Ain Shams University Faculty of Engineering

Course Code: CSE 412

Course Name: Digital Verification

Assignment 1

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Section: 1

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Requirements:

You have a multi-mode counter. It can count up and down by ones and by twos

There is a two-bit control bus input indicating which one of the four modes is active.

- 00 count up by 1
- 01 count up by 2
- 10 count down 1
- 11 count down 2

You also have an initial value input and a control signal called INIT. When INIT is logic 1, parallelly load that initial value into the multi-mode counter.

Whenever the count is equal to all zeros, set a signal called LOSER high. When the count is all ones, set a signal called WINNER high. In either case, the set signal should remain high for only one cycle.

With a pair of plain binary counters, count the number of times WINNER and LOSER goes high. When one of them reaches 15, set an output called GAMEOVER high.

If the game is over because LOSER got to 15 first, set a two-bit output called WHO to 2'b01. If the game is over because WINNER got to 15 first, set WHO to 2'b10. WHO should start at 2'b00 and return to it after each game over.

Then synchronously clear all the counters and start over.

Design and Code:

The System consists of two main modules and test bench module.

Main modules:

- Game Status module
- Counter module

Counter Module Code:

```
module counter(
    //===============
    // Output Ports
    //===============
    output reg [3:0] count_reg,      // Counter register
    //===============
    // Input Ports
    //===============
    input clk,                       // clock
    input reset,                     // reset
    input Init,                      // initialize   (1: initialize, 0: normal
operation)
    input [3:0] load,                // load value  (for counter initialization)
    input [1:0] control              // control     (0: count up by 1, 1: count up
by 2, 2: count down by 1, 3: count down by 2)
    );

  always @(posedge clk) begin
    if (reset) begin
      count_reg = 0;                            // reset counter
    end else begin
        //==============================
        // Initialization
        //==============================
        if (Init) begin
            count_reg = load;                    // initialize counter
        end
        //==============================
        // Counting
        //==============================
        else begin
            case(control)                         // Check the Control signal
            2'b00: count_reg = count_reg + 1;     //  00 count up by 1
            2'b01: count_reg = count_reg - 1;     //  01 count up by 2
            2'b10: count_reg = count_reg + 2;     //  10 count down by 1
            2'b11: count_reg = count_reg - 2;     //  11 count down by 2
            endcase
        end
    end
  end
endmodule
```

Game Status Module Code:

```
module Game_State#(
    //==============================
    // Top level block parameters
    //==============================
    parameter COUNTER_SIZE = 4          // number of bits in counter
    )(
    //===============
    // Output Ports
    //===============
    output reg [1:0] who,               // who is the winner
    output reg los,                     // loser signal when counter is all zeros
    output reg win,                     // winner signal when counter is all ones
    output reg gameover,          // gameover signal when loser or winner counters
reaches 15
    //===============
    // Input Ports
    //===============
    input clk,                          // clock
    input reset,                        // reset
    input [1:0] control,                // control signal
    input INIT,                         // initialization signal
    input [COUNTER_SIZE-1:0] i_value    // initialization value
    );
    //==============================
    // Signals
    //==============================
    wire start_over = reset | gameover; // start over signal     (1: start over and
reset all reg and modules, 0: normal operation)
    //==============================
    // Local registers
    //==============================
    reg [COUNTER_SIZE-1:0] count_reg;   // counter register (read-only)
    reg [3:0]wins, losses;              // winner and loser counters
    //==============================
    // Instantiate Counter module
    //==============================
    counter c1(.clk(clk), .reset(start_over), .Init(INIT), .load(i_value),
.control(control), .count_reg(count_reg));
    always@(posedge clk) begin
        // Reset Block
        if (start_over) begin
            who = 0;                    // reset Who register
            los = 0;                    // release Loser signal
            win = 0;                    // release Winner signal
            gameover <= 0;              // release Gameover signal
            wins = 0;                   // reset Winner counter
            losses = 0;                 // reset Loser counter
        end
        //==============================
        // Initialization
        //==============================
```

```
        else if(INIT) begin
            who = 0;                    // reset Who register
            los = 0;                    // release Loser signal
            win = 0;                    // release Winner signal
            wins = 0;                   // reset Winner counter
            losses = 0;                 // reset Loser counter
            gameover <= 0;              // release Gameover signal
        end
        // Normal Operation
        else begin
            if (count_reg == 15) begin
                win = 1;                // set Winner signal
                los = 0;                // release Loser signal
                wins = wins + 1;        // increment winner counter
            end else if(count_reg == 0) begin
                win = 0;                // release Winner signal
                los = 1;                // set Loser signal
                losses = losses + 1;    // increment loser counter
            end
            else begin
                win = 0;                // release Winner signal
                los = 0;                // release Loser signal
            end
            if (losses == 15) begin
                who = 1;                // Who with 01 to indicates Loser
                gameover <= 1;          // set Gameover signal
            end
            if (wins == 15) begin
                who = 2;                // Who with 10 to indicates Winner
                gameover <= 1;          // set Gameover signal
            end
        end
    end
endmodule
```

