Homework-2a**

* Design synthesizable SystemVerilog Model of 4-bit ALU (Arithmetic Logic Unit) which can perform following mentioned functions:

|  |  |  |
| --- | --- | --- |
| **Operation Select** | **Function** | **Function Definition** |
| 4'b0000 | operand1 + operand2 | Addition |
| 4'b0001 | operand1 - operand2 | Subtraction |
| 4'b0010 | operand1 \* operand2 | Multiplication |
| 4'b0011 | operand1 % operand2 | Division |
| 4'b0100 | operand1 / operand2 | Modulo |
| 4'b0101 | operand1 & operand2 | Bitwise AND |
| 4'b0110 | operand1 | operand2 | Bitwise OR |
| 4'b0111 | operand1 ^ operand2 | Bitwise XOR |
| 4'b1000 | operand1 && operand2 | Logical AND |
| 4'b1001 | operand1 || operand2 | Logical OR |
| 4'b1010 | operand1 << 1 | Left Shift by 1 |
| 4'b1011 | operand1 >> 1 | Right Shift by 1 |
| 4'b1100 | operand1 == operand2 | Logical Equality |
| 4'b1101 | operand1 != operand2 | Logical Inequality |
| 4'b1110 | operand1 < operand2 | Less Than Comparison |
| 4'b1111 | operand1 > operand2 | Greater Than Comparison |

**Block Diagram of alu\_top block**



* Create module with name "alu"
  + Declare 4-bit logic type input primary ports: operand1, operand2, operation
  + Declare 8-bit logic type output primary alu\_out
  + Declare parameter "N" with default value set as 4. N is used when declaring width of operand1 and operand2 primary ports
  + Use always block with operation, operand1, operand2 in its sensitivity list
  + Within always procedural block, use "case" statement to select between alu operations
  + Ensure default case expression is provided with addition operation
* Create another module alu\_top
  + Declare 4-bit logic type input primary ports: operand1, operand2, select
  + Declare 8-bit logic type output primary result
  + Instantiate alu module inside module alu\_top
  + In instance of alu, connect primary ports of alu\_top with alu primary ports using explicit name based binding approach
  + Add positive edge triggered flipfop at the output of alu

**Note:** flipflop logic is already implemented in alu\_top template code provided in lab folder

* Perform synthesis of alu\_top and alu module
  + Review resource usage report, RTL Netlist and Post Mapping Schematics
* Perform simulation of alut\_top using alu\_top\_testbench provided in lab folder
  + Review all 16 ALU operation results in waveform
  + Observe functional behavior of all ALU operations. Especially review the difference between logical and bitwise and / or operations

**Homework Submission:**

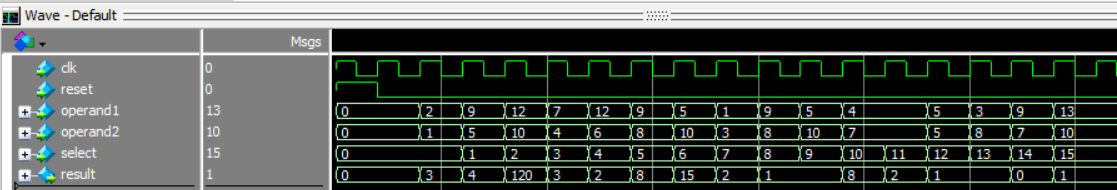
**Submit report (PDF file) which should include:**

* SystemVerilog code snapshot of module alu\_top and alu
* Provide snapshot of FPGA resource usage generated post synthesis
* Provide snapshot of schematic generated from RTL netlist viewer
* Provide snapshot of simulation waveform and explain simulation result

**Note:** Lab2.zip folder has following mentioned files:

* alu\_top.sv template code
* alu.sv template code
* alu\_top\_testbench.sv with full testbench implementation

**Reference Simulation Snapshot**



**Homework-2b**

**Develop synthesizable SystemVerilog code for 4-bit up down binary counter. Refer to below mentioned block diagram of up\_down\_counter when developing SystemVerilog code.**

**module up\_down\_counter**

**count[3:0]**

**up\_count\_value[3:0]ount**

mux\_2x1

instance

**clk**

up\_counter

instance

**in0[3:0]**

**clk**

**clear**

**out[3:0]**

**count\_value[3:0]**

**clear**

**clk**

down\_counter

instance

**sel**

**down\_count\_value[3:0]]ount**

**count [3:0]**

**in1[3:0]**

**clear**

**select**

* In up\_down\_counter there are two separate counters. These are :
  + 4-bit up counter which counts values from 0 to 15 in increment by 1 each clk cycle
  + 4-bit down counter which counts values from 15 to 0 in decrement by 1 each clk cycle
* Output of both up and down counters are connected to inputs of a 2-to-1 Multiplexer
  + When "select" input port of up\_down\_counter module is driven to '0' then output of multiplexer should reflect up\_counter count values (i.e. 0 to 15 count values)
  + When "select" input port of up\_down\_counter module is driven to '1' then output of multiplexer should generate down\_counter count values (i.e. 15 to 0 values)
* Review code for up\_counter module in up\_counter.sv file and using it as a reference update down\_counter module in down\_counter.sv file with required modification
* Review mux\_2to1.sv file and make update width of it primary ports in0, in1 and out to 4 bits
* Instantiate up\_counter, down\_counter and mux\_2x1 modules inside up\_down\_counter module and connect the ports of modules using explicit name based binding approach
  + Output count port from up\_counter and down\_counter should be connected to mux\_2x1 in0 and ini1 ports using wires up\_count\_value and down\_count\_value
  + Output out port of mux should be connected to primary port result of up\_down\_counter
  + Primary input port select of up\_down\_counter should be connected to sel port of mux\_2x1
  + Primary input port clk and clear should be connected to clk and clear ports of up\_counter and down\_counter
* Synthesize up\_down\_counter top level module along with sub-modules up-counter, down\_counter, mux\_2to1
* Review synthesis results (resource usage and RTL netlist/schematic)
* Run simulation using up\_down\_counter testbench code provided in Lab2 folder
* Review up down counter input output signals in simulation waveform

**Homework Submission**

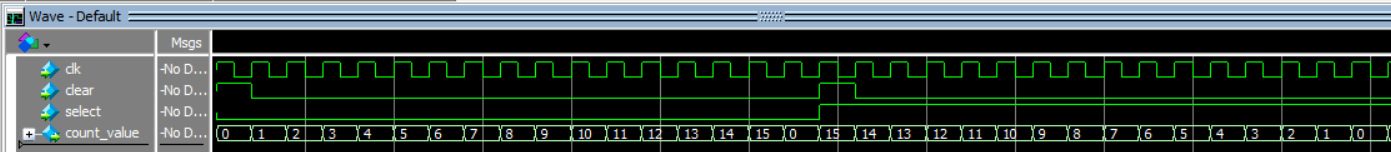
**Submit report (PDF file) which should include:**

* up\_down\_counter, up\_counter, down\_counter, mux\_2x1 SystemVerilog code
* Provide snapshot of FPGA resource usage generated post synthesis
* Provide snapshot of schematic generated from RTL netlist viewer
* Provide snapshot of simulation waveform and explain simulation result

**Note:** Lab2.zip folder has following mentioned files:

* up\_down\_counter.sv template code
* down\_coutner.sv with partial code
* up\_counter.sv with full implementation
* mux2to1.sv with full implementation
* up\_down\_counter\_testbench.sv with full testbench implementation

**Reference Simulation Snapshot**

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**When select ==1, down counter counting from 15 to 0**

**When select == 0, up counter counting from 0 to 15**