endtask

12. Commonly used Compiler Directives

```
`define word_size 32
`include ../header.v
`timescale 100ns/1ns            // ref_time_unit / precision
`ifdef , `else , `endif
e.g.
module and_op (a,b,c);
  output a;
  input b,c;
  `ifdef behavioral
    wire a = b & c;
  `else
    and a1(a,b,c);
  `endif
endmodule
```

13. Observing Outputs

```
$display ("Value of variable is %d", var);
integer flag;
initial flag = $fopen("out_file");
always @(....); // dump data in text file
    $fdisplay (flag, "%h", data[7:0]);
    ........
    $fclose ("out_file");
end
$monitor ($time, "a = %b and b = %b", clock, reset);
$fmonitor(flag, "value = %h", add[15:0]);
$monitoron;
$monitoroff;
```

14. Simulation Control

```
initial begin
    $dumpfile ("my.dump");      // dump in this file
    $dumpvars;                  // dump all signals
    $dumpvars (1,top);  // dump variables in module instance top.
    $dumpvars (2,top.m1);       // dump 2 levels below top.m1
    #1000 dumpoff ;             // stop dump
    #500 dumpon;                // start / restart dump
    $stop;                      // stop for interaction
    #1000 $finish;              // come out of simulation
end
```

15. Language Constructs not supported by most Synthesis tools

Declarations and Definitions
- **time** declaration
- **event** declaration
- **triand, trior, tri1, tri0,** and **trireg** net types
- Ranges and arrays for integers
- **primitive** definition

Statements
- **initial** statement
- delay control
- event control
- **wait** statement
- **repeat** statement
- **fork** statement
- **deassign** statement
- **force** statement
- **release** statement
- **defparam** statement

Operators
- Division and modulus operators for variables
- Case equality and inequality operators (=== and !==)

Gate-Level Constructs
- **pullup, pulldown,**
- **tranif0, tranif1, rtran, rtranif0, rtranif1**

Miscellaneous Constructs
- Compiler directives like **`ifdef, `endif** and **`else**
- Hierarchical names within a module

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1. Module

```
module module_name (list of ports);
  input / output / inout declarations
  net / reg declarations
  integer declarations
  parameter declarations

  gate/switch instances
  hierarchical instances
  parallel statements
endmodule
```

2. Parallel Statements

Following statements start executing simultaneously inside module

```
initial begin
  {sequential statements}
end
always begin
  {sequential statements}
end
assign wire_name = [expression];
```

3. Basic Data Types

a. Nets
e.g. **wire, wand, tri, wor**
- Continuously driven
- Gets new value when driver changes
- LHS of continuous assignment

```
tri [15:0] data;
  // unconditional
assign data[15:0] = data_in ;
  // conditional
assign data[15:0] = enable ? data_in : 16'bz;
```

b. Registers
e.g. **reg**
- Represents storage
- Always stores last assigned value
- LHS of an assignment in procedural block.

```
reg signal;
@ (posedge clock) signal = 1'b1; // positive edge
@ (reset) signal = 1'b0;         // event (both edges)
```

4. Sequential Statements

Given below are simple examples instead of BNF type of definitions.

```
• if (reset == 0) begin
    data = 8'b00;
  end
```

```
• case (operator)
    2'd0 : z = x + y;
    2'd1 : z = x - y;
    2'd2 : z = x * y;
   default : $display("Invalid operation");
  endcase
• initial begin                    // 50 MHz clock
    clock = 0;
     forever #10 clock = ~clock;
  end                              // precision 1 ns
• repeat (2) @ (posedge clk); // add 2 clock delay
• repeat (5) @ (posedge clk) bus <=data;
        // evaluate data when the assignment is encountered
        // and assign to bus after 5 clocks.
• repeat (flag) begin              // looping
    .... action ...
  end
• while ( i < 10) begin
    .... action ...
  end
• for ( i = 0; i < 9; i = i+1 ) begin
    .... action ...
  end
• wait ( !oe ) #5 data = d_in;
• @ ( negedge clock ) q = d;
• begin                            // finishes at time #25
    #10 x = y;
    #15 a = b;
  end
• fork                             // finishes at time #15
    #10 x = y;
    #15 a = b;
  join
```

