香港中文大學
The Chinese University of Hong Kong

CENG3430 Rapid Prototyping of Digital Systems

Lecture 12: VHDL versus Verilog

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Outline

- **VHDL** vs. **Verilog**
  - Background
  - Syntax and Popularity
  - Operators
  - Overall Structure
  - External I/O Declaration
  - Concurrent Statements
  - Sequential Statements
    - Edge Detection
  - Wire vs. Reg
  - Structural Design
  - Design Constructions
  - Case Study: Flip-flop

VHDL
Very High Speed Integrated Circuit
Hardware Description Language

What are VHDL and Verilog?

VHDL

Very High Speed Integrated Circuit
Hardware Description Language

- They are both hardware description languages for modeling hardware.
- They are each a notation to describe the behavioral and structural aspects of an electronic digital circuit.

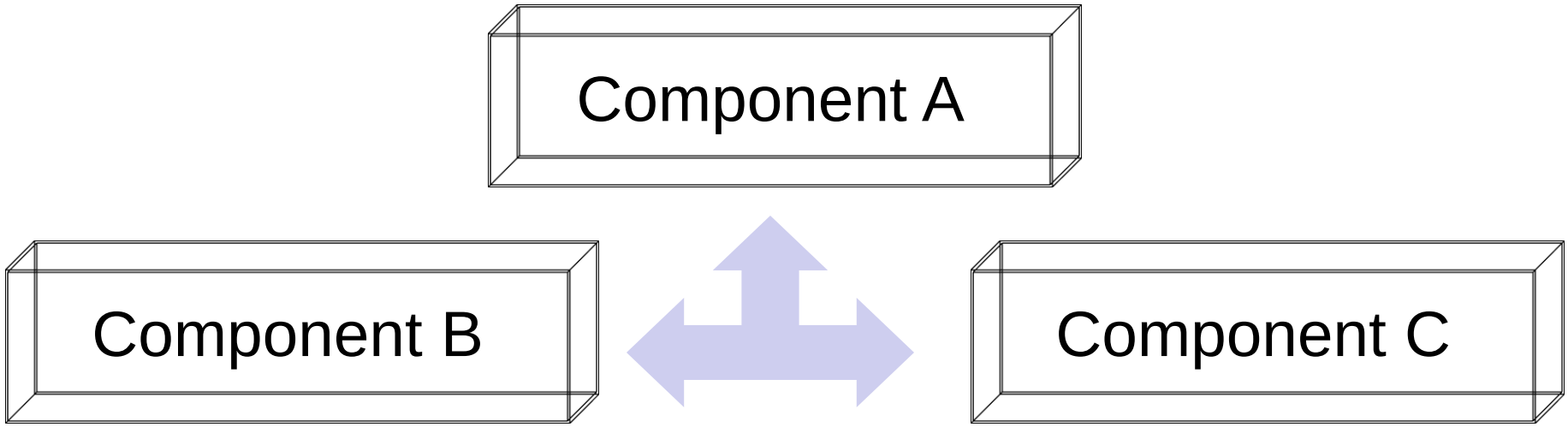
VHDL: Background

- **V**HSIC **H**ardware **D**escription **L**anguage
  - VHSIC: Very High Speed Integrated Circuit.
- Developed by **Department of Defense** (1981)
  - In 1986 rights where given to **IEEE**.
  - Became a standard and published in 1987.
  - Revised standard we know now published in 1993 (VHDL 1076-1993) regulated by VHDL international (VI).

VHDL
Very High Speed Integrated Circuit
Hardware Description Language

VHDL: Design Concept

- VHDL uses top-down approach to partition a design into small building blocks (i.e., **`components`**).
  - **Entity**: Describe interface signals and basic building blocks.
  - **Architecture**: Describe behavior, each entity can have multiple Architectures.