Test bench:

```
module Game_State_testbench  #(
    parameter CLOCK = 1,         // clock period
    parameter COUNTER_SIZE = 4   // number of bits in counter
    )(
    //===============
    // Output Ports
    //===============
    output reg clk,                          // clock
    output reg rst_l,                        // reset
    output reg [1:0] control,                // control signal
    output reg [COUNTER_SIZE-1:0] i_value,   // initialization value
    output reg INIT,                         // initialization signal
    //===============
    // Input Ports
    //===============
    input wire [1:0] who,                    // who is the winner
```

```
    input wire los,                      // loser signal when counter is all zeros
    input wire win,                       // winner signal when counter is all ones
    input wire gameover // gameover signal when loser or winner counters reaches 15
    );
    //==================
    // Local Variables
    //==================
    int Scenario_NUM;                        // number of scenarios
    //==============================
    // Instantiate the game module
    //==============================
    Game_State g1(
        .clk(clk),
        .reset(rst_l),
        .control(control),
        .i_value(i_value),
        .INIT(INIT),
        .who(who),
        .los(los),
        .win(win),
        .gameover(gameover)
    );
    //==============================
    // Create Counter
    //==============================
    always begin
        #CLOCK clk = ~clk;     // create clk works forever
    end
    //==============================
    // Initial Block of Testbench
    //==============================
    initial begin
        Scenario_NUM = 0;            // initialize scenario number
        clk = 1;                    // start the clock
        //=========================================
        // For Control Signal = 0 (Count up by 1)
        // Scenario 1: set initial value to 0
        // Scenario 2: set initial value to 1
        // Scenario 3: set initial value to 15
        //=========================================
        // For Control Signal = 2 (Count down by 1)
        // Scenario 4: set initial value to 0
        // Scenario 5: set initial value to 1
        // Scenario 6: set initial value to 15
        //=========================================
        for (int cont = 0; cont < 3; cont = cont + 2) begin
            for (int i_v = 0; i_v < 3; i_v = i_v + 1) begin
                rst_l = 1;                  // reset all registers
                control = cont;             // set control signal
                if(i_v == 2) i_value = 15;  // set initial value to 15
                else i_value = i_v;         // set initial value to 0 or 1
                INIT = 0;                   // release initialization signal
                #1                          // wait for one clock cycle
                rst_l = 0;                  // release reset
                INIT = 1;                   // set initialization signal
```

```
                #2                          // wait for two clock cycles
                INIT = 0;                   // release initialization signal
                #481                        // wait for 481 clock cycles
                rst_l = 1;                  // reset all registers
            end
        end
        //=========================================
        // For Control Signal = 1 (Count up by 2)
        // Scenario 7: set initial value to 0
        // Scenario 8: set initial value to 1
        // Scenario 9: set initial value to 2
        // Scenario 10: set initial value to 15
        //=========================================
        // For Control Signal = 3 (Count down by 2)
        // Scenario 11: set initial value to 0
        // Scenario 12: set initial value to 1
        // Scenario 13: set initial value to 2
        // Scenario 14: set initial value to 15
        //=========================================
        for (int cont = 1; cont < 4; cont = cont + 2) begin
            for (int i_v = 0; i_v < 4; i_v = i_v + 1) begin
                rst_l = 1;                  // reset all registers
                control = cont;             // set control signal
                if(i_v == 3) i_value = 15;  // set initial value to 15
                else i_value = i_v;         // set initial value to 0, 1, or 2
                INIT = 0;                   // release initialization signal
                #1                          // wait for one clock cycle
                rst_l = 0;                  // release reset
                INIT = 1;                   // set initialization signal
                #2                          // wait for two clock cycles
                INIT = 0;                   // release initialization signal
                #251                        // wait for 251 clock cycles
                rst_l = 1;                  // reset all registers
            end
        end
    end
    //=========================================
    // Dump variables to view them in the waveform
    //=========================================
    initial begin
        $dumpfile("wave.vcd");
        $dumpvars;
        #5000 $finish;
    end
    //=========================================
    // Print Outputs for Each Scenario
    //=========================================
    always@(posedge gameover)begin
        if(who == 2)
            $display("Scenario Num = %0d -------WINNER", Scenario_NUM);
        else
            $display("Scenario Num = %0d -------LOSER", Scenario_NUM);
        Scenario_NUM = Scenario_NUM +1;
  end
endmodule
```

Output scenarios:

First Scenario:

Control Signal = 2’b00 (count up by 1) initial value = 4’b0000

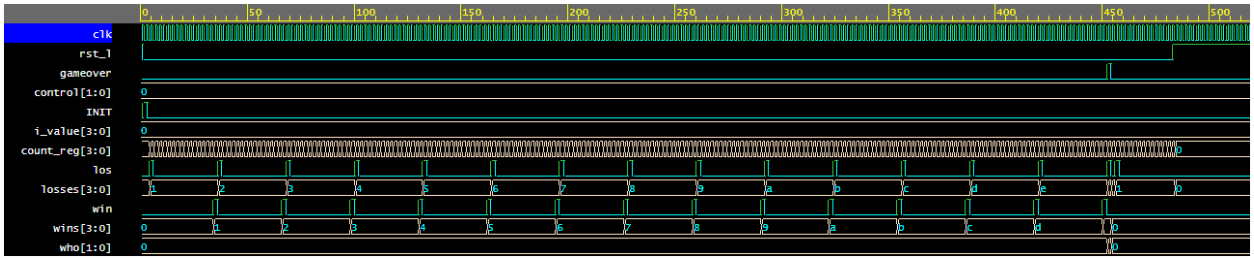

Figure 1

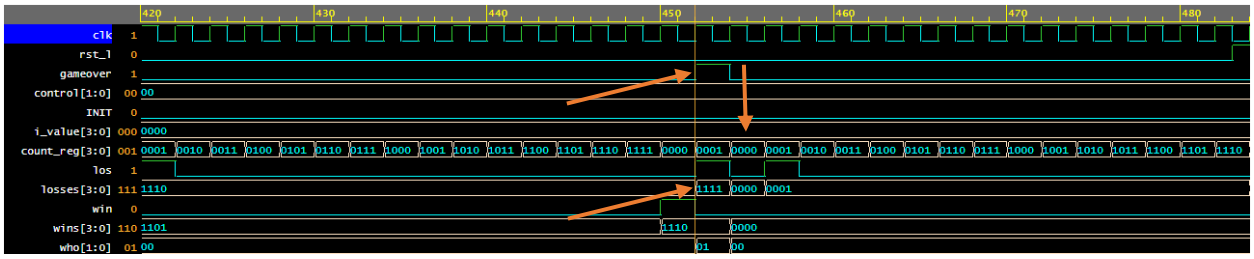

Figure 2

As we started from Zero, loser counter will be ahead from the winner counter by one.

