Logic and Computer Design Fundamentals

Verilog

Part 1 – Chapter 4 – Basics and Types of Descriptions

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Overview

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Verilog Notation - 1

- Verilog is:
  - Case sensitive
  - Based on the programming languages C and ADA
- Comments
  - Single Line

    ```
    //                    [end of line]
    ```
  - Multiple Line

    ```
    /*
                                        */
    ```
- List element separator: `,`
- Statement terminator: `;`

Verilog Notation - 2

- Binary Values for Constants and Variables
  - `0`
  - `1`
  - `X` or `x` – Unknown
  - `Z` or `z` – High impedance state (open circuit)
- Constants
  - n′b[integer]: `1′b1 = 1, 8′b1 = 000000001, 4′b0101= 0101, 8′bxxxxxxxx, 8′bxxxx = 0000xxxx`
  - n′h[integer]: `8′hA9 = 10101001, 16′hf1= 0000000011110001`
- Identifier Examples
  - Scalar: `A,C,RUN,stop,m,n`
  - Vector: `sel[0:2], f[0:5], ACC[31:0], SUM[15:0], sum[15:0]`

Verilog Keywords & Constructs - 1

- Keywords are lower case
- `module` – fundamental building block for Verilog designs
  - Used to construct design hierarchy
  - Cannot be nested
- `endmodule` – ends a module – not a statement => no “`;`”
- Module Declaration
  - `module` *module_name* `(`*module_port*, *module_port*, …`);`
  - Example: `module full_adder (A, B, c_in, c_out, S);`

Verilog Keywords & Constructs - 2

- Input Declaration
  - Scalar
    - `input` *list of input identifiers*`;`
    - Example: `input A, B, c_in;`
  - Vector
    - `input[`*range*`]` *list of input identifiers*`;`
    - Example: `input[15:0] A, B, data;`
- Output Declaration
  - Scalar Example: `output c_out, OV, MINUS;`
  - Vector Example: `output[7:0] ACC, REG_IN, data_out;`

Verilog Keywords & Constructs - 3

- **Primitive Gates**
  - `buf, not, and, or, nand, nor, xor, xnor`
  - Syntax: *gate_operator instance_identifier* (*output, input_1, input_2, …*)
  - Examples:

```
and A1 (F, A, B); //F = A B
or O1 (w, a, b, c)
     O2 (x, b, c, d, e);     //w=a+b+c,x=b
  +c+d+e
```

Verilog Operators - 1

- **Bitwise Operators**

`~`	NOT
`&`	AND
`|`	OR
`^`	XOR
`^~` or `~^`	XNOR

- **Example:**

```
input[3:0] A, B;
output[3:0] Z ;
assign Z = A | ~B;
```

Verilog Operators - 2

- Arithmetic Operators

  `+,  -,` (plus others)

- Logical & Relational Operators

  !, &&, | |, = =, !=, >=, <=, >, < (plus others)