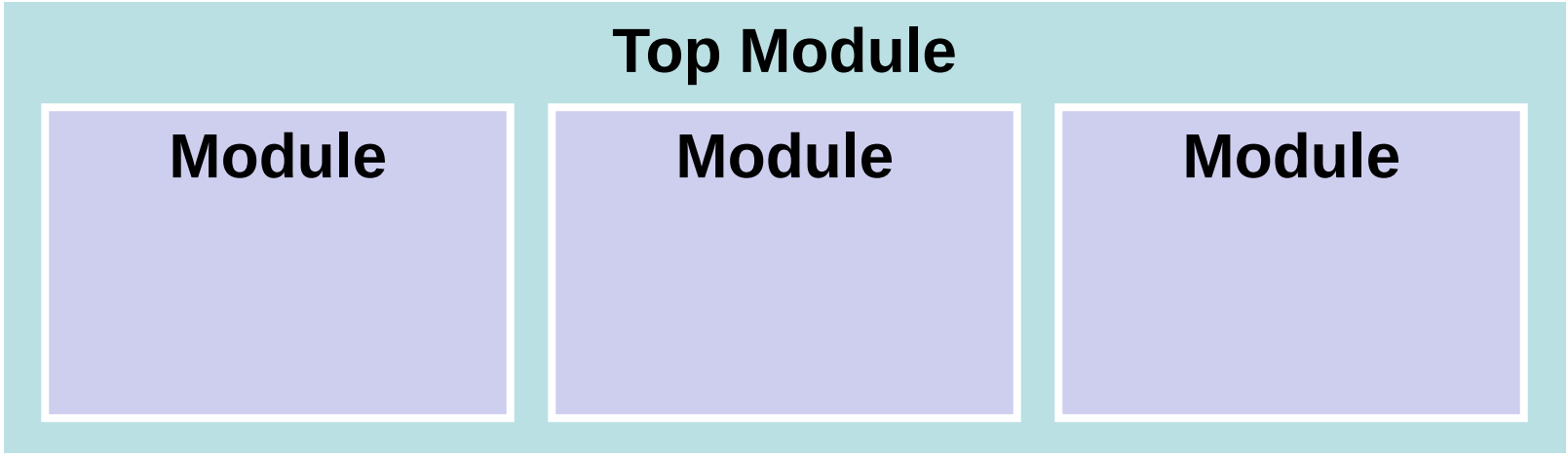
Connected by **`port map`** in architecture body

Verilog: Background

- Developed by **Gateway Design Automation** (1980)
  - Later acquired by **Cadence Design** (1989) who made it public in 1990
  - Became a standardized in 1995 by **IEEE** (Std 1364) regulated by Open Verilog International (OVI)

Verilog: Design Concept

- The building block in Verilog is called **`module`**.
  - There is only one module per file (**.v**) usually.
  - Modules connect through their ports (similarly as in VHDL).
  - A top level module invokes instances of other modules.



Connected by relating I/O and internal wires

Syntax and Popularity

VHDL
Very High Speed Integrated Circuit
Hardware Description Language

Verilog HDL

Popularity	
VHDL is more popular with European companies.	**Verilog** is more popular with US companies.

Programming Style (Syntax)	
VHDL is similar to Ada programming language.	**Verilog** is similar to C/Pascal programming language.
VHDL is NOT case-sensitive.	**Verilog** is case-sensitive.
VHDL is more "verbose" than **Verilog**.	

Operators

	VHDL	Verilog		VHDL	Verilog
Add	+	+	Bitwise Negation	not	~
Subtract	-	-	Bitwise NAND	nand	~&
Multiplication	*	*	Bitwise NOR	nor	~|
Division	/	/	Bitwise XNOR	xnor	~^
Modulo	mod	%	Greater (or Equal)	>, >=	>, >=
Absolute	abs	N/A	Less (or Equal)	<, <=	<, <=
Exponentiation	**	**	Logical Equality	=	==
Concatenation	&	{ , }	Logical Inequality	/=	!=
Left Shift	sll	<<	Logical AND	and	&&
Right Shift	srl	>>	Logical OR	or	||
Bitwise AND	and	&	Logical Negation	not	!
Bitwise OR	or	|	Case Equality	N/A	===
Bitwise XOR	xor	^	Case Inequality	N/A	!==

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VHDL
Very High Speed Integrated Circuit Hardware Description Language

Overall Structure

VHDL (.vhd)

```
-- Library Declaration
library IEEE;
...
-- Entity Declaration
entity mux is
...
end mux
-- Architecture Body
architecture arch of mux is
begin
...
end arch;
```