So, the output signal WHO will be 2’b01 indicating that game over happened because of Loser.

As shown in (Figure 2) all signal is cleared to initial value after game-over is signaled.

Second Scenario:

Control Signal = 2’b00 (count up by 1) initial value = 4’b0001

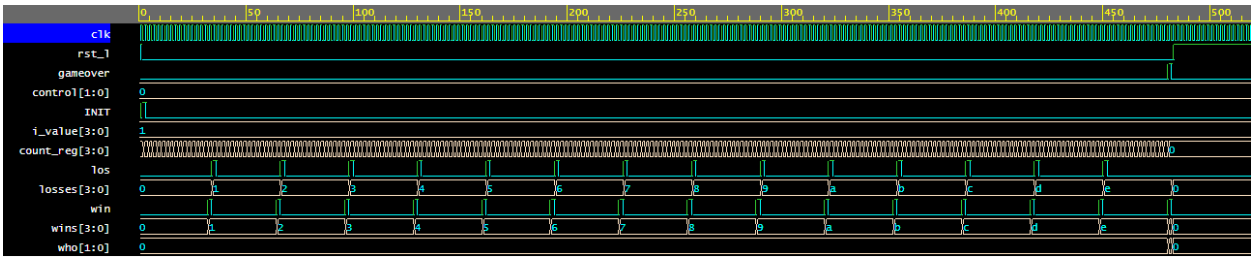

Figure 3

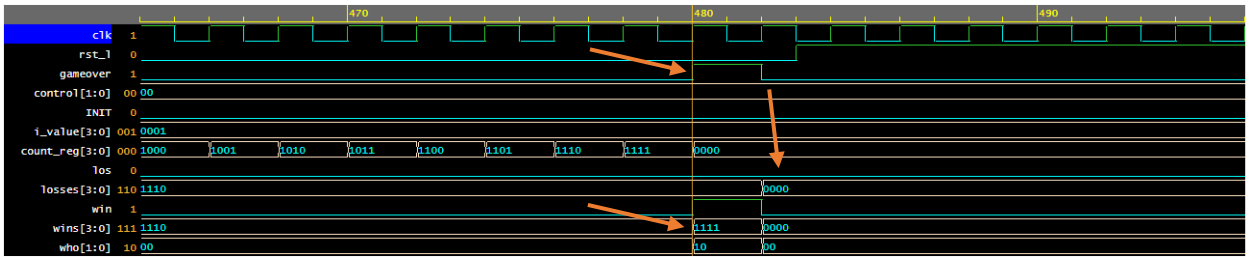

Figure 4

Third Scenario:

Control Signal = 2’b00 (count up by 1) initial value = 4’b1111

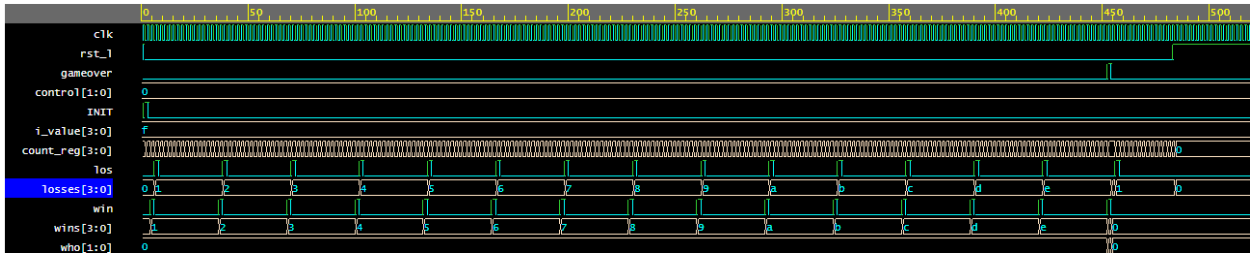

Figure 5

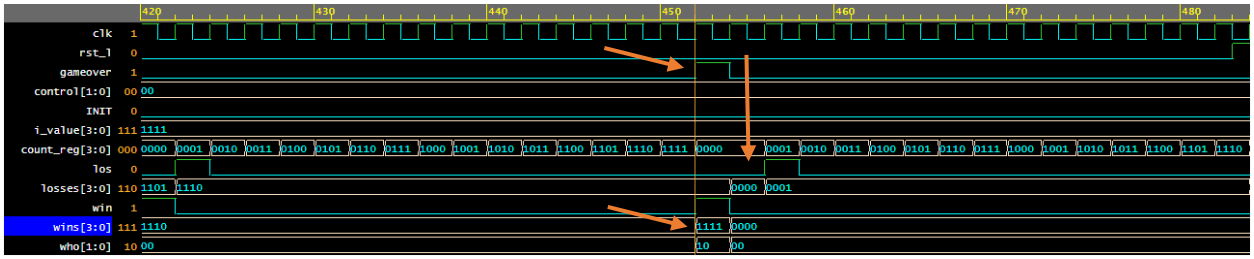

Figure 6

As we started from num between 1 to 15, winner counter will be ahead from the loser counter by one.

