ECE 6213

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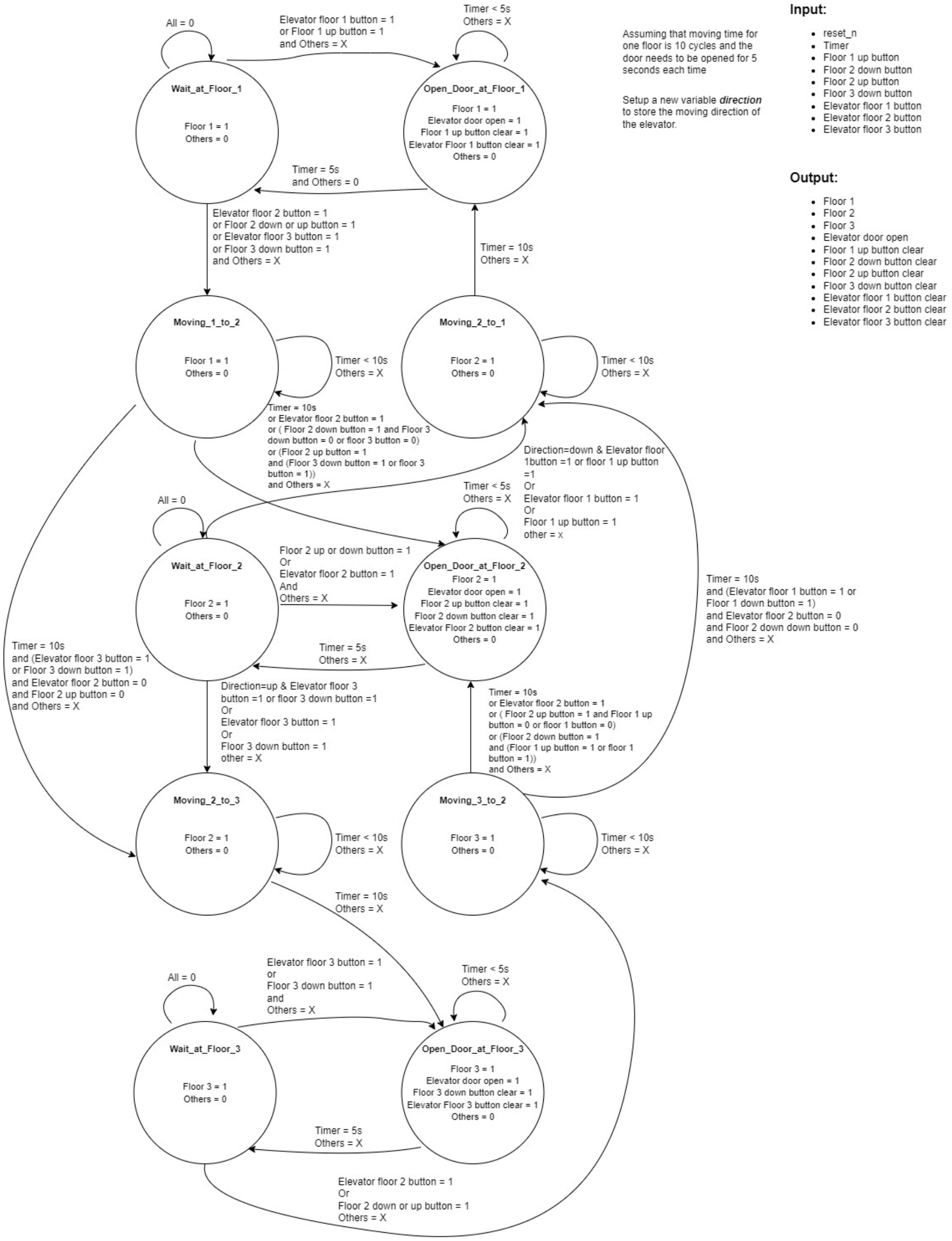
Project-3

Elevator Controller Report

## FSM Diagram

Introduced a new variable *direction* that stores the moving direction to solve the problem like Floor 1 -> Floor 3 / Pickup on Floor 2 Pressed Floor 1 and elevator goes to Floor 1 first instead of continuing going to Floor 3.


All = 0
Elevator floor 1 button = 1 or Floor 1 up button = 1 and Others = X
Timer < 5s Others = X
Wait_at_Floor_1
Floor 1 = 1 Others = 0
Open_Door_at_Floor_1
Floor 1 = 1 Elevator door open = 1 Floor 1 up button clear = 1 Elevator Floor 1 button clear = 1 Others = 0
Timer = 5s and Others = 0
Elevator floor 2 button = 1 or Floor 2 down or up button = 1 or Elevator floor 3 button = 1 or Floor 3 down button = 1 and Others = X
Timer = 10s Others = X
Moving_1_to_2
Floor 1 = 1 Others = 0
Timer < 10s Others = X
Moving_2_to_1
Floor 2 = 1 Others = 0
Timer < 10s Others = X
Timer = 10s or Elevator floor 2 button = 1 or ( Floor 2 down button = 1 and Floor 3 down button = 0 or floor 3 button = 0) or (Floor 2 up button = 1 and (Floor 3 down button = 1 or floor 3 button = 1)) and Others = X
Direction=down & Elevator floor 1button =1 or floor 1 up button =1 Or Elevator floor 1 button = 1 Or Floor 1 up button = 1 other = x
All = 0
Timer < 5s Others = X
Wait_at_Floor_2
Floor 2 = 1 Others = 0
Floor 2 up or down button = 1 Or Elevator floor 2 button = 1 And Others = X
Open_Door_at_Floor_2
Floor 2 = 1 Elevator door open = 1 Floor 2 up button clear = 1 Floor 2 down button clear = 1 Elevator Floor 2 button clear = 1 Others = 0
Timer = 5s Others = X
Timer = 10s and (Elevator floor 1 button = 1 or Floor 1 down button = 1) and Elevator floor 2 button = 0 and Floor 2 down down button = 0 and Others = X
Timer = 10s and (Elevator floor 3 button = 1 or Floor 3 down button = 1) and Elevator floor 2 button = 0 and Floor 2 up button = 0 and Others = X
Direction=up & Elevator floor 3 button =1 or floor 3 down button =1 Or Elevator floor 3 button = 1 Or Floor 3 down button = 1 other = X
Timer = 10s or Elevator floor 2 button = 1 or ( Floor 2 up button = 1 and Floor 1 up button = 0 or floor 1 button = 0) or (Floor 2 down button = 1 and (Floor 1 up button = 1 or floor 1 button = 1)) and Others = X
Moving_2_to_3
Floor 2 = 1 Others = 0
Timer < 10s Others = X
Moving_3_to_2
Floor 3 = 1 Others = 0
Timer < 10s Others = X
Timer = 10s Others = X
Elevator floor 3 button = 1 or Floor 3 down button = 1 and Others = X
All = 0
Timer < 5s Others = X
Wait_at_Floor_3
Floor 3 = 1 Others = 0
Open_Door_at_Floor_3
Floor 3 = 1 Elevator door open = 1 Floor 3 down button clear = 1 Elevator Floor 3 button clear = 1 Others = 0
Timer = 5s Others = X
Elevator floor 2 button = 1 Or Floor 2 down or up button = 1 Others = X

Assuming that moving time for one floor is 10 cycles and the door needs to be opened for 5 seconds each time

Setup a new variable ***direction*** to store the moving direction of the elevator.

**Input:**

- reset_n
- Timer
- Floor 1 up button
- Floor 2 down button
- Floor 2 up button
- Floor 3 down button
- Elevator floor 1 button
- Elevator floor 2 button
- Elevator floor 3 button

**Output:**

- Floor 1
- Floor 2
- Floor 3
- Elevator door open
- Floor 1 up button clear
- Floor 2 down button clear
- Floor 2 up button clear
- Floor 3 down button clear
- Elevator floor 1 button clear
- Elevator floor 2 button clear
- Elevator floor 3 button clear