Verilog (.v)

```
// One Module
module mux ( ... );
...
endmodule
```

External I/O Declaration

VHDL

```
-- Library Declaration
…
-- Entity Declaration
entity mux is
port(a,b,s: in std_logic;
     y: out std_logic);
end mux
-- Architecture Body
architecture arch of mux is
begin
...
end arch;
```

Verilog

```
// One Module
module mux (a, b, s, y);
input a,b,s;
output y;
...
endmodule
```

Concurrent & Sequential Statements

VHDL

```
-- Entity Declaration
entity mux is
port(a,b,s: in std_logic;
     y: out std_logic);
end mux
architecture arch of mux is
begin
-- concurrent statements
process (...) begin
  -- sequential statements
end process;
end arch;
```

Verilog

```
// One Module
module mux (a, b, s, y);
input a,b,s;
output y;
-- concurrent statements
always @(...)
begin
  -- sequential statements
end process;
endmodule
```

1) Concurrent Statement

VHDL: *inside architecture body, outside the process*

```
signal a, b: std_logic_vector(7 downto 0); -- array
signal c, d, e: std_logic;
a(3 downto 0) <= b(7 downto 4);
b(7 downto 4) <= "0000";
c <= d and e; -- bitwise AND
```

LHS <= RHS;

- **LHS** must be **signal**.
- The **LHS** will be updated whenever **RHS** changes.

Verilog: *outside the always@ block*

```
wire [7:0] a, b; // array
wire c, d, e;
assign a[3:0] = c[7:4];
assign b[7:4] = 'b0000; // binary
assign c = d & e; // bitwise AND
```

assign LHS = RHS;

- **LHS** must be **wire**.
- The **LHS** will be updated whenever **RHS** changes.

Class Exercise 12.1

Student ID: _____ Date:
Name: _____ _____

- Translate the following VHDL program to Verilog:

```
library IEEE;
use IEEE.STD_LOGIC_1164.ALL;
entity abc is
  port (a,b,c: in std_logic;
        y: out std_logic);
end abc;
architecture abc_arch of
abc is
signal x : std_logic;
begin
  x <= a nor b;
  y <= x and c;
end abc_arch;
```

2) Sequential Statement

VHDL

```
architecture arch of ex is
begin
process( sensitivity list )
variable a, b, c;
begin
   -- LHS could be signals
      (suggested) or variables
   -- signal assignment (<=)
      for both combinational logic
      and sequential logic
   -- variable assignment (:=)
end;
end arch;
```

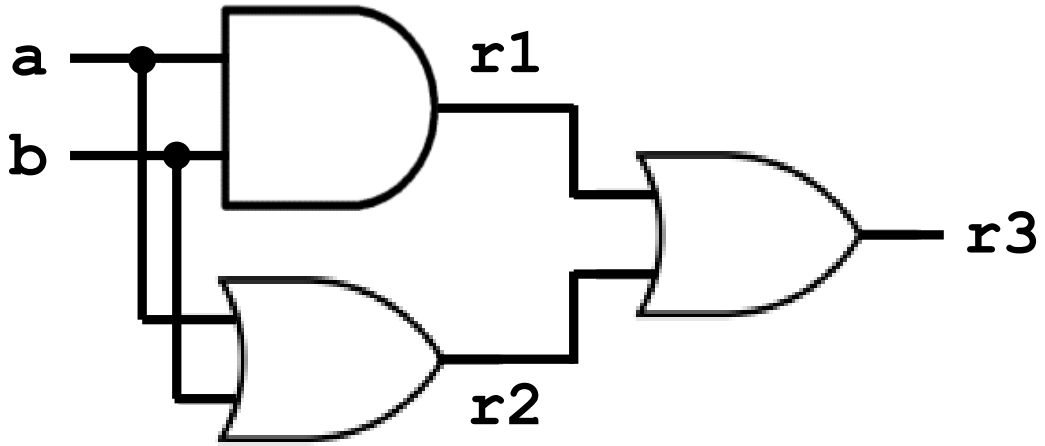
Verilog

```
module ex (…);
reg a, b, c;
always @ ( conditions )
begin
   // LHS must be reg (not wire)
   // blocking assignment (=)
      for combinational logic
   // non-blocking assignment
      (<=) for sequential logic
end
endmodule
```