So, the output signal WHO will be 2’b10 indicating that game over happened because of Winner.

As shown in (Figures 4,6) all signal is cleared to initial value after game-over is signaled.

Forth Scenario:

Control Signal = 2’b10 (counting down by 1) initial value = 4’b0000

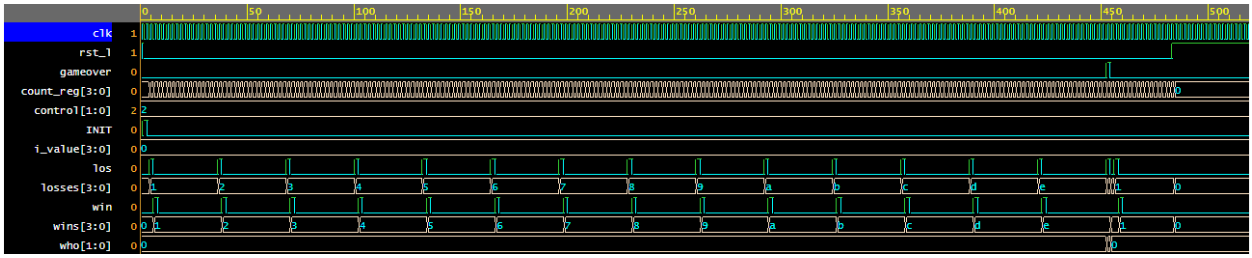

Figure 7

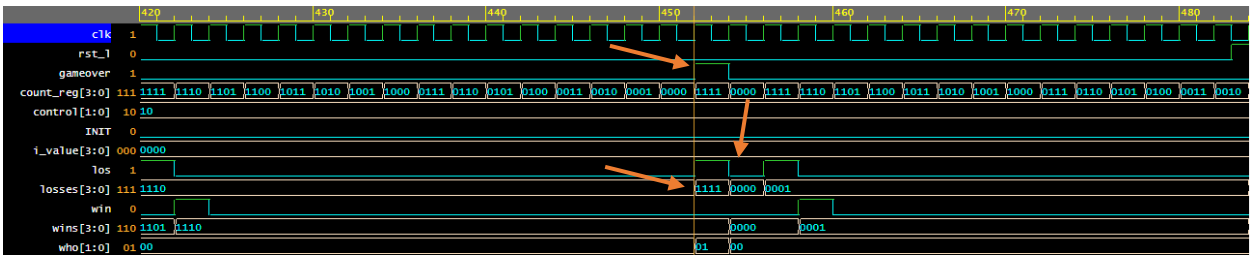

Figure 8

Fifth Scenario:

Control Signal = 2’b10 (counting down by 1) initial value = 4’b0001

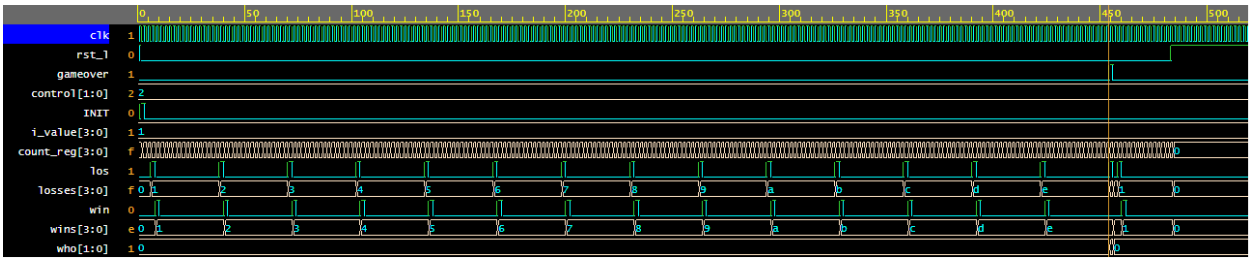

Figure 9

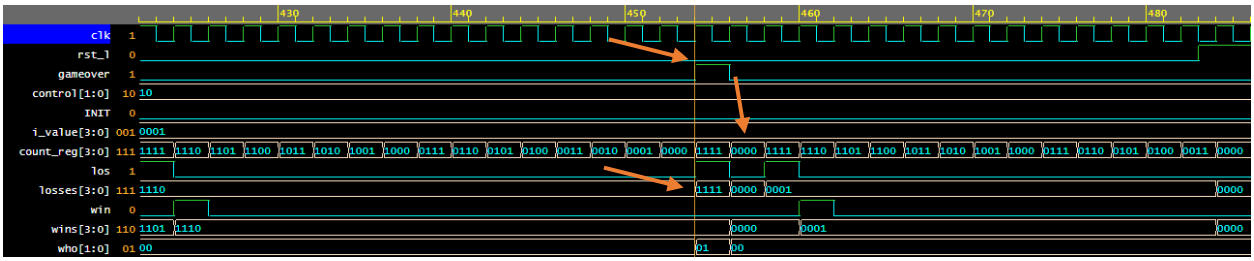

Figure 10

As we started from num between 0 to 14, loser counter will be ahead from the winner counter by one.

So, the output signal WHO will be 2’b01 indicating that game over happened because of Loser.

As shown in (Figure 8,10) all signal is cleared to initial value after game-over is signaled.