# Verilog Code

## Elevator_controller module:

```
`timescale 1ns / 1ps
//////////////////////////////////////////////////////////////////////////////////
// ECE6213
// Yihui Wang
// Elevator controller module
//
//
//////////////////////////////////////////////////////////////////////////////////

module elevator_controller (
  input clk,
  input rstn,
  input floor_1_up_button,
  input floor_2_up_button,
  input floor_2_down_button,
  input floor_3_down_button,
  input elevator_floor_1_button,
  input elevator_floor_2_button,
  input elevator_floor_3_button,

  output reg floor_1 = 1'b1,
  output reg floor_2 = 1'b0,
  output reg floor_3 = 1'b0,
  output reg elevator_door_open = 1'b0,
  output reg floor_1_up_button_clear = 1'b0,
  output reg floor_2_up_button_clear = 1'b0,
  output reg floor_2_down_button_clear = 1'b0,
  output reg floor_3_down_button_clear = 1'b0,
  output reg elevator_floor_1_button_clear = 1'b0,
  output reg elevator_floor_2_button_clear = 1'b0,
  output reg elevator_floor_3_button_clear = 1'b0
);

  // State defination
  parameter wait_at_floor_1 = 10'b0000000001;
  parameter open_door_at_floor_1 = 10'b0000000010;
  parameter moving_1_to_2 = 10'b0000000100;
  parameter moving_2_to_1 = 10'b0000001000;
  parameter wait_at_floor_2 = 10'b0000010000;
  parameter open_door_at_floor_2 = 10'b0000100000;
  parameter moving_2_to_3 = 10'b0001000000;
  parameter moving_3_to_2 = 10'b0010000000;
  parameter wait_at_floor_3 = 10'b0100000000;
  parameter open_door_at_floor_3 = 10'b1000000000;

  // State register
  reg [9:0] state = wait_at_floor_1;
  reg [9:0] next = 10'd0;

  // Counter register
  reg [3:0] count = 4'd0;
  reg [3:0] count_next = 4'd0;

  // Elevator direction register
  reg elevator_direction = 1'b0;
  reg elevator_direction_next = 1'b0;

  // Elevator direction logic
  always @(posedge clk, negedge rstn) begin
    if (rstn == 1'b0) begin
      elevator_direction <= 1'b0;
    end
    else begin
      elevator_direction <= elevator_direction_next;
    end
  end

  always @(*) begin
    elevator_direction_next <= (next[2]|next[6])? 1'b1: ((next[3]|next[7])? 1'b0:
elevator_direction);
  end

  // counter
  always @(posedge clk, negedge rstn) begin
    if (rstn == 1'b0) begin
      count <= 4'd0;
    end
    else begin
      count <= count_next;
    end
  end

  always @(*) begin
    if ((state==open_door_at_floor_1)|(state==open_door_at_floor_2)|(state==open_door_at_floor_3))
begin
      if (count == 4'd4) count_next <= 4'd0;
      else count_next <= count + 4'd1;
    end
    else if
((state==moving_1_to_2)|(state==moving_2_to_1)|(state==moving_2_to_3)|(state==moving_3_to_2))
begin
      if (count == 4'd9) count_next <= 4'd0;
      else count_next <= count + 4'd1;
    end
    else count_next <= 4'd0;
  end

  // Sequential logic for state
  always @(posedge clk, negedge rstn) begin

    if (rstn == 1'b0) begin
      state <= wait_at_floor_1;
    end else begin
      state <= next;
    end

  end

  // Combination state transition logic
  always @(*) begin
    case (state)
      wait_at_floor_1: begin
        if (elevator_floor_1_button | floor_1_up_button) begin
          next = open_door_at_floor_1;
        end
                else if
(elevator_floor_2_button|elevator_floor_3_button|floor_2_down_button|floor_2_down_button|floor_3_d
own_button) begin
          next = moving_1_to_2;
        end else next = wait_at_floor_1;
      end

      open_door_at_floor_1: begin
        if (count == 4'd4) next = wait_at_floor_1;
        else next = open_door_at_floor_1;
      end

      moving_1_to_2: begin
        if (count == 4'd9) begin
          if (elevator_floor_2_button | floor_2_up_button) begin
            next = open_door_at_floor_2;
          end else if (elevator_floor_3_button | floor_3_down_button) begin
            next = moving_2_to_3;
```

```
     end
    end else next = moving_1_to_2;
   end

   open_door_at_floor_2: begin
    if (count == 4'd4) next = wait_at_floor_2;
    else next = open_door_at_floor_2;
   end

   wait_at_floor_2: begin
    if (elevator_floor_2_button | floor_2_up_button | floor_2_down_button) begin
     next = open_door_at_floor_2;
    end else if ((elevator_floor_3_button | floor_3_down_button) & elevator_direction) begin
     next = moving_2_to_3;
    end else if ((elevator_floor_1_button | floor_1_up_button) & ~elevator_direction) begin
     next = moving_2_to_1;
    end else if (floor_1_up_button | elevator_floor_1_button) begin
     next = moving_2_to_1;
    end else if (floor_3_down_button | elevator_floor_3_button) begin
     next = moving_2_to_3;
    end else next = wait_at_floor_2;
   end

   moving_2_to_3: begin
    if (count == 4'd9) begin
     next = open_door_at_floor_3;
    end else next = moving_2_to_3;
   end

   open_door_at_floor_3: begin
    if (count == 4'd4) next = wait_at_floor_3;
    else next = open_door_at_floor_3;
   end

   wait_at_floor_3: begin
    if (elevator_floor_3_button | floor_3_down_button) begin
     next = open_door_at_floor_3;
    end
        else if
(elevator_floor_2_button|elevator_floor_1_button|floor_2_down_button|floor_2_up_button|floor_1_up_
button) begin
     next = moving_3_to_2;
    end else next = wait_at_floor_3;
   end

   moving_3_to_2: begin
    if (count == 4'd9) begin
     if (elevator_floor_2_button | floor_2_down_button) begin
      next = open_door_at_floor_2;
     end else if (elevator_floor_1_button | floor_1_up_button) begin
      next = moving_2_to_1;
     end
    end else next = moving_3_to_2;
   end

   moving_2_to_1: begin
    if (count == 4'd9) begin
     next = open_door_at_floor_1;
    end else next = moving_2_to_1;
   end
  endcase
 end

 // Output logic
 always @(*) begin

  floor_1 = |state[2:0];
  floor_2 = |state[6:3];
  floor_3 = |state[9:7];
```

```
    elevator_door_open = state[1] | state[5] | state[9];
    floor_1_up_button_clear = state[1];
    floor_2_up_button_clear = state[5];
    floor_2_down_button_clear = state[5];
    floor_3_down_button_clear = state[9];
    elevator_floor_1_button_clear = state[1];
    elevator_floor_2_button_clear = state[5];
    elevator_floor_3_button_clear = state[9];

  end

endmodule
```

## Elevator_top module

```
`timescale 1ns / 1ps
//////////////////////////////////////////////////////////////////////////////////
// ECE6213
// Yihui Wang
// Elevator top module
//
//
//////////////////////////////////////////////////////////////////////////////////

module elevator_top (input clk,
                            input rstn,
                            input floor_1_up_button_pressed,
                            input floor_2_up_button_pressed,
                            input floor_2_down_button_pressed,
                            input floor_3_down_button_pressed,
                            input elevator_floor_1_button_pressed,
                            input elevator_floor_2_button_pressed,
                            input elevator_floor_3_button_pressed,
                            output floor_1_out,
                            output floor_2_out,
                            output floor_3_out,
                            output elevator_door_open_out,
                            output floor_1_up_button_out,
                            output floor_2_up_button_out,
                            output floor_2_down_button_out,
                            output floor_3_down_button_out,
                            output elevator_floor_1_button_out,
                            output elevator_floor_2_button_out,
                            output elevator_floor_3_button_out);

    wire floor_1_up_button_clear;
    wire floor_2_up_button_clear;
    wire floor_2_down_button_clear;
    wire floor_3_down_button_clear;
    wire elevator_floor_1_button_clear;
    wire elevator_floor_2_button_clear;
    wire elevator_floor_3_button_clear;

    elevator_controller elevator_controller_inst (
    .clk                          (clk),
    .rstn                         (rstn),
    .floor_1_up_button            (floor_1_up_button_out),
    .floor_2_up_button            (floor_2_up_button_out),
    .floor_2_down_button          (floor_2_down_button_out),
    .floor_3_down_button          (floor_3_down_button_out),
    .elevator_floor_1_button      (elevator_floor_1_button_out),
    .elevator_floor_2_button      (elevator_floor_2_button_out),
    .elevator_floor_3_button      (elevator_floor_3_button_out),
    .floor_1                      (floor_1_out),
    .floor_2                      (floor_2_out),
    .floor_3                      (floor_3_out),
    .elevator_door_open           (elevator_door_open_out),
    .floor_1_up_button_clear      (floor_1_up_button_clear),
    .floor_2_up_button_clear      (floor_2_up_button_clear),
    .floor_2_down_button_clear    (floor_2_down_button_clear),
    .floor_3_down_button_clear    (floor_3_down_button_clear),
    .elevator_floor_1_button_clear(elevator_floor_1_button_clear),
    .elevator_floor_2_button_clear(elevator_floor_2_button_clear),
    .elevator_floor_3_button_clear(elevator_floor_3_button_clear)
    );

    elevator_button floor_1_up_button (
    .clk           (clk),
    .rst_n         (rstn),
    .button_pressed(floor_1_up_button_pressed),
    .clear         (floor_1_up_button_clear),
    .button_out    (floor_1_up_button_out)
    );

    elevator_button floor_2_up_button (
    .clk           (clk),
    .rst_n         (rstn),
    .button_pressed(floor_2_up_button_pressed),
    .clear         (floor_2_up_button_clear),
    .button_out    (floor_2_up_button_out)
    );

    elevator_button floor_2_down_button (
    .clk           (clk),
    .rst_n         (rstn),
    .button_pressed(floor_2_down_button_pressed),
    .clear         (floor_2_down_button_clear),
    .button_out    (floor_2_down_button_out)
    );

    elevator_button floor_3_down_button (
    .clk           (clk),
    .rst_n         (rstn),
    .button_pressed(floor_3_down_button_pressed),
    .clear         (floor_3_down_button_clear),
    .button_out    (floor_3_down_button_out)
    );

    elevator_button elevator_floor_1_button (
    .clk           (clk),
    .rst_n         (rstn),
    .button_pressed(elevator_floor_1_button_pressed),
    .clear         (elevator_floor_1_button_clear),
    .button_out    (elevator_floor_1_button_out)
    );

    elevator_button elevator_floor_2_button (
    .clk           (clk),
    .rst_n         (rstn),
    .button_pressed(elevator_floor_2_button_pressed),
    .clear         (elevator_floor_2_button_clear),
    .button_out    (elevator_floor_2_button_out)
    );

    elevator_button elevator_floor_3_button (
    .clk           (clk),
    .rst_n         (rstn),
    .button_pressed(elevator_floor_3_button_pressed),
    .clear         (elevator_floor_3_button_clear),
    .button_out    (elevator_floor_3_button_out)
    );


endmodule
```