- Concatenation & Replication Operators

  {identifier_1, identifier_2, …}

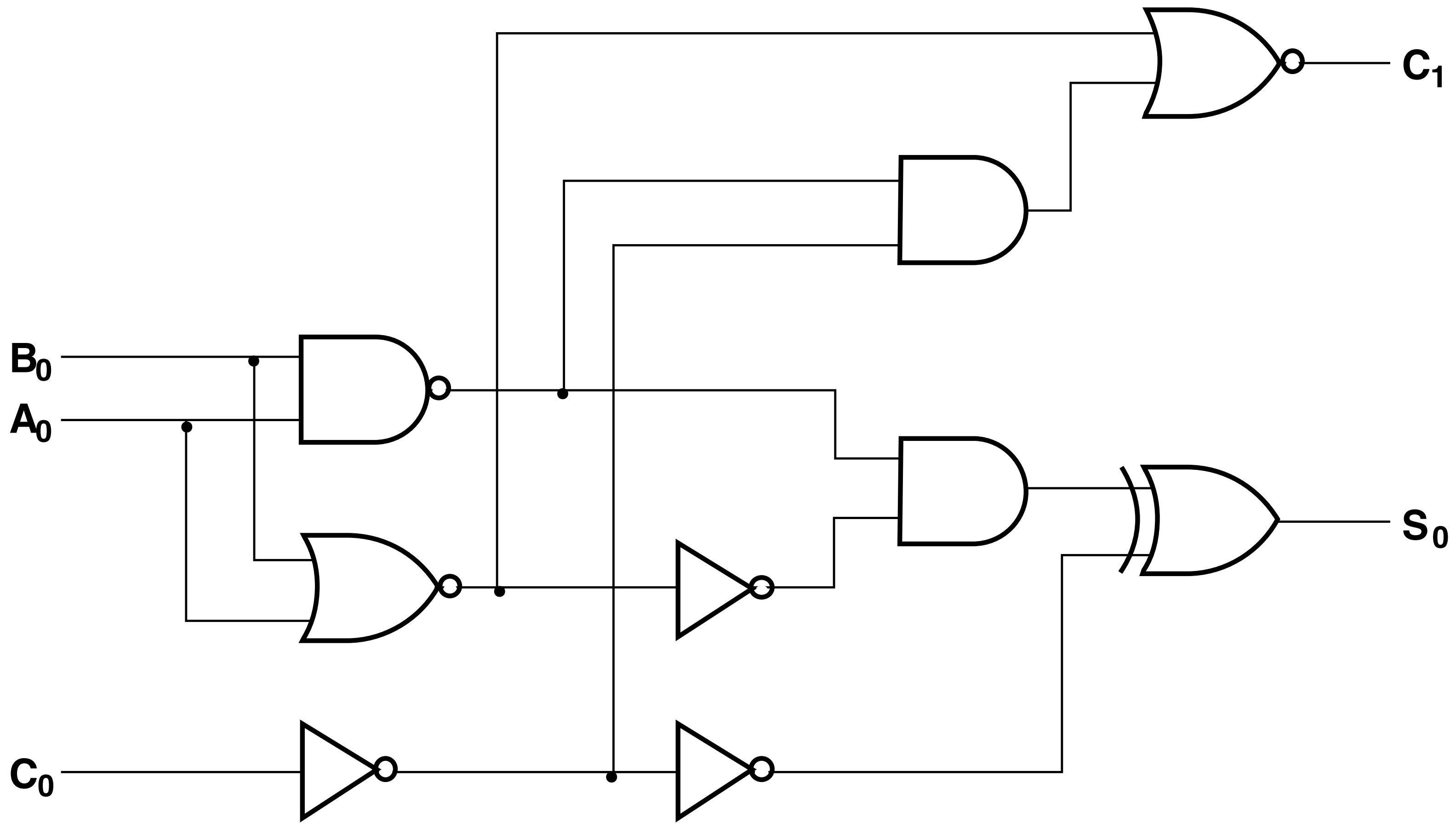
  {n{identifier}}

  - Examples: `{REG_IN[6:0],Serial_in},`

    `{8 {1’b0}}`

1st Example to Illustrate Verilog Description Types

- IC7283 – a 1-bit adder from a commerical IC



Structural Verilog

- Circuits can be described by a netlist as a text alternative to a diagram – Example IC7283

```
module IC7283 (A0, B0, C0, C1, S0);
   input A0, B0, C0;
   output C1, S0;
//Seven internal wires needed
   wire N1, N2, N3, N4, N5, N6, N7;
// Ports on primitive gates - output port
// is listed first
   not  G1 (N3,C0), G2 (N5,N2), G3 (N6,N3);
   nand G4 (N1,A0,B0);
   nor  G5 (N2,A0,B0), G6 (C1,N2,N4);
   and  G7 (N4,N1,N3), G8 (N7,N1,N5);
   xor  G9 (S0,N6,N7);
endmodule
```