2) Sequential Statements: Blocking

- **Blocking assignments (=)** in a sequential block (i.e., `always@`) are executed before the execution of the statements that follow it.
  - All blocking assignments are executed in a sequentially way.
- **Usage**: Use blocking assignments in **`always@`** blocks to synthesize combinational logic (i.e. no clock!).

```
reg r1, r2, r3;
...
always @ (a or b)
begin
   r1 = a & b;
   r2 = a | b;
   r3 = r1 | r2;
end
```



Class Exercise 12.2

Student ID: _____ Date:
Name: _____ _____

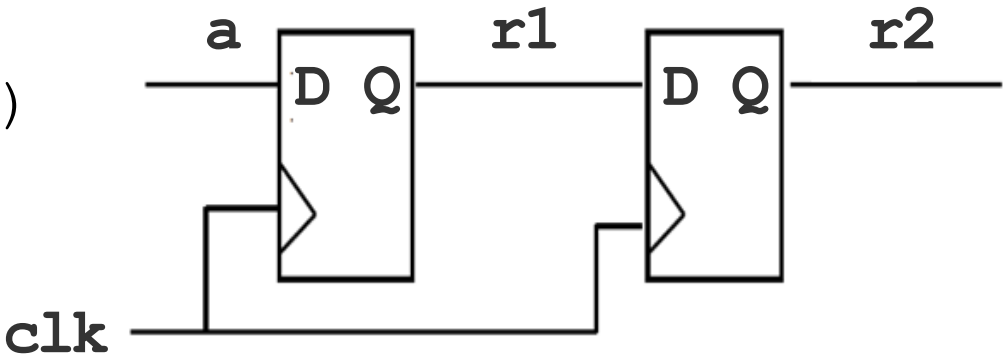
- Translate the following Verilog program to VHDL:

```
reg r1, r2, r3;
...
always @ (a or b)
begin
   r1 = a & b;
   r2 = a | b;
   r3 = r1 | r2;
end
```

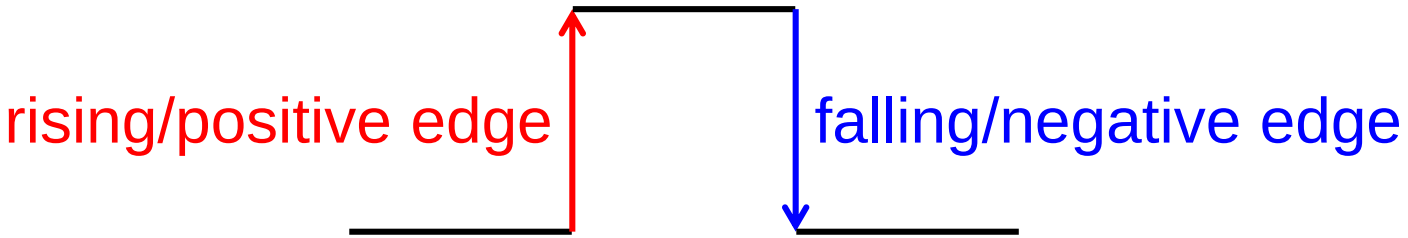
2) Sequential Statements: Non-Blocking

- **Non-blocking assignments (<=)** in a sequential block (i.e., `always@`) are executed within the same time step regardless of the order.
  - All non-blocking assignments will take effect at the next clock edge (concurrently, not sequentially!).
- **Usage**: Use non-blocking assignments in **`always@`** blocks to synthesize sequential logic (i.e. has clock!).

```
reg r1, r2;
...
always @ (posedge clk)
begin
  r1 <= a;
  r2 <= r1;
end
```



Edge Detection



VHDL

```
process (clk)
begin
   ...
   if rising_edge(CLK)
                or
   if falling_edge(CLK)
   ...
end
```

sensitivity list

conditions

Verilog

```
always @ (posedge clk)
                or
always @ (negedge clk)
begin

   ...

end
```

conditions

Class Exercise 12.3

Student ID: _____ Date:
Name: _____ _____

- Translate the following Verilog program to VHDL:

```
reg r1, r2;
...
always @ (posedge clk)
begin
  r1 <= a;
  r2 <= r1;
end
```

"wire" vs. "reg" in Verilog

- **Wire**: Has ***no*** memory
  - It must be **physical wire** in the circuit.
  - It does ***not*** hold the value.
  - **Usage:** Cannot use "**`wire`**" in the left-hand-side of assignments inside **`always@`** blocks!