## Testbench module

```
`timescale 1ns / 1ps
//////////////////////////////////////////////////////////////////////////////////
// ECE6213
// Yihui Wang
// Elevator controller testbench
//
//
//////////////////////////////////////////////////////////////////////////////////

module elevator_top_tb;
  reg  clk = 0;
  reg  rstn = 0;
  reg  floor_1_up_button_pressed = 0;
  reg  floor_2_up_button_pressed = 0;
  reg  floor_2_down_button_pressed = 0;
  reg  floor_3_down_button_pressed = 0;
  reg  elevator_floor_1_button_pressed = 0;
  reg  elevator_floor_2_button_pressed = 0;
  reg  elevator_floor_3_button_pressed = 0;
  wire floor_1_out;
  wire floor_2_out;
  wire floor_3_out;
  wire elevator_door_open_out;
  wire floor_1_up_button_out;
  wire floor_2_up_button_out;
  wire floor_2_down_button_out;
  wire floor_3_down_button_out;
  wire elevator_floor_1_button_out;
  wire elevator_floor_2_button_out;
  wire elevator_floor_3_button_out;

  reg [7:0] error_count;
  reg [8*58:0] testcase;


  elevator_top DUT (
      .clk(clk),
      .rstn(rstn),
      .floor_1_up_button_pressed(floor_1_up_button_pressed),
      .floor_2_up_button_pressed(floor_2_up_button_pressed),
      .floor_2_down_button_pressed(floor_2_down_button_pressed),
      .floor_3_down_button_pressed(floor_3_down_button_pressed),
      .elevator_floor_1_button_pressed(elevator_floor_1_button_pressed),
      .elevator_floor_2_button_pressed(elevator_floor_2_button_pressed),
      .elevator_floor_3_button_pressed(elevator_floor_3_button_pressed),
      .floor_1_out(floor_1_out),
      .floor_2_out(floor_2_out),
      .floor_3_out(floor_3_out),
      .elevator_door_open_out(elevator_door_open_out),
      .floor_1_up_button_out(floor_1_up_button_out),
      .floor_2_up_button_out(floor_2_up_button_out),
      .floor_2_down_button_out(floor_2_down_button_out),
      .floor_3_down_button_out(floor_3_down_button_out),
      .elevator_floor_1_button_out(elevator_floor_1_button_out),
      .elevator_floor_2_button_out(elevator_floor_2_button_out),
      .elevator_floor_3_button_out(elevator_floor_3_button_out)
  );

  always #1 clk = ~clk;

  initial begin
    #10 rstn = 1;
  end

  always @(posedge elevator_door_open_out) begin
```

```
    case ({floor_3_out,floor_2_out,floor_1_out})
      3'b001: begin
        if (floor_1_up_button_out) begin
          $display("  Elevator opened at Floor 1 due to Floor 1 UP button         @Time %7t",
$time);
        end
        else if (elevator_floor_1_button_out) begin
          $display("  Elevator opened at Floor 1 due to Elevator Floor 1 button   @Time %7t",
$time);
        end
      end
      3'b010: begin
        if (floor_2_up_button_out) begin
          $display("  Elevator opened at Floor 2 due to Floor 2 UP button         @Time %7t",
$time);
        end
        else if (floor_2_down_button_out) begin
          $display("  Elevator opened at Floor 2 due to Floor 2 down button       @Time %7t",
$time);
        end
        else if (elevator_floor_2_button_out) begin
          $display("  Elevator opened at Floor 2 due to Elevator Floor 2 button   @Time %7t",
$time);
        end
      end
      3'b100: begin
        if (floor_3_down_button_out) begin
          $display("  Elevator opened at Floor 3 due to Floor 3 down button       @Time %7t",
$time);
        end
        else if (elevator_floor_3_button_out) begin
          $display("  Elevator opened at Floor 3 due to Elevator Floor 3 button   @Time %7t",
$time);
        end
      end
      default:;
    endcase

  end

  initial begin

    $display("\n===============================================TESTBENCH==========================
=================\n");

    testcase = "#0 Initializing                                           ";
    error_count = 8'd0;

    $monitor("\n----------------------------------------------------------------------------------
-----------------\nTestcase: %s  Time = %t\n------------------------------------------------------
---------------------------------------------\n", testcase, $time);

    #10 rstn = 1;


    // test case #1
    testcase = "#1 Floor 1 -> Floor 2                                     ";
    #1
    error_count = compare_outputs(1'b1, floor_1_out, "Floor 1 output", error_count);
    #10
    floor_1_up_button_pressed = 1'b1;
    #2
    floor_1_up_button_pressed = 1'b0;

    #10
    elevator_floor_2_button_pressed = 1'b1;
    #2
    elevator_floor_2_button_pressed = 1'b0;
```

```
// back to floor 1 for test case #2
#80
error_count = compare_outputs(1'b1, floor_2_out, "Floor 2 output", error_count);
elevator_floor_1_button_pressed = 1'b1;
#2
elevator_floor_1_button_pressed = 1'b0;

// test case #2

#80
if (floor_1_out) begin
  testcase = "#2 Floor 1 -> Floor 3                                     ";
end
error_count = compare_outputs(1'b1, floor_1_out, "Floor 1 output", error_count);
floor_1_up_button_pressed = 1'b1;
#2
floor_1_up_button_pressed = 1'b0;

#10
elevator_floor_3_button_pressed = 1'b1;
#2
elevator_floor_3_button_pressed = 1'b0;

// back to floor 2 for test case #3
#80
error_count = compare_outputs(1'b1, floor_3_out, "Floor 3 output", error_count);
elevator_floor_2_button_pressed = 1'b1;
#2
elevator_floor_2_button_pressed = 1'b0;

// test case #3
#80
if (floor_2_out) begin
  testcase = "#3 Floor 2 -> Floor 3                                     ";
end
error_count = compare_outputs(1'b1, floor_2_out, "Floor 2 output", error_count);
floor_2_up_button_pressed = 1'b1;
#2
floor_2_up_button_pressed = 1'b0;

#10
elevator_floor_3_button_pressed = 1'b1;
#2
elevator_floor_3_button_pressed = 1'b0;

// back to floor 2 for test case #4
#80
error_count = compare_outputs(1'b1, floor_3_out, "Floor 3 output", error_count);
elevator_floor_2_button_pressed = 1'b1;
#2
elevator_floor_2_button_pressed = 1'b0;

// test case #4
#80
if (floor_2_out) begin
  testcase =  "#4 Floor 2 -> Floor 1                                     ";
end
error_count = compare_outputs(1'b1, floor_2_out, "Floor 2 output", error_count);
floor_2_down_button_pressed = 1'b1;
#2
floor_2_down_button_pressed = 1'b0;

#10
elevator_floor_1_button_pressed = 1'b1;
#2
elevator_floor_1_button_pressed = 1'b0;

// back to floor 3 for test case #5
```

```
#80
error_count = compare_outputs(1'b1, floor_1_out, "Floor 1 output", error_count);
elevator_floor_3_button_pressed = 1'b1;
#2
elevator_floor_3_button_pressed = 1'b0;

// test case #5

#80
if (floor_3_out) begin
  testcase = "#5 Floor 3 -> Floor 2                                     ";
end
error_count = compare_outputs(1'b1, floor_3_out, "Floor 3 output", error_count);
floor_3_down_button_pressed = 1'b1;
#2
floor_3_down_button_pressed = 1'b0;

#10
elevator_floor_2_button_pressed = 1'b1;
#2
elevator_floor_2_button_pressed = 1'b0;

// back to floor 3 for test case #6
#80
error_count = compare_outputs(1'b1, floor_2_out, "Floor 2 output", error_count);
elevator_floor_3_button_pressed = 1'b1;
#2
elevator_floor_3_button_pressed = 1'b0;

// test case #6

#80
if (floor_3_out) begin
  testcase = "#6 Floor 3 -> Floor 1                                     ";
end
error_count = compare_outputs(1'b1, floor_3_out, "Floor 3 output", error_count);
floor_3_down_button_pressed = 1'b1;
#2
floor_3_down_button_pressed = 1'b0;

#10
elevator_floor_1_button_pressed = 1'b1;
#2
elevator_floor_1_button_pressed = 1'b0;

#60
error_count = compare_outputs(1'b1, floor_1_out, "Floor 1 output", error_count);

// test case #7
testcase = "#7 Floor 1 -> Floor 3 / Pickup on Floor 2                 ";
#20
if (floor_1_out) begin
  testcase = "#7 Floor 1 -> Floor 3 / Pickup on Floor 2                 ";
end
error_count = compare_outputs(1'b1, floor_1_out, "Floor 1 output", error_count);
floor_1_up_button_pressed = 1'b1;
#2
floor_1_up_button_pressed = 1'b0;

#10
elevator_floor_3_button_pressed = 1'b1;
floor_2_up_button_pressed = 1'b1;
#2
elevator_floor_3_button_pressed = 1'b0;
floor_2_up_button_pressed = 1'b0;

#30
error_count = compare_outputs(1'b1, floor_2_out, "Floor 2 output", error_count);
error_count = compare_outputs(1'b1, elevator_door_open_out, "Door open output", error_count);
```

```
#30
error_count = compare_outputs(1'b1, floor_3_out, "Floor 3 output", error_count);

// test case #8

#20
if (floor_3_out) begin
  testcase = "#8 Floor 3 -> Floor 1 / Pickup on Floor 2                 ";
end
error_count = compare_outputs(1'b1, floor_3_out, "Floor 3 output", error_count);
floor_3_down_button_pressed = 1'b1;
#2
floor_3_down_button_pressed = 1'b0;

#10
elevator_floor_1_button_pressed = 1'b1;
floor_2_down_button_pressed = 1'b1;
#2
elevator_floor_1_button_pressed = 1'b0;
floor_2_down_button_pressed = 1'b0;

#30
error_count = compare_outputs(1'b1, floor_2_out, "Floor 2 output", error_count);
error_count = compare_outputs(1'b1, elevator_door_open_out, "Door open output", error_count);
#30
error_count = compare_outputs(1'b1, floor_1_out, "Floor 1 output", error_count);

// test case #9a
#20
if (floor_1_out) begin
  testcase = "#9a Floor 1 -> Floor 3 / Pickup on Floor 2 pressed Floor 1";
end
error_count = compare_outputs(1'b1, floor_1_out, "Floor 1 output", error_count);
floor_1_up_button_pressed = 1'b1;
#2
floor_1_up_button_pressed = 1'b0;

#10
elevator_floor_3_button_pressed = 1'b1;
floor_2_up_button_pressed = 1'b1;
#2
elevator_floor_3_button_pressed = 1'b0;
floor_2_up_button_pressed = 1'b0;

#30
error_count = compare_outputs(1'b1, floor_2_out, "Floor 2 output", error_count);
error_count = compare_outputs(1'b1, elevator_door_open_out, "Door open output", error_count);

#10
elevator_floor_1_button_pressed = 1'b1;
#2
elevator_floor_1_button_pressed = 1'b0;

#20
error_count = compare_outputs(1'b1, floor_3_out, "Floor 3 output", error_count);
#50
error_count = compare_outputs(1'b1, floor_1_out, "Floor 1 output", error_count);

// back to floor 3 for test case #9b
#10
error_count = compare_outputs(1'b1, floor_1_out, "Floor 1 output", error_count);
elevator_floor_3_button_pressed = 1'b1;
#2
elevator_floor_3_button_pressed = 1'b0;

// test case #9b
#80
if (floor_3_out) begin
  testcase = "#9b Floor 3 -> Floor 1 / Pickup on Floor 2 pressed Floor 3";
```

```
    end
    floor_3_down_button_pressed = 1'b1;
    #2
    floor_3_down_button_pressed = 1'b0;

    #10
    elevator_floor_1_button_pressed = 1'b1;
    floor_2_down_button_pressed = 1'b1;
    #2
    elevator_floor_1_button_pressed = 1'b0;
    floor_2_down_button_pressed = 1'b0;

    #30
    error_count = compare_outputs(1'b1, floor_2_out, "Floor 2 output", error_count);
    error_count = compare_outputs(1'b1, elevator_door_open_out, "Door open output", error_count);

    #10
    elevator_floor_3_button_pressed = 1'b1;
    #2
    elevator_floor_3_button_pressed = 1'b0;

    #20
    error_count = compare_outputs(1'b1, floor_1_out, "Floor 1 output", error_count);
    #50
    error_count = compare_outputs(1'b1, floor_3_out, "Floor 3 output", error_count);

    $display("\n***************************\nFINAL ERROR COUNT: %8d\n***************************",
error_count);

    $display("\n===============================================FINISH=============================
=================\n");

    $finish;
  end

  function [7:0] compare_outputs (
    input     expected_value,
    input     actual_value,
    input [8*19:0] signal_name,
    input [7:0] error_count);
    if ( expected_value == actual_value ) begin
      compare_outputs = error_count;
    end
    else begin
      $display("    FAIL** %s: Expected = %b, Actual = %b, Time = %t", signal_name,
expected_value, actual_value, $time);
      compare_outputs = error_count + 1;
    end
  endfunction // compare_outputs

endmodule
```