Sixth Scenario:

Control Signal = 2’b10 (counting down by 1) initial value = 4’b1111

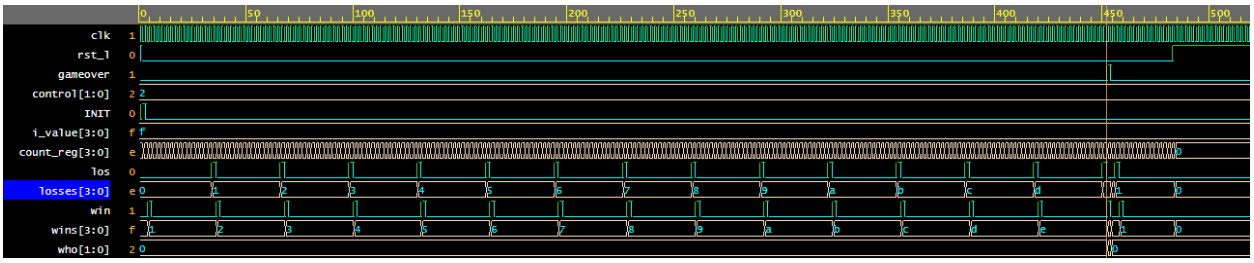

Figure 11

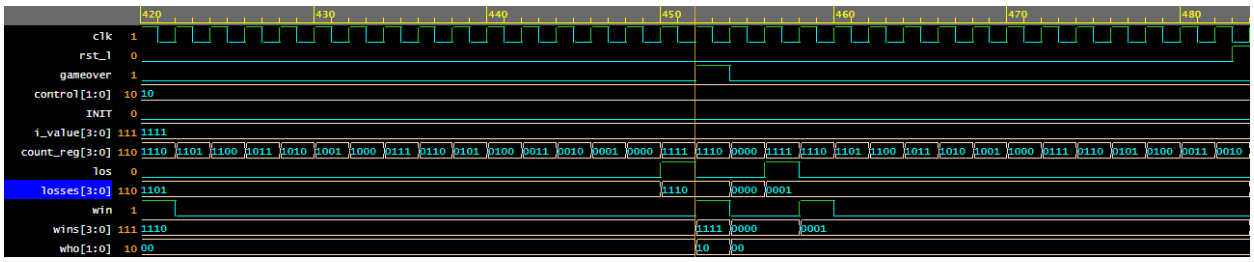

Figure 12

As we started from 15, winner counter will be ahead from the loser counter by one.

So, the output signal WHO will be 2'b10 indicating that game over happened because of Winner.

As shown in (Figure 12) all signal is cleared to initial value after game-over is signaled.

Seventh Scenario:

Control Signal = 2'b01 (count up by 2) initial value = 4'b0000

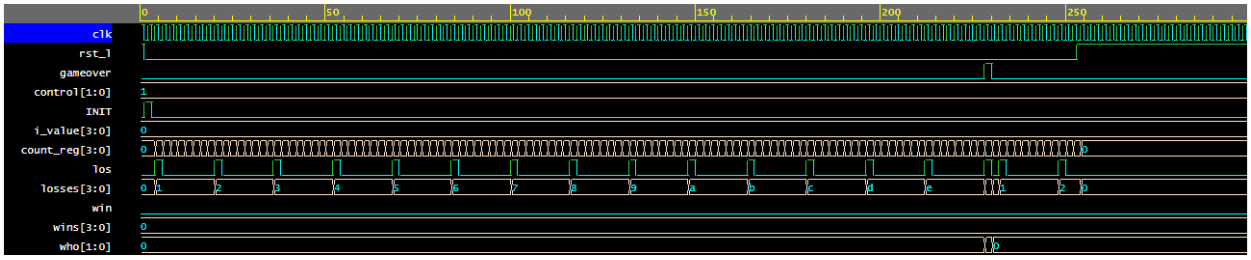

Figure 13

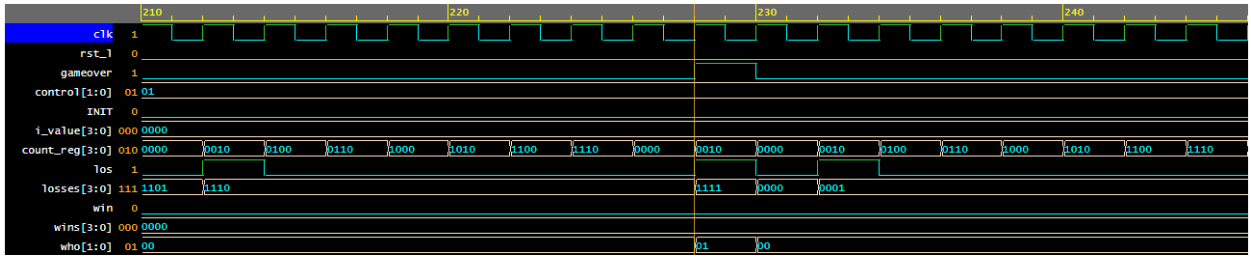

Figure 14

Eighth Scenario:

Control Signal = 2'b01 (count up by 2) initial value = 4'b0010

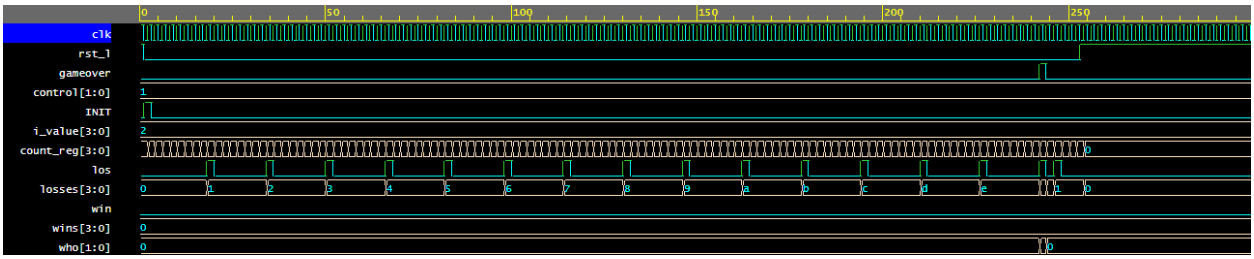

Figure 15

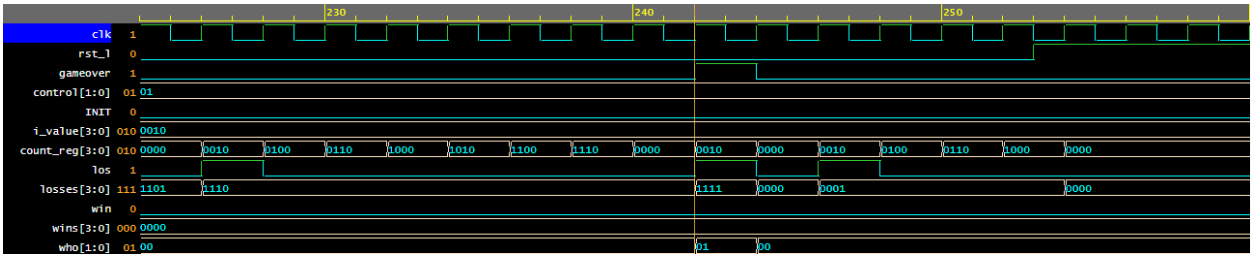

Figure 16

As we started from 0,2(EVEN NUMBER), loser counter will be ahead from the winner counter by one.

So, the output signal WHO will be 2'b10 indicating that game over happened because of Loser.

As shown in (Figures 16,14) all signal is cleared to initial value after game-over is signaled.

Nineth Scenario:

Control Signal = 2'b01 (count up by 2) initial value = 4'b0001

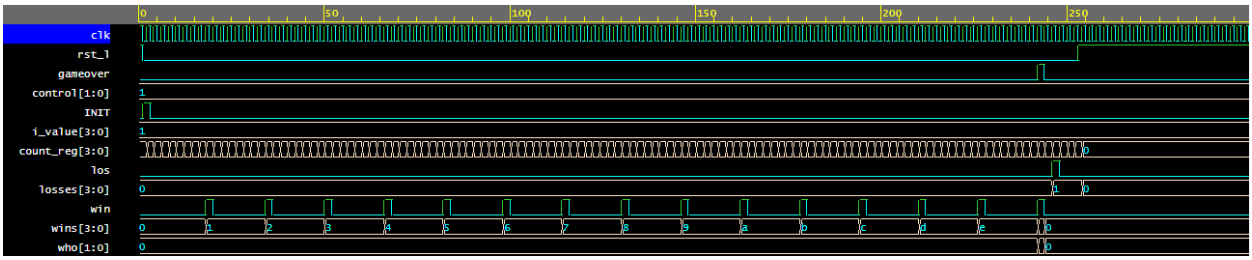

Figure 17

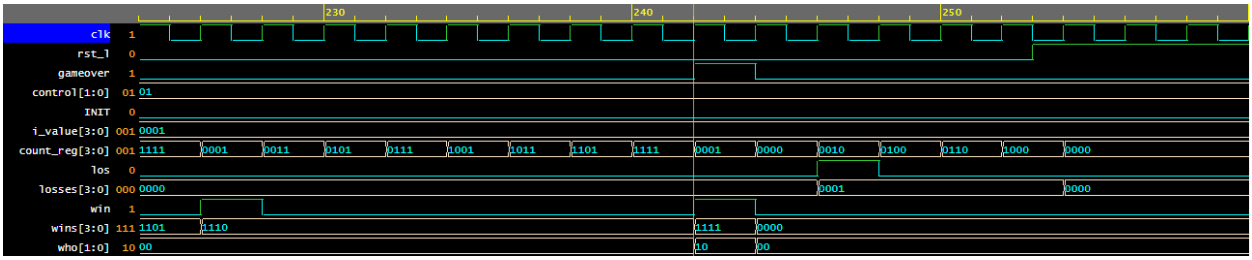

Figure 18

Tenth Scenario:

Control Signal = 2'b01 (count up by 2) initial value = 4'b1111

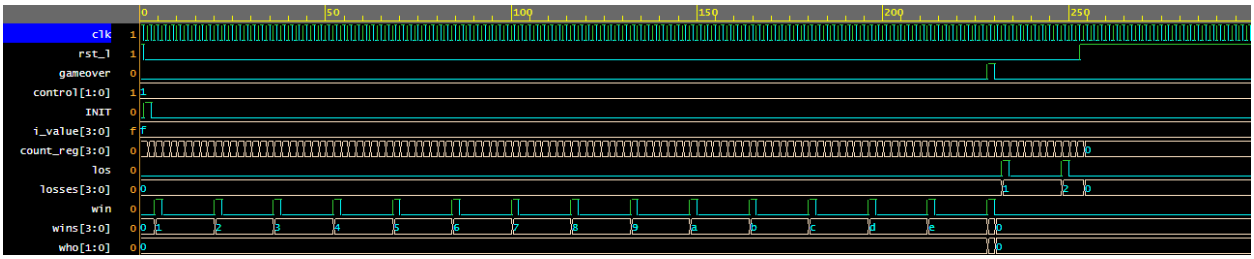

Figure 19

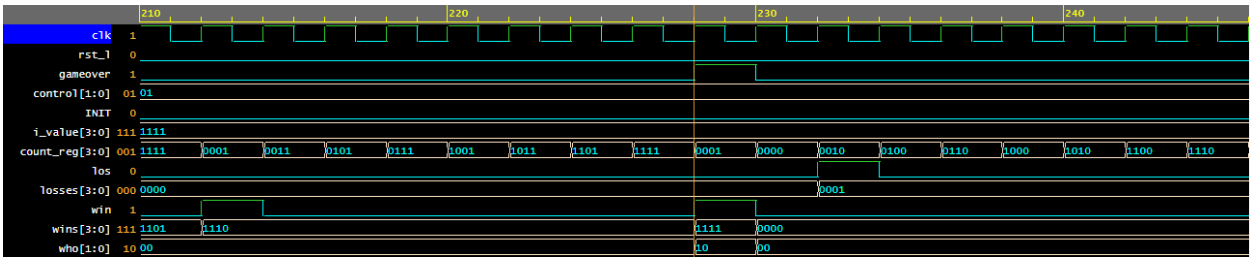

Figure 20

As we started from 1,15(ODD NUMBER), winner counter will be ahead from the loser counter by one.

So, the output signal WHO will be 2'b10 indicating that game over happened because of Winner.

As shown in (Figures 18,20) all signal is cleared to initial value after game-over is signaled.

Eleventh Scenario:

Control Signal = 2'b11 (count down by 2) initial value = 4'b0000

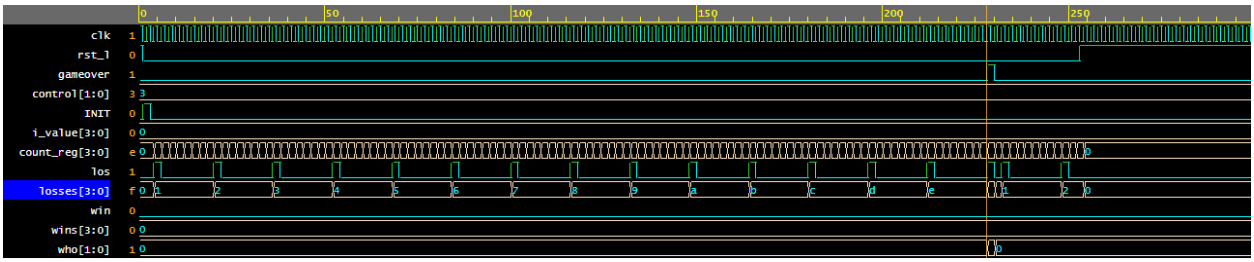

Figure 21

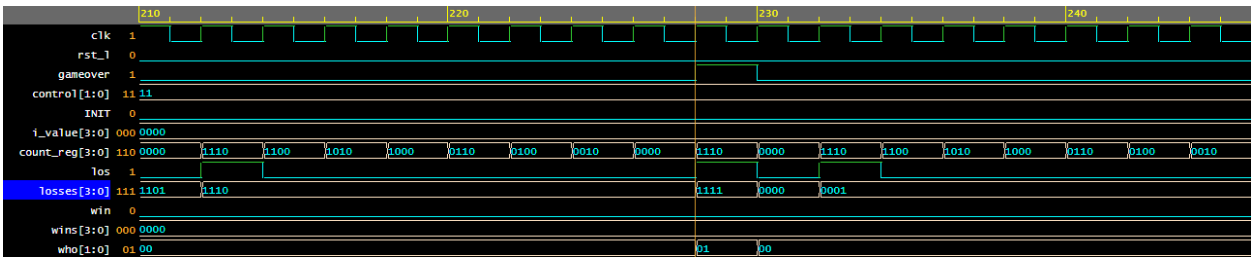

Figure 22

Twelfth Scenario:

Control Signal = 2'b11 (count down by 2) initial value = 4'b0010

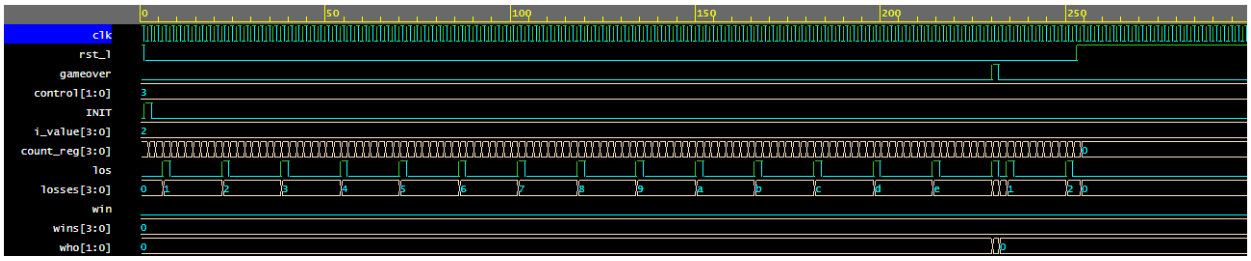

Figure 23

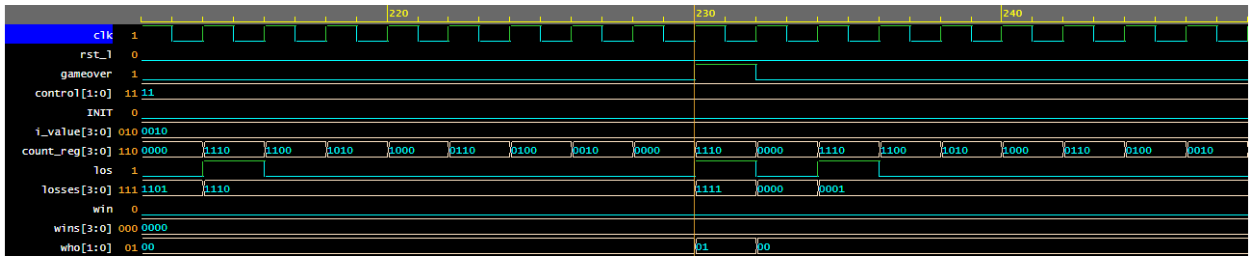

Figure 24

As we started from 0,2(EVEN NUMBER), loser counter will be ahead from the winner counter by one.