- **Reg**: Has memory
  - It could be a **flip-flop** or a **physical wire**.
  - It holds the value until a new value is assigned.
  - **Usage:** Cannot use "**`reg`**" in the left-hand side of assignments outside **`always@`** blocks (i.e., concurrent assignment)!

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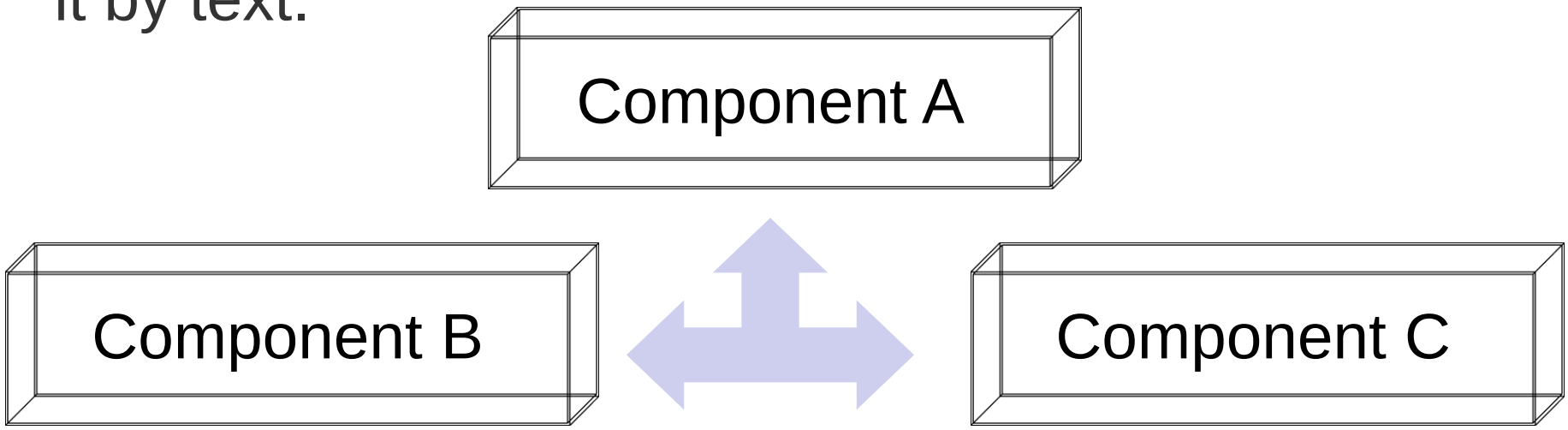
VHDL
Very High Speed Integrated Circuit
Hardware Description Language

Structural Design in VHDL (1/2)

- Structural Design in VHDL: Like a circuit but describe it by text.



Connected by **`port map`** in architecture body

- **Design Steps**:
  - **Step 1**: Create **`entities`**
  - **Step 2**: Create **`components`** from **`entities`**
  - **Step 3**: Use "**`port map`**" to relate the components