# Testbench Result

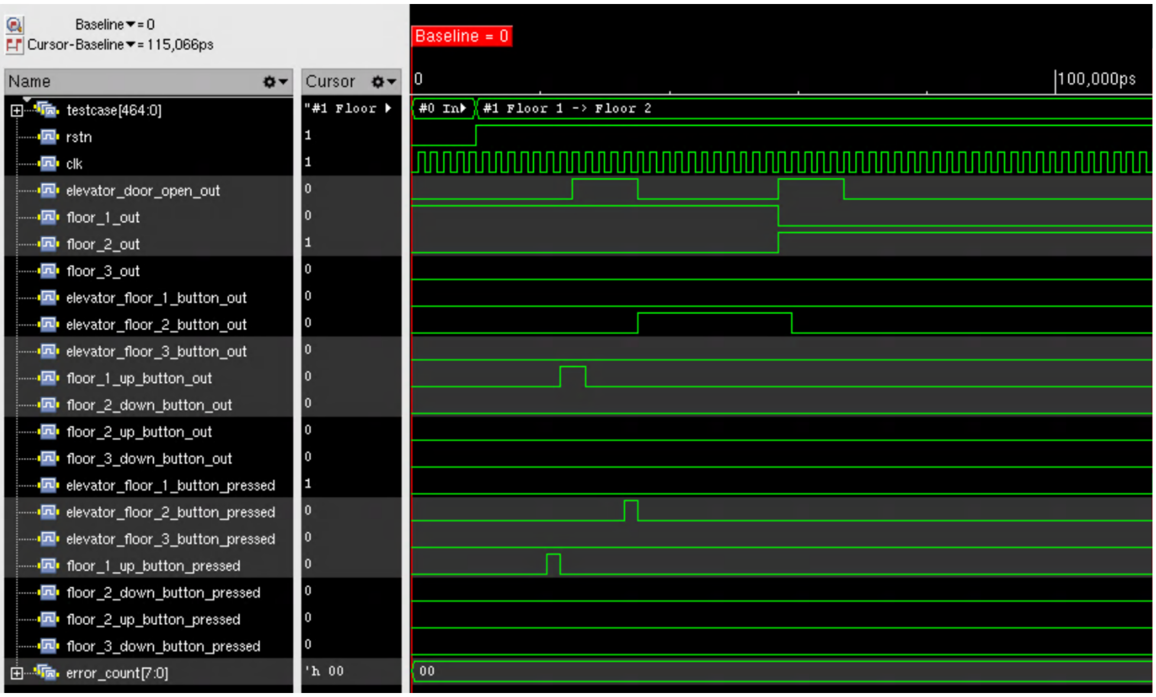
## Console log:

```
================================================TESTBENCH===========================================

----------------------------------------------------------------------------------------------------

Testcase:  #0 Initializing                                              Time =                    0

----------------------------------------------------------------------------------------------------

----------------------------------------------------------------------------------------------------

Testcase:  #1 Floor 1 -> Floor 2                                        Time =                10000

----------------------------------------------------------------------------------------------------

  Elevator opened at Floor 1 due to Floor 1 UP button         @Time   25000

  Elevator opened at Floor 2 due to Elevator Floor 2 button   @Time   57000

  Elevator opened at Floor 1 due to Elevator Floor 1 button   @Time  139000

----------------------------------------------------------------------------------------------------

Testcase:  #2 Floor 1 -> Floor 3                                        Time =               197000

----------------------------------------------------------------------------------------------------

  Elevator opened at Floor 1 due to Floor 1 UP button         @Time  201000

  Elevator opened at Floor 3 due to Elevator Floor 3 button   @Time  253000

  Elevator opened at Floor 2 due to Elevator Floor 2 button   @Time  315000

----------------------------------------------------------------------------------------------------

Testcase:  #3 Floor 2 -> Floor 3                                        Time =               373000

----------------------------------------------------------------------------------------------------

  Elevator opened at Floor 2 due to Floor 2 UP button         @Time  377000

  Elevator opened at Floor 3 due to Elevator Floor 3 button   @Time  409000

  Elevator opened at Floor 2 due to Elevator Floor 2 button   @Time  491000

----------------------------------------------------------------------------------------------------

Testcase:  #4 Floor 2 -> Floor 1                                        Time =               549000

----------------------------------------------------------------------------------------------------

  Elevator opened at Floor 2 due to Floor 2 down button       @Time  553000

  Elevator opened at Floor 1 due to Elevator Floor 1 button   @Time  585000

  Elevator opened at Floor 3 due to Elevator Floor 3 button   @Time  687000

----------------------------------------------------------------------------------------------------

Testcase:  #5 Floor 3 -> Floor 2                                        Time =               725000

----------------------------------------------------------------------------------------------------

  Elevator opened at Floor 3 due to Floor 3 down button       @Time  729000

  Elevator opened at Floor 2 due to Elevator Floor 2 button   @Time  761000

  Elevator opened at Floor 3 due to Elevator Floor 3 button   @Time  843000

----------------------------------------------------------------------------------------------------

Testcase:  #6 Floor 3 -> Floor 1                                        Time =               901000

----------------------------------------------------------------------------------------------------
```

```
  Elevator opened at Floor 3 due to Floor 3 down button      @Time  905000

  Elevator opened at Floor 1 due to Elevator Floor 1 button   @Time  957000

---------------------------------------------------------------------------------------------------

Testcase:  #7 Floor 1 -> Floor 3 / Pickup on Floor 2                   Time =              975000

---------------------------------------------------------------------------------------------------

  Elevator opened at Floor 1 due to Floor 1 UP button        @Time  999000

  Elevator opened at Floor 2 due to Floor 2 UP button        @Time 1031000

  Elevator opened at Floor 3 due to Elevator Floor 3 button   @Time 1063000

---------------------------------------------------------------------------------------------------

Testcase:  #8 Floor 3 -> Floor 1 / Pickup on Floor 2                   Time =             1089000

---------------------------------------------------------------------------------------------------

  Elevator opened at Floor 3 due to Floor 3 down button      @Time 1093000

  Elevator opened at Floor 2 due to Floor 2 down button      @Time 1125000

  Elevator opened at Floor 1 due to Elevator Floor 1 button   @Time 1157000

---------------------------------------------------------------------------------------------------

Testcase:  #9a Floor 1 -> Floor 3 / Pickup on Floor 2 pressed Floor 1  Time =             1183000

---------------------------------------------------------------------------------------------------

  Elevator opened at Floor 1 due to Floor 1 UP button        @Time 1187000

  Elevator opened at Floor 2 due to Floor 2 UP button        @Time 1219000

  Elevator opened at Floor 3 due to Elevator Floor 3 button   @Time 1251000

  Elevator opened at Floor 1 due to Elevator Floor 1 button   @Time 1303000

  Elevator opened at Floor 3 due to Elevator Floor 3 button   @Time 1363000

---------------------------------------------------------------------------------------------------

Testcase:  #9b Floor 3 -> Floor 1 / Pickup on Floor 2 pressed Floor 3  Time =             1401000

---------------------------------------------------------------------------------------------------

  Elevator opened at Floor 3 due to Floor 3 down button      @Time 1405000

  Elevator opened at Floor 2 due to Floor 2 down button      @Time 1437000

  Elevator opened at Floor 1 due to Elevator Floor 1 button   @Time 1469000

  Elevator opened at Floor 3 due to Elevator Floor 3 button   @Time 1521000


***************************

FINAL ERROR COUNT:        0

***************************

===============================================FINISH==============================================
```