Dataflow Verilog - 1

- Circuit function can be described by assign statements using Boolean equations – Example IC7283

```
module IC7283_df1 (A0, B0, C0, C1, S0);
   input A0, B0, C0;
   output C1, S0;
   wire N1, N2;
   assign N1 = ~(A0 & B0); //Note:
// Cannot write ~& for NAND
   assign N2 = ~(A0 | B0);
   assign C1 = ~((N1 & ~C0) | N2);
   assign S0 = (~N2 & N1)^(~(~C0));
endmodule
```

2nd Example to Illustrate Verilog Description Types

- **Priority Encoder**

Inputs					Outputs			
D4	D3	D2	D1	D0	A2	A1	A0	V
0	0	0	0	0	X	X	X	0
0	0	0	0	1	0	0	0	1
0	0	0	1	X	0	0	1	1
0	0	1	X	X	0	1	0	1
0	1	X	X	X	0	1	1	1
1	X	X	X	X	1	0	0	1

Dataflow Verilog - 2

- Circuit function can be described by assign statements using the conditional operator with binary combinations as in a truth table – Example Priority Encoder

```
module priority_encoder_df2 (D, A, V);
   input[4:0] D;
   output[2:0] A;
   output V;
//Conditional:(X) ? Y: Z - if X is true, then Y,else Z
   assign A = (D[4] == 1'b1) ? 3'b100 :
               (D[3] == 1'b1) ? 3'b011 :
               (D[2] == 1'b1) ? 3'b010 :
               (D[1] == 1'b1) ? 3'b001 :
               (D[0] == 1'b1) ? 3'b000 : 3'bxxx;
   assign V = (D == 5'b00000) ? 1'b0 : 1'b1;
endmodule
```

Dataflow Verilog - 3

- Circuit function can be described by assign statements using the conditional operator for binary decisions on inputs

```
module priority_encoder_df3 (D, A, V);
   input[4:0] D;
   output[2:0] A;
   output V;
// Conditional: (X) ? Y: Z If X is true,
// then Y, else Z
   assign A = D[4] ? 3'b100: D[3] ? 3'b011: D[2]
      ? 3'b010: D[1] ? 3'b001: D[0] ? 3'b000: 3'bxxx;
   assign V = (D == 5'b00000) ? 1'b0: 1'b1;
endmodule
```

Combinational Circuit Testbench

- ***Testbench*** **– a program that is used to verify the correctness of an HDL representation for a circuit**
  - **Applies a set of input combinations to the circuit that thoroughly tests the HDL representation**
  - **Assists in verifying the correctness of the corresponding outputs:**
    - **By displaying the inputs and outputs for manual verification**
    - **By comparing the outputs to those of a known correct representation for the circuit**

Combinational Testbench Example - 1

- A Verilog testbench for a combinational circuit with n inputs and m outputs that:
  - applies all possible binary input combinations as stimuli to the circuit
  - provides the circuit outputs for manual verification
- Stimuli Generation
  - Uses a clocked binary up counter to generate stimuli
  - Stops the simulation when all combinations have been applied

Combinational Testbench Example - 2

- Verilog code:

```
`timescale 1 ns / 100 ps //sets time unit /
  // simulation interval (ps - picoseconds (10-12 sec)
module priority_encoder_testbench;
reg clk; //clock to advance counter
reg[4:0] stim; //stimuli counter storage for D[4:0]
wire[3:0] results; //wires to hold A[1:0],V
//Following instantiates the circuit being tested
priority_encoder_df3 x1 (stim[4:0], results [3:1], results
  [0]);
initial //initializes clk and stim to 0 and
//stops simulation after 33 combinations applied
begin
   clk <= 0;
   stim <= 4'b0;
   #330 $stop;
end
```

Combinational Testbench Example - 3

- **Verilog code (continued):**

```
always
begin
#5 //waits 5 time units before toggling clock
forever
#5 clk <= ~clk; //toggles clock every 5 time units
end

always@(posedge clk)//conditions increment on
// the positive edge of clk
begin
stim <= stim + 1; //increments counter by 1
end
endmodule
```

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