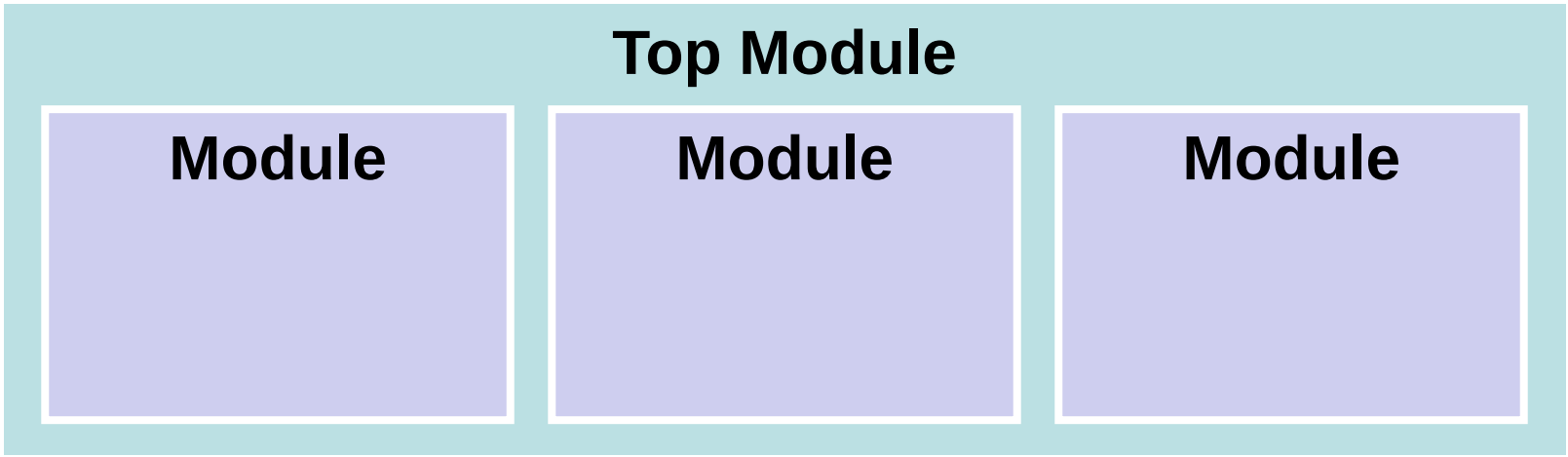
Structural Design in VHDL (2/2)

```
1  library IEEE;
2  use IEEE.STD_LOGIC_1164.ALL;
3  entity and2 is                          Step 1
4  port (a,b: in STD_LOGIC;
5          c: out STD_LOGIC );
6  end and2;
7  architecture and2_arch of and2 is
8  begin
9    c <= a and b;
10 end and2_arch;
11 ---------------------------------
12 library IEEE;
13 use IEEE.STD_LOGIC_1164.ALL;
14 entity or2 is                          Step 1
15 port (a,b: in STD_LOGIC;
16         c: out STD_LOGIC );
17 end or2;
18 architecture or2_arch of or2 is
19 begin
20   c <= a or b;
21 end or2_arch;
```

```
1  library IEEE;
2  use IEEE.STD_LOGIC_1164.ALL;
3  ---------------------------------------
4  entity test is
5  port ( in1: in STD_LOGIC; in2: in STD_LOGIC;
6         in3: in STD_LOGIC;
7        out1: out STD_LOGIC );
8  end test;
9  architecture test_arch of test is
10 component and2 --create component          Step 2
11   port (a,b: in std_logic; c: out std_logic);
12 end component ;
13 component or2 --create component
14   port (a,b: in std_logic; c: out std_logic);
15 end component ;
16 signal inter_sig: std_logic;
17 begin                                      Step 3
18   label1: and2 port map (in1, in2, inter_sig);
19   label2: or2 port map (inter_sig, in3, out1);
20 end test_arch;
```

Structural Design in Verilog (1/2)

- Structural Design in Verilog: One top module, several (sub) modules.



Connected by relating I/O and internal wires

- **Design Steps**:

  Step 1: Create (sub) **`module(s)`** (usually in separate **`.v`** files)

  Step 2: Define a **`top-module`** to interconnect **`module(s)`**

Structural Design in Verilog (2/2)

and2.v

Step 1

```
module and2(
  input a,
  input b,
  output c
  );
  assign c = a & b;
endmodule
```

or2.v

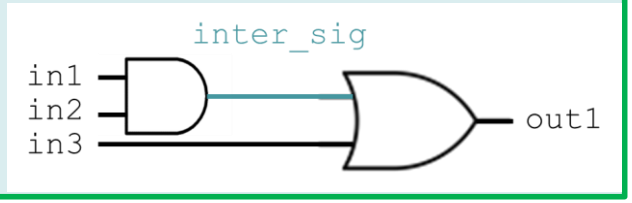
Step 1

```
module or2(
  input a,
  input b,
  output c
  );
  assign c = a | b;
endmodule
```