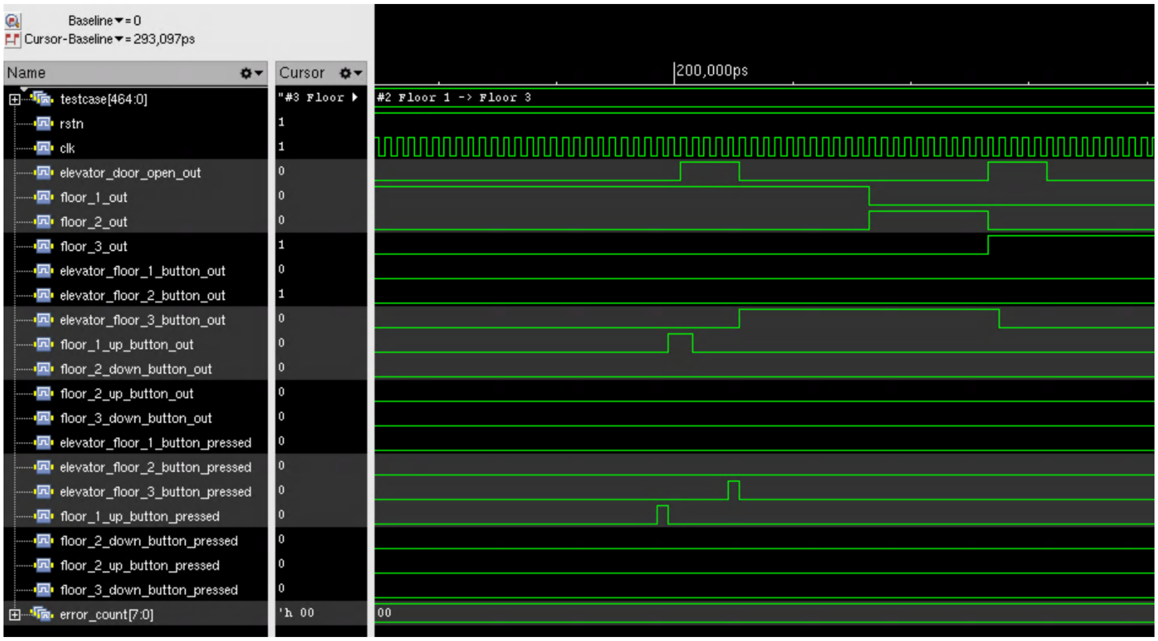
**Waveform:**

Test case #1: Floor 1 -> Floor 2



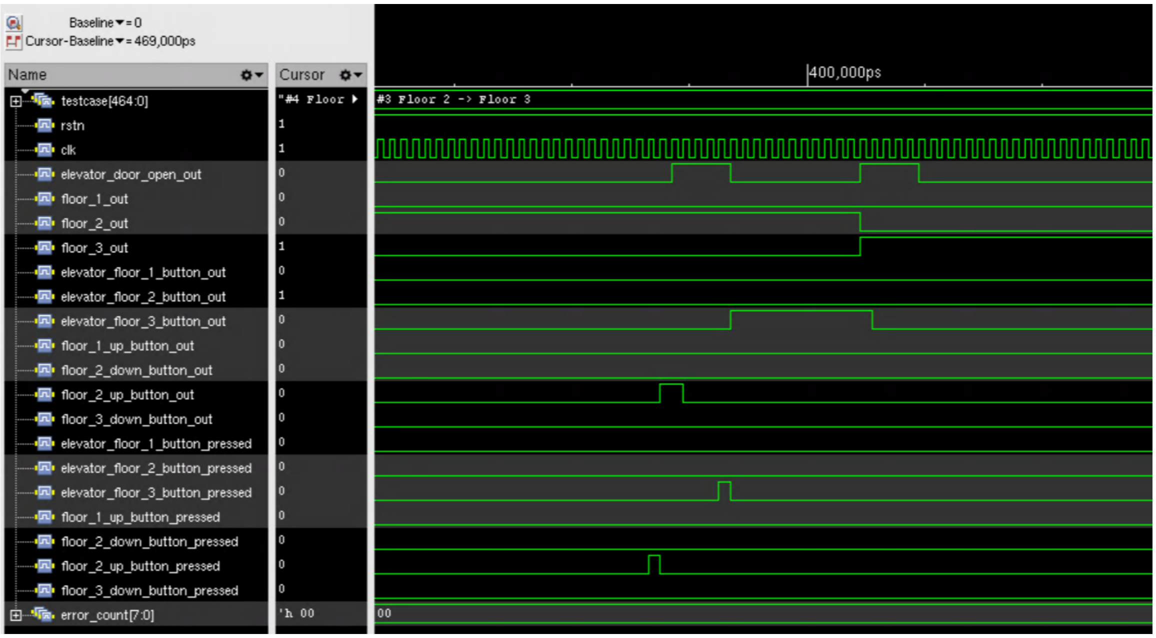
| Name | Cursor |
|---|---|
| testcase[464:0] | "#1 Floor ▸ |
| rstn | 1 |
| clk | 1 |
| elevator_door_open_out | 0 |
| floor_1_out | 0 |
| floor_2_out | 1 |
| floor_3_out | 0 |
| elevator_floor_1_button_out | 0 |
| elevator_floor_2_button_out | 0 |
| elevator_floor_3_button_out | 0 |
| floor_1_up_button_out | 0 |
| floor_2_down_button_out | 0 |
| floor_2_up_button_out | 0 |
| floor_3_down_button_out | 0 |
| elevator_floor_1_button_pressed | 1 |
| elevator_floor_2_button_pressed | 0 |
| elevator_floor_3_button_pressed | 0 |
| floor_1_up_button_pressed | 0 |
| floor_2_down_button_pressed | 0 |
| floor_2_up_button_pressed | 0 |
| floor_3_down_button_pressed | 0 |
| error_count[7:0] | 'h 00 |