5. Gate Primitives

and	(out, in_1, ..., in_n);	**nand**	(out, in_1, ..., in_n);
or	(out, in_1, ..., in_n);	**nor**	(out, in_1, ..., in_n);
xor	(out, in_1, ..., in_n);	**xnor**	(out, in_1, ..., in_n);
buf	(out_1, .. ,out_n, in);	**not**	(out_1, .. ,out_n, in);
bufif0	(out, in, control);	**bufif1**	(out, in, control);
notif0	(out, in, control);	**notif1**	(out, in, control);
pullup	(out);	**pulldown**	(out);

6. Delays

```
Single delay                    : and  #5 my_and(...);
Rise/fall                       : and  #(5,7) my_and(...);
Rise/fall/Transport             : bufif1 #(10,15,5) my_buf(...);
All delays as min:typ:max       : or  #(4:5:6, 6:7:8) my_or (...);
```

Compiler options for delays

+maxdelays, +typdelays(default), +mindelays

e.g. **verilog** +maxdelays test.v

7. Operators

{}, {{}}	concatenation
+ - * /	arithmetic
%	modulus
> >= < <=	relational
!	logical negation
&&	logical and
||	logical or
==	logical equality
!=	logical inequality
===	case equality
!==	case inequality
~	bit-wise negation
&	bit-wise and
|	bit-wise inclusive or
^	bit-wise exclusive or
^~ or ~^	bit-wise equivalence
&	reduction and
~&	reduction nand
|	reduction or
~|	reduction nor
^	reduction xor
~^ or ^~	reduction xnor
<<	left shift
>>	right shift
? :	conditional
or	Event or

8. Specify Blocks

```
specify
        // specparam declarations (min:typ:max)
  specparam t_setup = 8:9:10, t_hold = 11:12:13;
        // timing constraints checks
  $setup (data, posedge clock, t_rise);
  $hold (posedge clear, data, t_hold);
        // simple pin to pin path delay
  (a => out) = 9; // => means parallel connection
        // edge sensitive pin to pin path delay
  (posedge clock => (out +: in)) = (10,8);
        // state dependent pin to pin path delay
  if (state_a = = 2'b01) (a, b *> out) = 15;
        // *> means full connection
endspecify
```

9. Memory Instantiation

```
module mem_test;
reg  [7:0]  memory [0:10];      // memory declaration
integer i ;
initial begin
  // reading the memory content file
  $readmemh ("contents.dat", memory);
  // display contents of initialized memory
  for  ( i = 0; i < 9; i = i+1 )
      $display ("Memory [%d] = %h", i, memory[i]);
end
endmodule
```

"contents.dat" contains

```
@02      ab    da
@06      00    01
```

- This simple memory model can be used for feeding input data values to simulation environment.
- $readmemb can be used for feeding binary values from contents file.

10. Blocking and Non-blocking Statements

```
// These blocking statements exhibit race condition.
always @(posedge clock)
    a = b;
always @(posedge clock)
    b = a;
// This Non-blocking statement  removes above race condition
// and gives true swapping operation
always @(posedge clock)
    a <= b;
always @(posedge clock)
    b <= a;
```

11. Functions and Tasks

Function

- A function can enable another function but not another task.
- Function always executes in 0 simulation time.
- Functions must not contain any delay, event, or timing control statement.
- Functions must have at least one input argument. They can have more than one input.
- Functions always return a single value. They cannot have output or inout argument.

e.g.

```
....
parity = calc_parity(addr);
....
function calc_parity;
input [31:0] address;
begin
    calc_parity = ^address;
end
endfunction
```

Task

- A task can enable other tasks and functions
- Tasks may execute in non-zero simulation time.
- Tasks may contain delay, event or timing control statements
- Tasks may have zero or more arguments of type input, output or inout.
- Tasks do not return with a value but can pass multiple values through output and inout arguments.

```
....
Cycle_read (read_in, oe_in, data, addr );
....
task  Cycle_read;
input        read, oe; // notice the sequence
output [7:0]  data;
input [15:0]  address;
begin
    #10 read_pin = read;
    # 05 oe_pin = oe;
    data = some_function(address);
end
```