top_module.v

Step 2

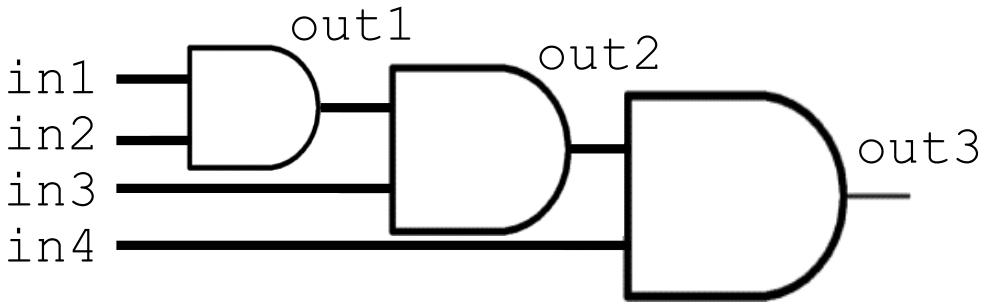
```
module top_module(
  input in1, input in2, input in3,
  output out1 );
  wire inter_sig;
  and2 and2_ins(
    .a(in1),
    .b(in2),
    .c(inter_sig)
  );
  or2 or2_ins(
    .a(inter_sig),
    .b(in3),
    .c(out1)
  );
endmodule
```



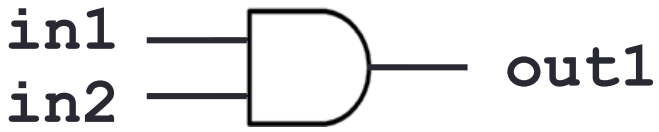
Class Exercise 12.4

Student ID: _____ Date:
Name: _____ _____

- Implement the following circuit in Veirlog:



Design Constructions (1/4)



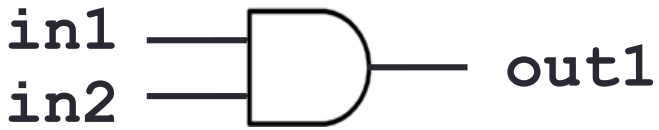
VHDL: `when-else` *(concurrent, outside* ***`process`****)*

```
architecture arch of ex is
begin
  out1 <= '1' when in1 = '1' and in2 = '1' else '0';
end arch ex_arch;
```

Verilog: `assign ? :` *(concurrent, outside* ***`always@`*** *block)*

```
module ex (...);
  assign out1 = (in1=='b1 && in2=='b1) ? 'b1 : 'b0;
  // 'b: binary; 'o: octal; 'd: decimal; 'h: hexadecimal
endmodule
```

Design Constructions (2/4)



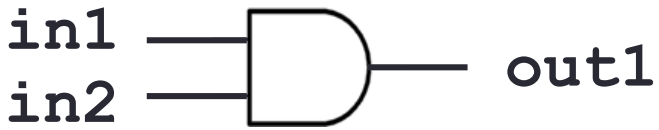
VHDL: `if-then-else`
*(sequential, inside **`process`**)*

```
process(in1, in2)
begin
  if in1='1' and in2='1'
  then
    out1 <= '1';
  else
    out1 <= '0';
  end if;
end process;
```

Verilog: `if-else`
*(sequential, inside **`always@`**)*

```
always @(in1, in2)
begin
  if (in1=='b1 && in2=='b1)
  begin
      out1 = 'b1;
  end
  else
  begin
    out1 = 'b0;
  end
end
```

Design Constructions (3/4)



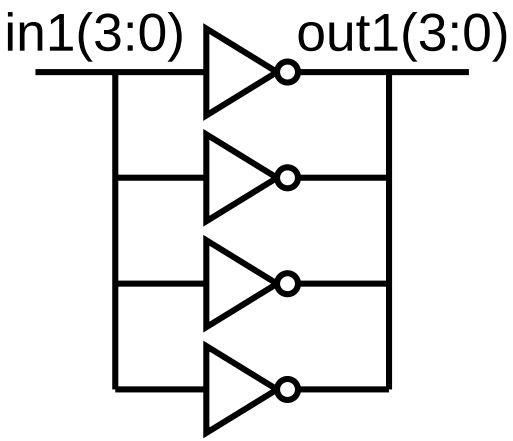
VHDL: `case-when`
*(sequential, inside **`process`**)*

```
process(b)
begin
   case b is
     when "00"|"11" =>
       out1 <= '0';
       out2 <= '1';
     when others    =>
       out1 <= '1';
       out2 <= '0';
   end case;
end process;
```

Verilog: `case`
*(sequential, inside **`always@`**)*

```
always @(b)
begin
   case (b)
     'b00 || 'b11:
       out1 = 'b0;
       out2 = 'b1;
     default:
       out1 = 'b1;
       out2 = 'b0;
   endcase
end
```