Test case #2: Floor 1 -> Floor 3

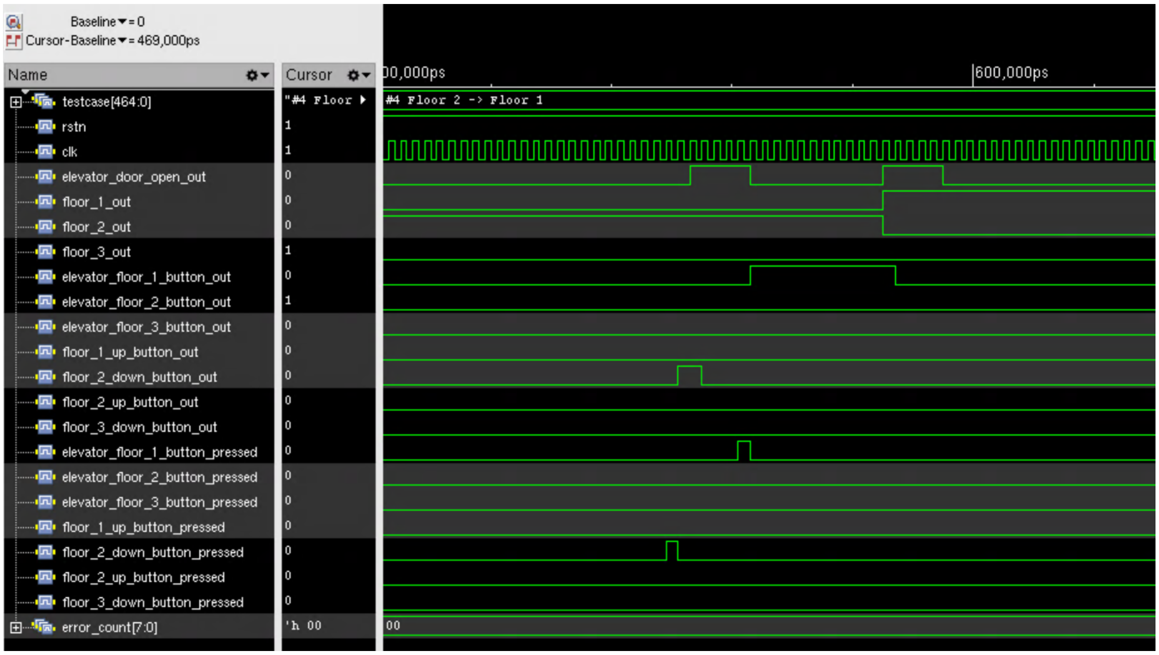


| Name | Cursor |
|---|---|
| testcase[464:0] | "#3 Floor ▸ |
| rstn | 1 |
| clk | 1 |
| elevator_door_open_out | 0 |
| floor_1_out | 0 |
| floor_2_out | 0 |
| floor_3_out | 1 |
| elevator_floor_1_button_out | 0 |
| elevator_floor_2_button_out | 1 |
| elevator_floor_3_button_out | 0 |
| floor_1_up_button_out | 0 |
| floor_2_down_button_out | 0 |
| floor_2_up_button_out | 0 |
| floor_3_down_button_out | 0 |
| elevator_floor_1_button_pressed | 0 |
| elevator_floor_2_button_pressed | 0 |
| elevator_floor_3_button_pressed | 0 |
| floor_1_up_button_pressed | 0 |
| floor_2_down_button_pressed | 0 |
| floor_2_up_button_pressed | 0 |
| floor_3_down_button_pressed | 0 |
| error_count[7:0] | 'h 00 |

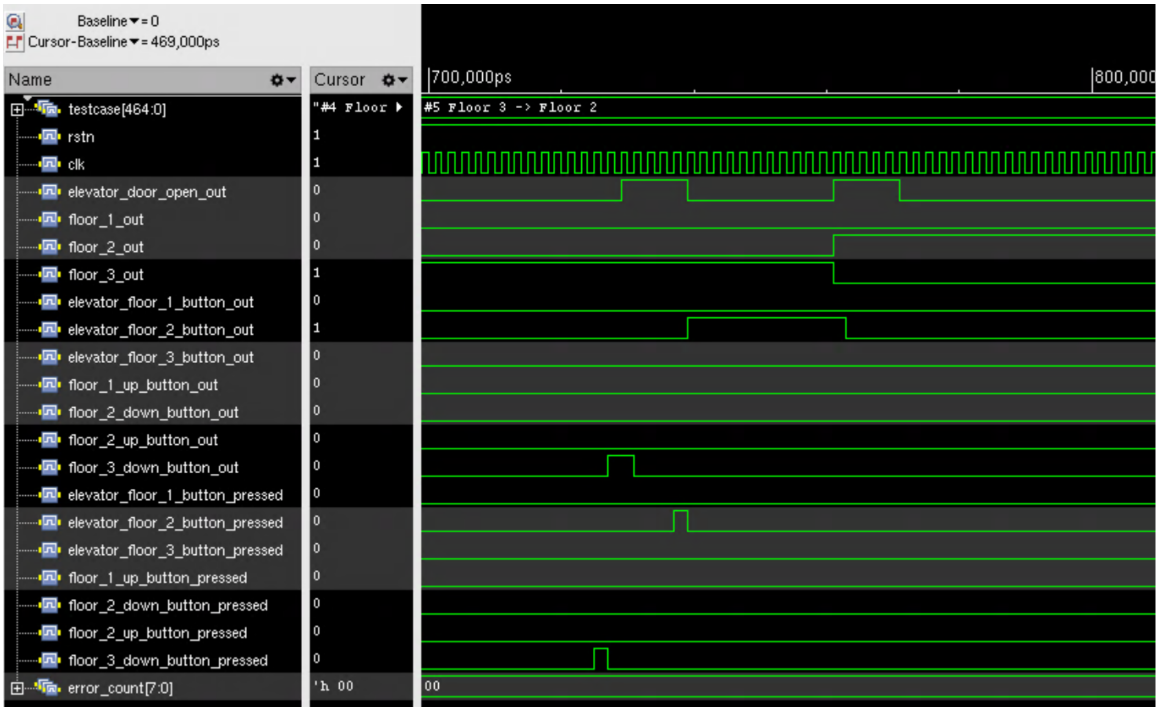
Test case #3: Floor 2 -> Floor 3


Baseline ▾ = 0
Cursor-Baseline ▾ = 469,000ps
Name
Cursor
400,000ps
testcase[464:0] "#4 Floor ▸
#3 Floor 2 -> Floor 3
rstn 1
clk 1
elevator_door_open_out 0
floor_1_out 0
floor_2_out 0
floor_3_out 1
elevator_floor_1_button_out 0
elevator_floor_2_button_out 1
elevator_floor_3_button_out 0
floor_1_up_button_out 0
floor_2_down_button_out 0
floor_2_up_button_out 0
floor_3_down_button_out 0
elevator_floor_1_button_pressed 0
elevator_floor_2_button_pressed 0
elevator_floor_3_button_pressed 0
floor_1_up_button_pressed 0
floor_2_down_button_pressed 0
floor_2_up_button_pressed 0
floor_3_down_button_pressed 0
error_count[7:0] 'h 00
00

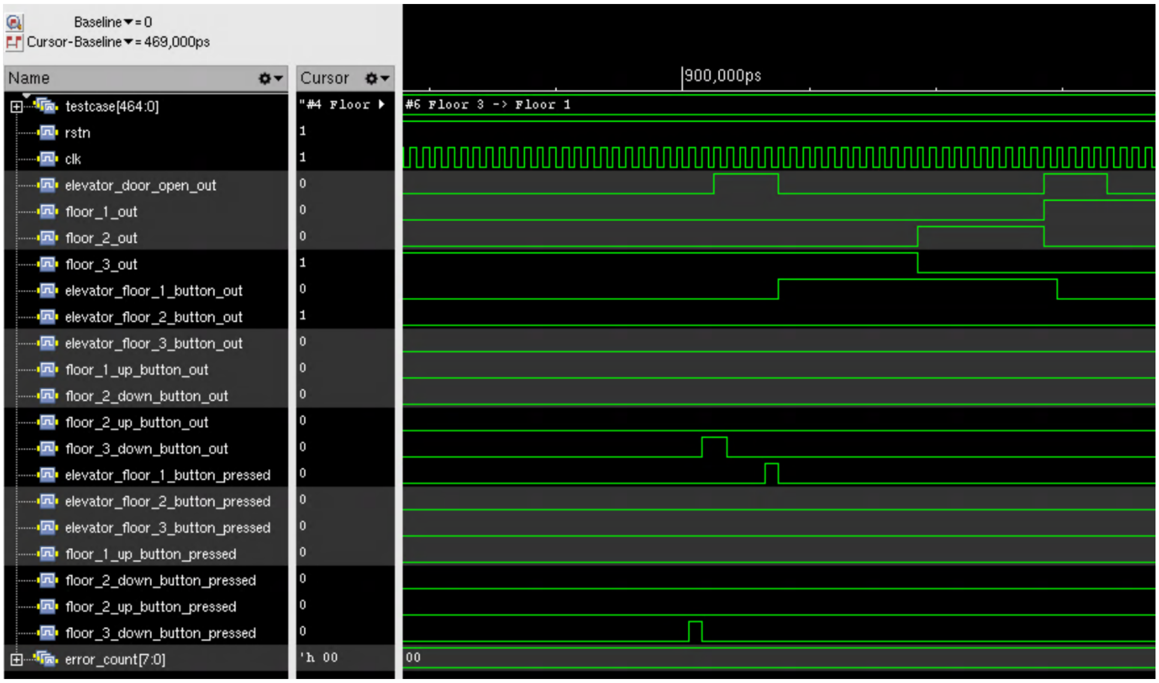
Test case #4: Floor 2 -> Floor 1


Baseline ▾ = 0
Cursor-Baseline ▾ = 469,000ps
Name
Cursor
00,000ps
600,000ps
testcase[464:0] "#4 Floor ▸
#4 Floor 2 -> Floor 1
rstn 1
clk 1
elevator_door_open_out 0
floor_1_out 0
floor_2_out 0
floor_3_out 1
elevator_floor_1_button_out 0
elevator_floor_2_button_out 1
elevator_floor_3_button_out 0
floor_1_up_button_out 0
floor_2_down_button_out 0
floor_2_up_button_out 0
floor_3_down_button_out 0
elevator_floor_1_button_pressed 0
elevator_floor_2_button_pressed 0
elevator_floor_3_button_pressed 0
floor_1_up_button_pressed 0
floor_2_down_button_pressed 0
floor_2_up_button_pressed 0
floor_3_down_button_pressed 0
error_count[7:0] 'h 00
00