So, the output signal WHO will be 2'b10 indicating that game over happened because of Loser.

As shown in (Figures 22,24) all signal is cleared to initial value after game-over is signaled.

Thirteenth Scenario:

Control Signal = 2'b11 (count down by 2) initial value = 4'b0001

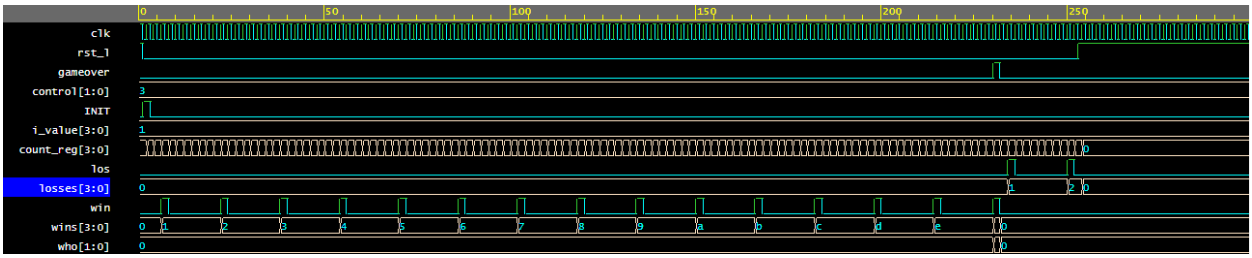

Figure 25

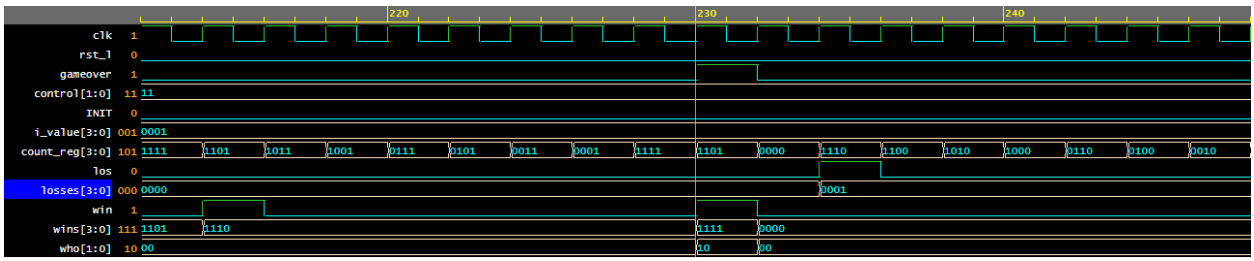

Figure 26

Fourteenth Scenario:

Control Signal = 2'b11 (count down by 2) initial value = 4'b1111

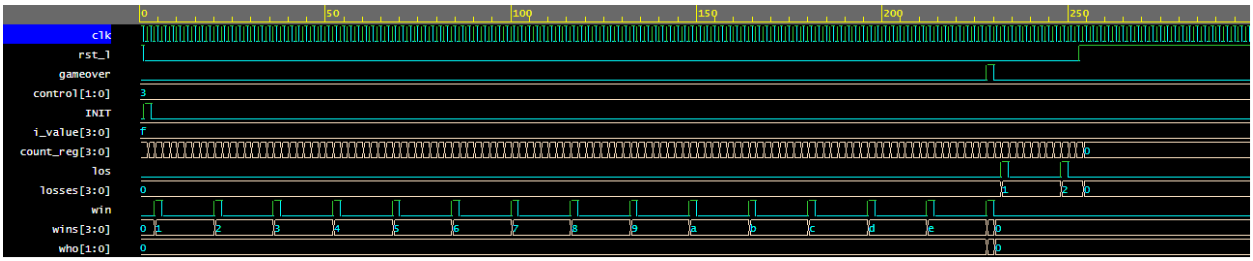

Figure 27

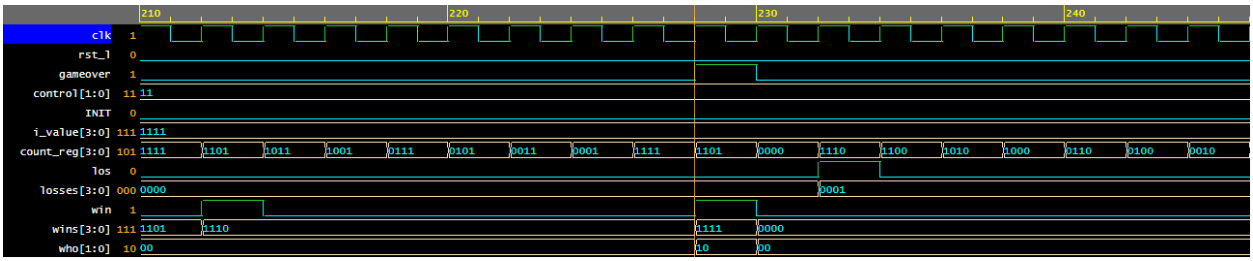

Figure 28

As we started from 1,15(ODD NUMBER), winner counter will be ahead from the loser counter by one.

So, the output signal WHO will be 2'b10 indicating that game over happened because of Winner.

As shown in (Figures 26,28) all signal is cleared to initial value after game-over is signaled.