Design Constructions (4/4)



VHDL: `for-in-to-loop`
*(sequential, inside **`process`**)*

```
process(in1)
begin
  for i in 0 to 3 loop
    out1(i) <= not in1(i);
  end loop;
end process;
```

Verilog: `for-loop`
*(sequential, inside **`always@`**)*

```
always @(in1)
begin
  for(idx=0; idx<4; idx+=1)
  begin
    out1[idx] = ~in1[idx];
  end
end
```

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Posedge Flip-flop with Sync Reset (1/2)

VHDL

```
entity dff is
port(D,CLK,RESET:
     in std_logic;
     Q: out std_logic);
end dff;
architecture dff_arch of
dff is begin
  process(CLK) begin
    if rising_edge(CLK)then
      if (RESET = '1') then
        Q <= '0';
      else
        Q <= D;
      end if;
    end if;
  end process;
end dff_arch;
```

Verilog

```
module dff(
    input D,
    input CLK,
    input RESET,
    output reg Q);
always @(posedge CLK)
begin

  if (RESET) begin
    Q <= 1'b0;
  end
  else begin
    Q <= D;
  end

end
endmodule
```

Posedge Flip-flop with Sync Reset (2/2)

Verilog

```
module dff(
    input D,
    input CLK,
    input RESET,
    output reg Q);
always @(posedge CLK)
begin

  if (RESET) begin
    Q <= 1'b0;
  end
  else begin
    Q <= D;
  end

end
endmodule
```

- **`Input`** must be **`wire`**.
- **`Output`** could be either **`wire`** or **`reg`**.
  - The default option is **`wire`**.
  - But you can specify an **`output`** as **`wire`** or **`reg`** depending on how you will assign it a value.

Posedge Flip-flop with Async Reset (1/2)

VHDL

```
entity dff is
port(D,CLK,RESET:
     in std_logic;
     Q: out std_logic);
end dff;
architecture dff_arch of
dff is begin
  process(CLK,RESET) begin
    if (RESET = '1')
    then
      Q <= '0';
    elsif rising_edge(CLK)
    then
      Q <= D;
    end if;
end process;
end dff_arch;
```

Verilog

```
module dff(
    input D,
    input CLK,
    input RESET,
    output reg Q);
always @(posedge CLK or
          posedge RESET)
begin
  if (RESET) begin
    Q <= 1'b0;
  end
  else begin
    Q <= D;
  end

end
endmodule
```

Posedge Flip-flop with Async Reset (2/2)

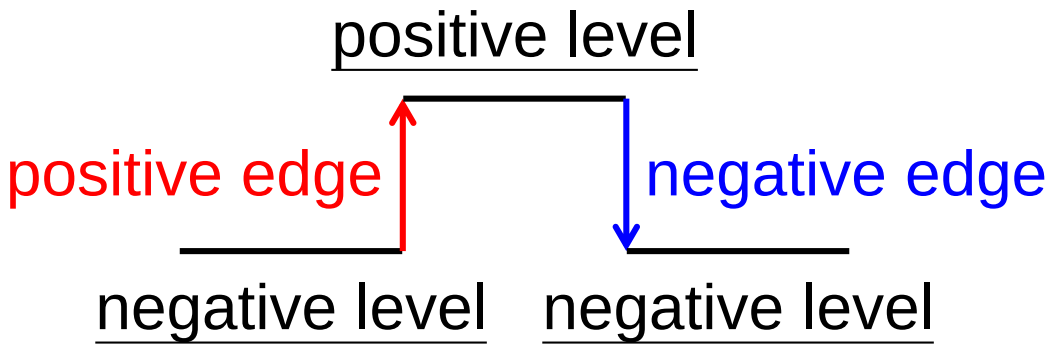
Verilog

```
module dff(
    input D,
    input CLK,
    input RESET,
    output reg Q);
always @(posedge CLK or
         posedge RESET)
begin
  if (RESET) begin
    Q <= 1'b0;
  end
  else begin
    Q <= D;
  end

end
endmodule
```

Question: What if we do not specify "**posedge**" for the **RESET** signal?

```
[Synth 8-434] mixed level sensitive and edge triggered event controls are not supported for synthesis!
```



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