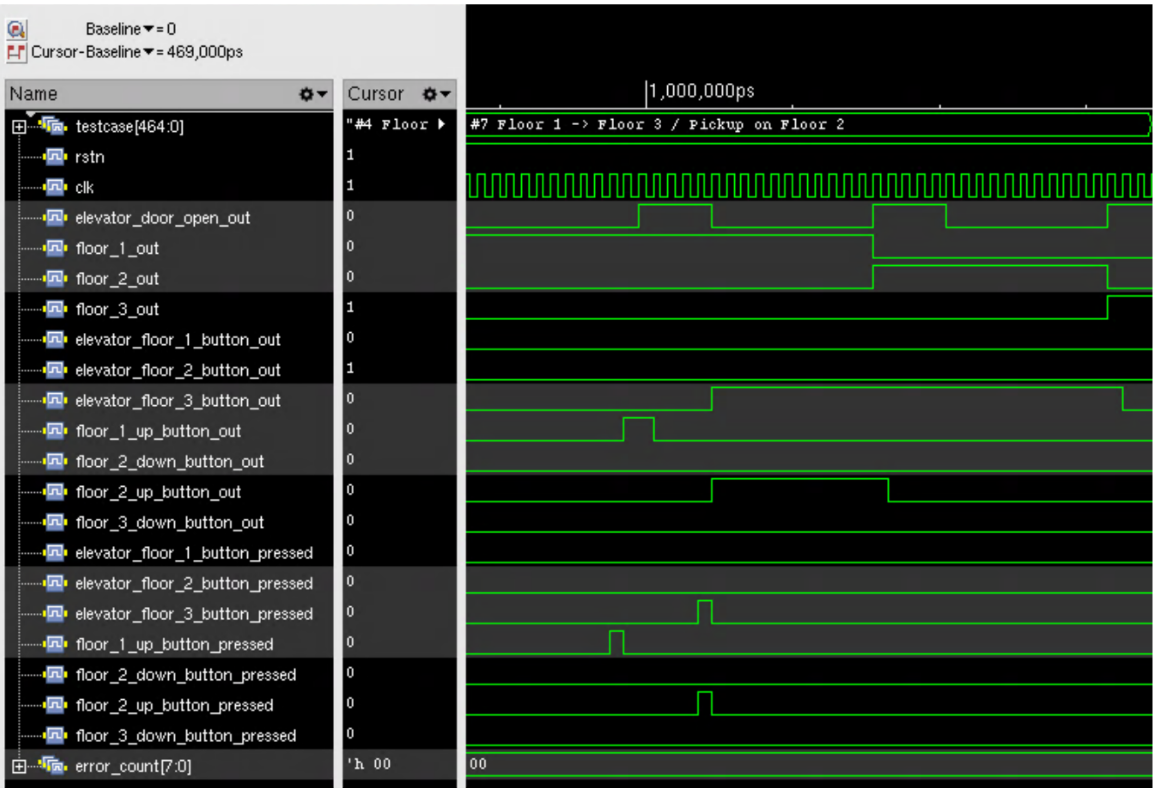
Test case #5: Floor 3 -> Floor 2


Baseline = 0
Cursor-Baseline = 469,000ps
Name
Cursor
700,000ps
800,000
testcase[464:0] "#4 Floor
#5 Floor 3 -> Floor 2
rstn 1
clk 1
elevator_door_open_out 0
floor_1_out 0
floor_2_out 0
floor_3_out 1
elevator_floor_1_button_out 0
elevator_floor_2_button_out 1
elevator_floor_3_button_out 0
floor_1_up_button_out 0
floor_2_down_button_out 0
floor_2_up_button_out 0
floor_3_down_button_out 0
elevator_floor_1_button_pressed 0
elevator_floor_2_button_pressed 0
elevator_floor_3_button_pressed 0
floor_1_up_button_pressed 0
floor_2_down_button_pressed 0
floor_2_up_button_pressed 0
floor_3_down_button_pressed 0
error_count[7:0] 'h 00
00

Test case #6: Floor 3 -> Floor 1


Baseline = 0
Cursor-Baseline = 469,000ps
Name
Cursor
900,000ps
testcase[464:0] "#4 Floor
#6 Floor 3 -> Floor 1
rstn 1
clk 1
elevator_door_open_out 0
floor_1_out 0
floor_2_out 0
floor_3_out 1
elevator_floor_1_button_out 0
elevator_floor_2_button_out 1
elevator_floor_3_button_out 0
floor_1_up_button_out 0
floor_2_down_button_out 0
floor_2_up_button_out 0
floor_3_down_button_out 0
elevator_floor_1_button_pressed 0
elevator_floor_2_button_pressed 0
elevator_floor_3_button_pressed 0
floor_1_up_button_pressed 0
floor_2_down_button_pressed 0
floor_2_up_button_pressed 0
floor_3_down_button_pressed 0
error_count[7:0] 'h 00
00

Test case #7: Floor 1 -> Floor 3 / Pickup on Floor 2



Baseline = 0
Cursor-Baseline = 469,000ps

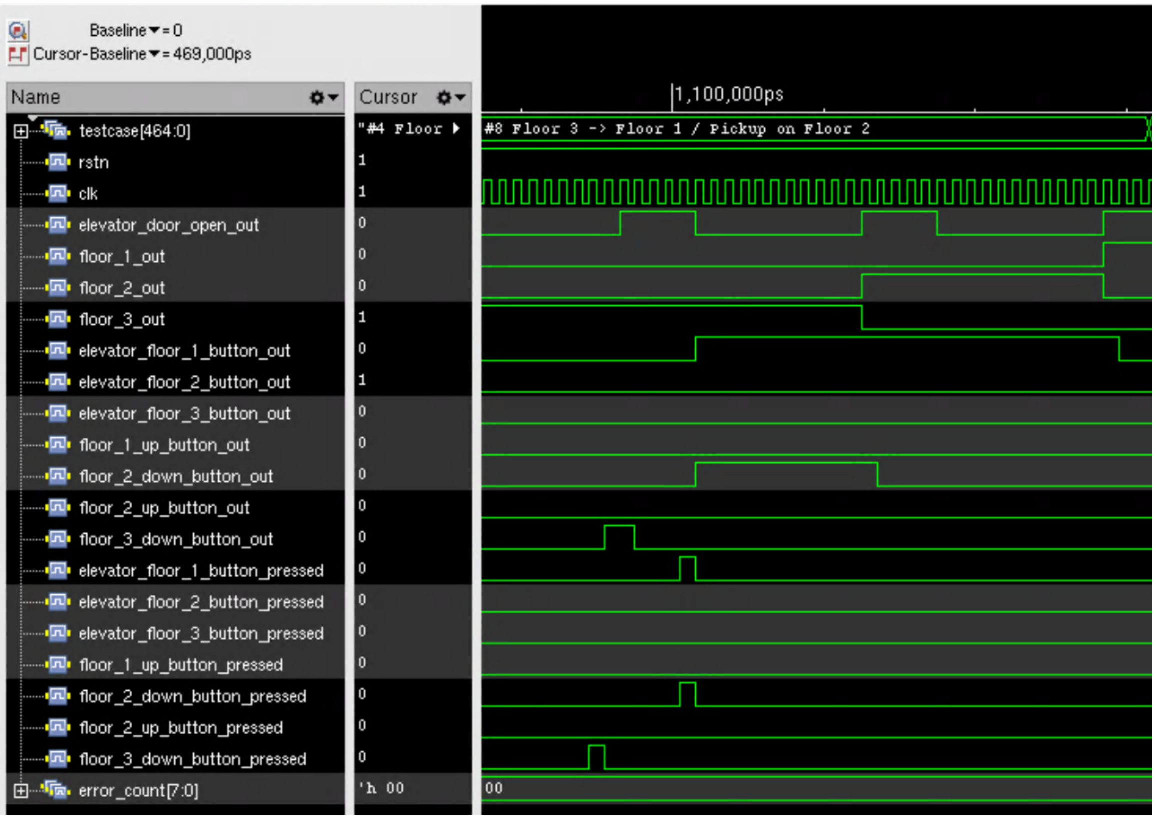
1,000,000ps

| Name | Cursor |
|---|---|
| testcase[464:0] | "#4 Floor |
| rstn | 1 |
| clk | 1 |
| elevator_door_open_out | 0 |
| floor_1_out | 0 |
| floor_2_out | 0 |
| floor_3_out | 1 |
| elevator_floor_1_button_out | 0 |
| elevator_floor_2_button_out | 1 |
| elevator_floor_3_button_out | 0 |
| floor_1_up_button_out | 0 |
| floor_2_down_button_out | 0 |
| floor_2_up_button_out | 0 |
| floor_3_down_button_out | 0 |
| elevator_floor_1_button_pressed | 0 |
| elevator_floor_2_button_pressed | 0 |
| elevator_floor_3_button_pressed | 0 |
| floor_1_up_button_pressed | 0 |
| floor_2_down_button_pressed | 0 |
| floor_2_up_button_pressed | 0 |
| floor_3_down_button_pressed | 0 |
| error_count[7:0] | 'h 00 |

#7 Floor 1 -> Floor 3 / Pickup on Floor 2

00

Test case #8: Floor 3 -> Floor 1 /Pickup on Floor 2



Baseline = 0
Cursor-Baseline = 469,000ps

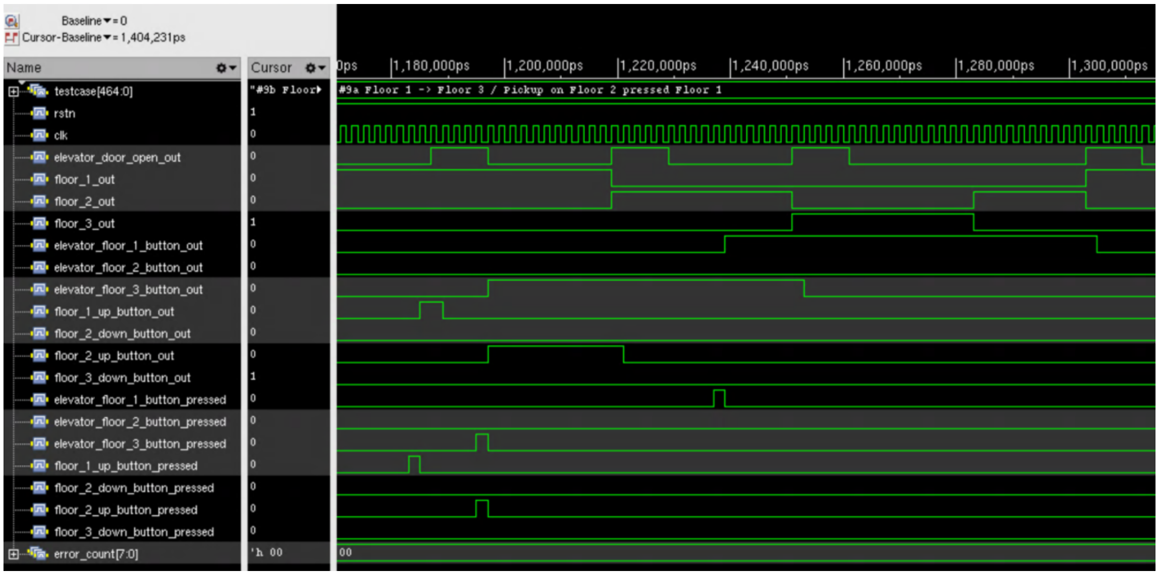
1,100,000ps

| Name | Cursor |
|---|---|
| testcase[464:0] | "#4 Floor |
| rstn | 1 |
| clk | 1 |
| elevator_door_open_out | 0 |
| floor_1_out | 0 |
| floor_2_out | 0 |
| floor_3_out | 1 |
| elevator_floor_1_button_out | 0 |
| elevator_floor_2_button_out | 1 |
| elevator_floor_3_button_out | 0 |
| floor_1_up_button_out | 0 |
| floor_2_down_button_out | 0 |
| floor_2_up_button_out | 0 |
| floor_3_down_button_out | 0 |
| elevator_floor_1_button_pressed | 0 |
| elevator_floor_2_button_pressed | 0 |
| elevator_floor_3_button_pressed | 0 |
| floor_1_up_button_pressed | 0 |
| floor_2_down_button_pressed | 0 |
| floor_2_up_button_pressed | 0 |
| floor_3_down_button_pressed | 0 |
| error_count[7:0] | 'h 00 |

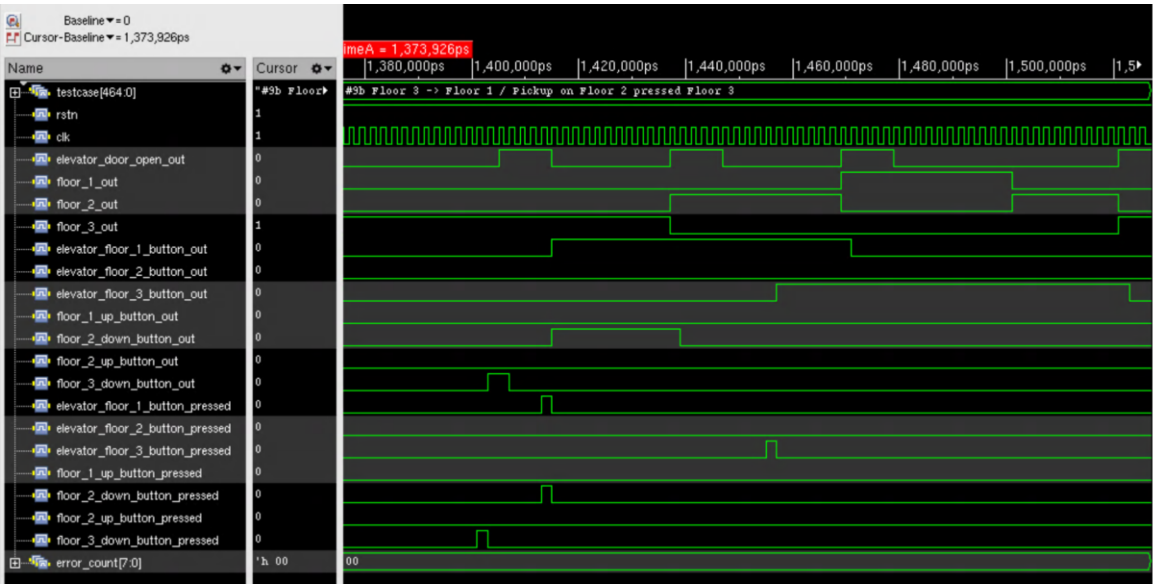
#8 Floor 3 -> Floor 1 / Pickup on Floor 2

00

Test case #9a: Floor1 -> Floor 3 / Pickup on Floor 2 pressed Floor 1


Baseline ▾ = 0
Cursor-Baseline ▾ = 1,404,231ps
Name
Cursor
0ps
1,180,000ps
1,200,000ps
1,220,000ps
1,240,000ps
1,260,000ps
1,280,000ps
1,300,000ps
testcase[464:0] "#9b Floor▸
#9a Floor 1 -> Floor 3 / Pickup on Floor 2 pressed Floor 1
rstn 1
clk 0
elevator_door_open_out 0
floor_1_out 0
floor_2_out 0
floor_3_out 1
elevator_floor_1_button_out 0
elevator_floor_2_button_out 0
elevator_floor_3_button_out 0
floor_1_up_button_out 0
floor_2_down_button_out 0
floor_2_up_button_out 0
floor_3_down_button_out 1
elevator_floor_1_button_pressed 0
elevator_floor_2_button_pressed 0
elevator_floor_3_button_pressed 0
floor_1_up_button_pressed 0
floor_2_down_button_pressed 0
floor_2_up_button_pressed 0
floor_3_down_button_pressed 0
error_count[7:0] 'h 00
00

Test case #9b: Floor 33 -> Floor 1 / Pickup on Floor 2 pressed Floor 3


Baseline ▾ = 0
Cursor-Baseline ▾ = 1,373,926ps
imeA = 1,373,926ps
Name
Cursor
1,380,000ps
1,400,000ps
1,420,000ps
1,440,000ps
1,460,000ps
1,480,000ps
1,500,000ps
1,5▸
testcase[464:0] "#9b Floor▸
#9b Floor 3 -> Floor 1 / Pickup on Floor 2 pressed Floor 3
rstn 1
clk 1
elevator_door_open_out 0
floor_1_out 0
floor_2_out 0
floor_3_out 1
elevator_floor_1_button_out 0
elevator_floor_2_button_out 0
elevator_floor_3_button_out 0
floor_1_up_button_out 0
floor_2_down_button_out 0
floor_2_up_button_out 0
floor_3_down_button_out 0
elevator_floor_1_button_pressed 0
elevator_floor_2_button_pressed 0
elevator_floor_3_button_pressed 0
floor_1_up_button_pressed 0
floor_2_down_button_pressed 0
floor_2_up_button_pressed 0
floor_3_down_button_pressed 0
error_count[7:0] 'h 00
00