

# ELC 2137 Lab 11: FSM: Guessing Game

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## Summary

This lab looks to expand on previous labs by expanding into larger systems with more modules. It allowed us to learn how to explain the role of finite state machines in digital systems logic, explain the difference between a Mealy output and a Moore output, and implement a state machine in Verilog. In completing this lab, the following skills were gained: ability to recognize and run a debounce circuit, the ability to develop a game using Mealy or Moore outputs, the ability to implement a clock-driven, guessing game using pushbuttons, leds, switches, and an instance of a counter module.

## Results

### Deliverable Questions:

- a)** At what time in the simulation did the debounce circuit reach each of the four states? (zero, wait1, one, wait0)? The debounce circuit reaches each of the four states at around the following times: zero at 20ns, wait1 at 200ns, one at 245ns, and wait0 at 420ns.
- b)** Why can this game not be implemented with regular sequential logic? If implemented with regular sequential logic, the game would not skip to win or skip to lose without going through the entire states of s0, s1, s2, and s3.
- c)** What type of outputs did you use for your design (Mealy or Moore)? I used Moore outputs for my design. Although it can be slower to operate, it has less probability of total failure.

Below are the simulations for the modules, debounce and guess FSM and pictures of the board for win and lose for on-board testing of guessing game.



Figure 1: Debounce Simulation Results

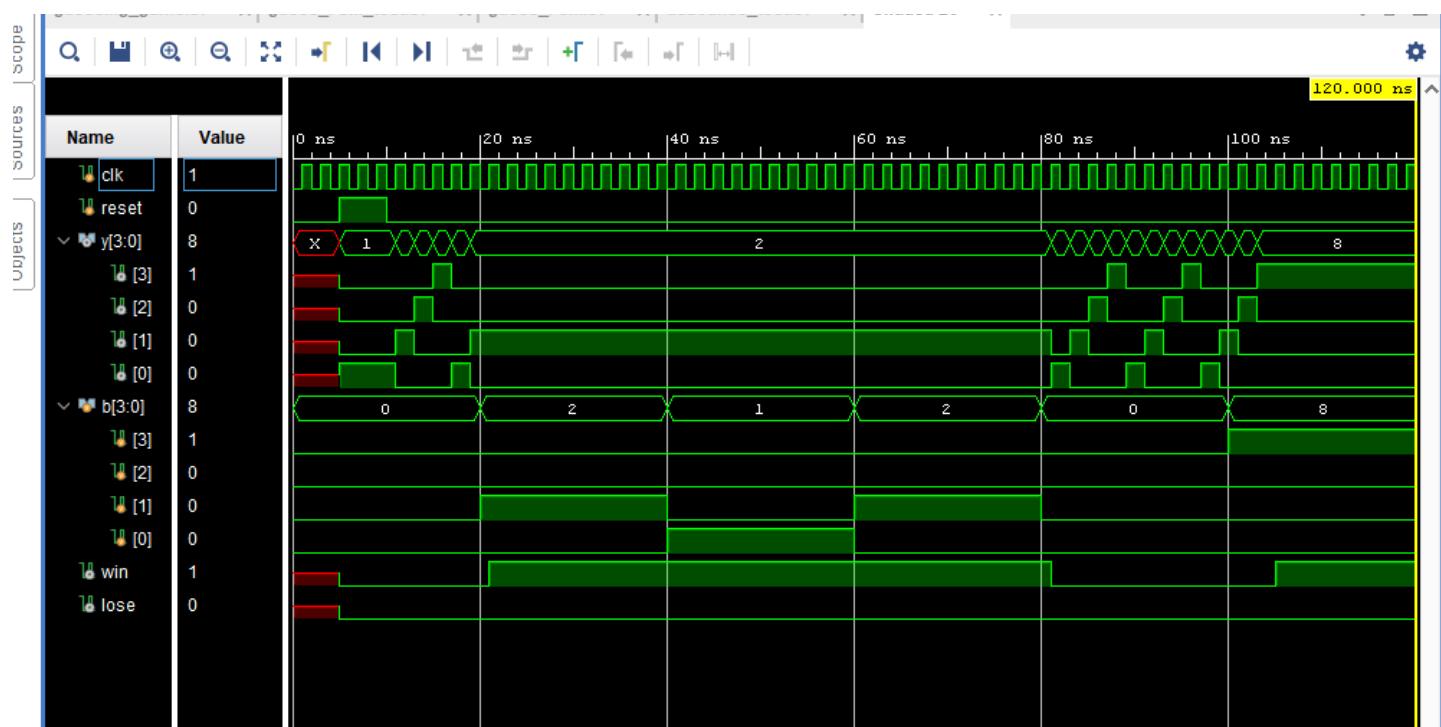


Figure 2: Guess FSM Simulation Results

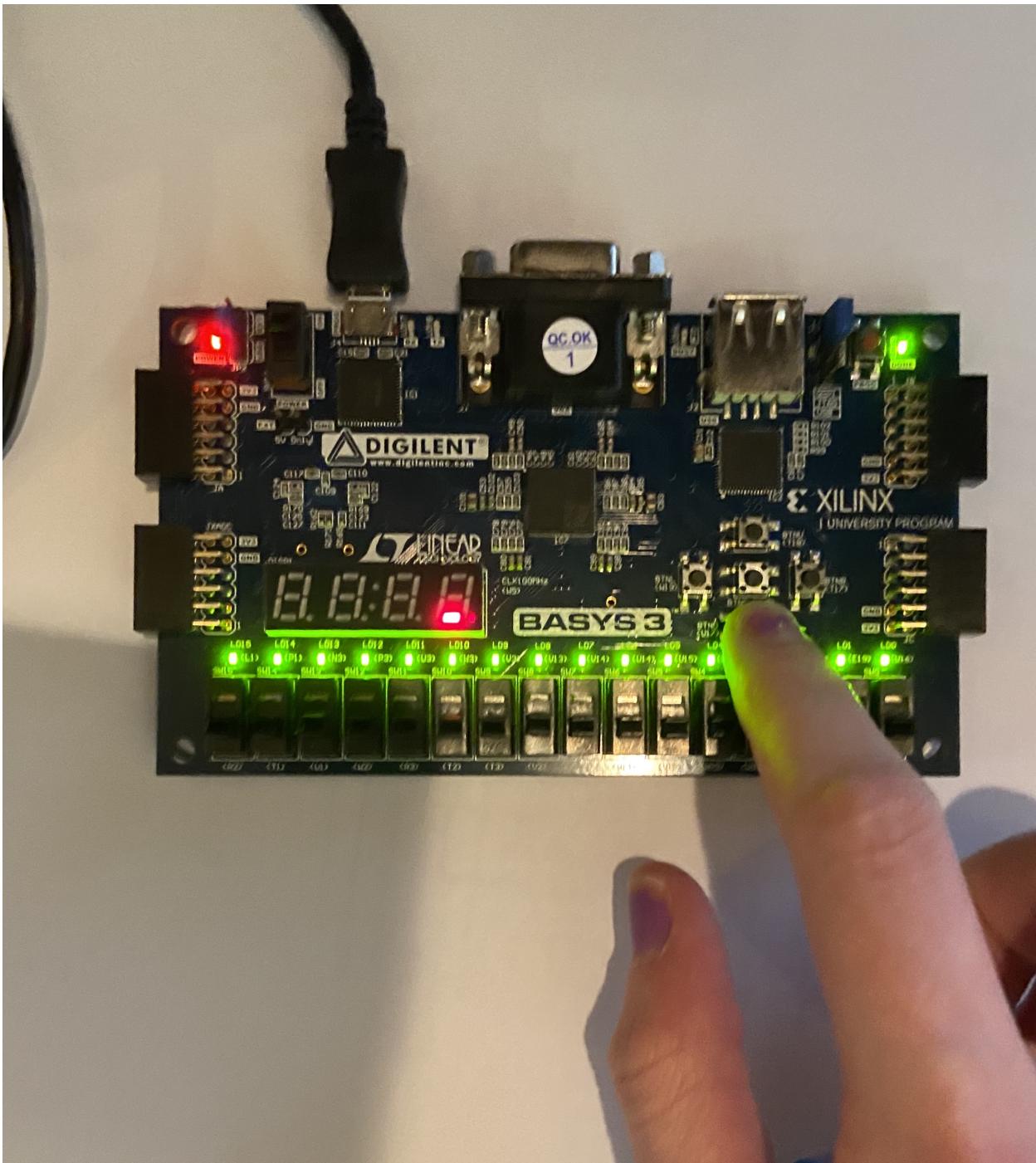


Figure 3: Game Results Simulation 1 - Win

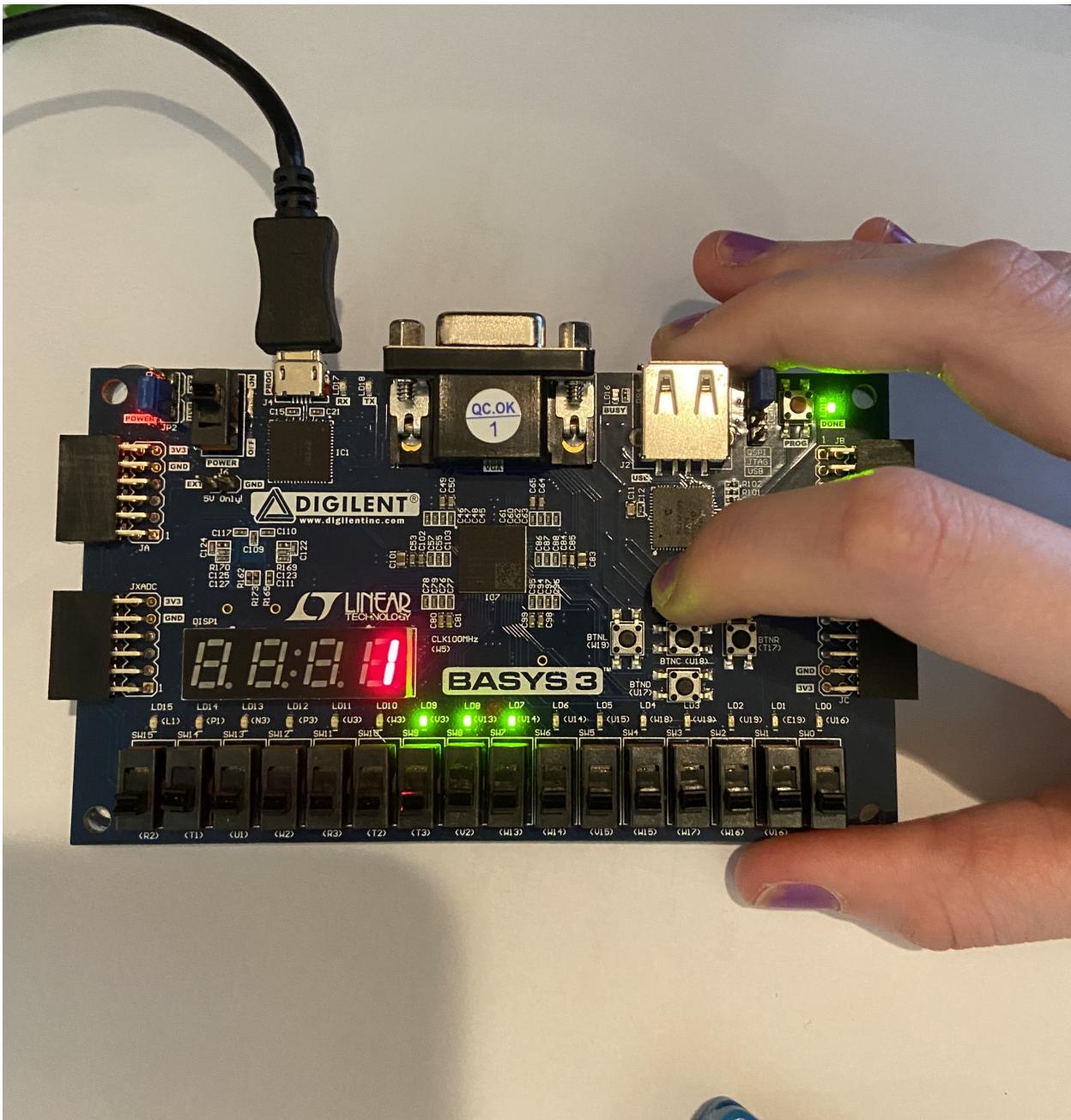


Figure 4: Game Results Simulation 2 - Lose

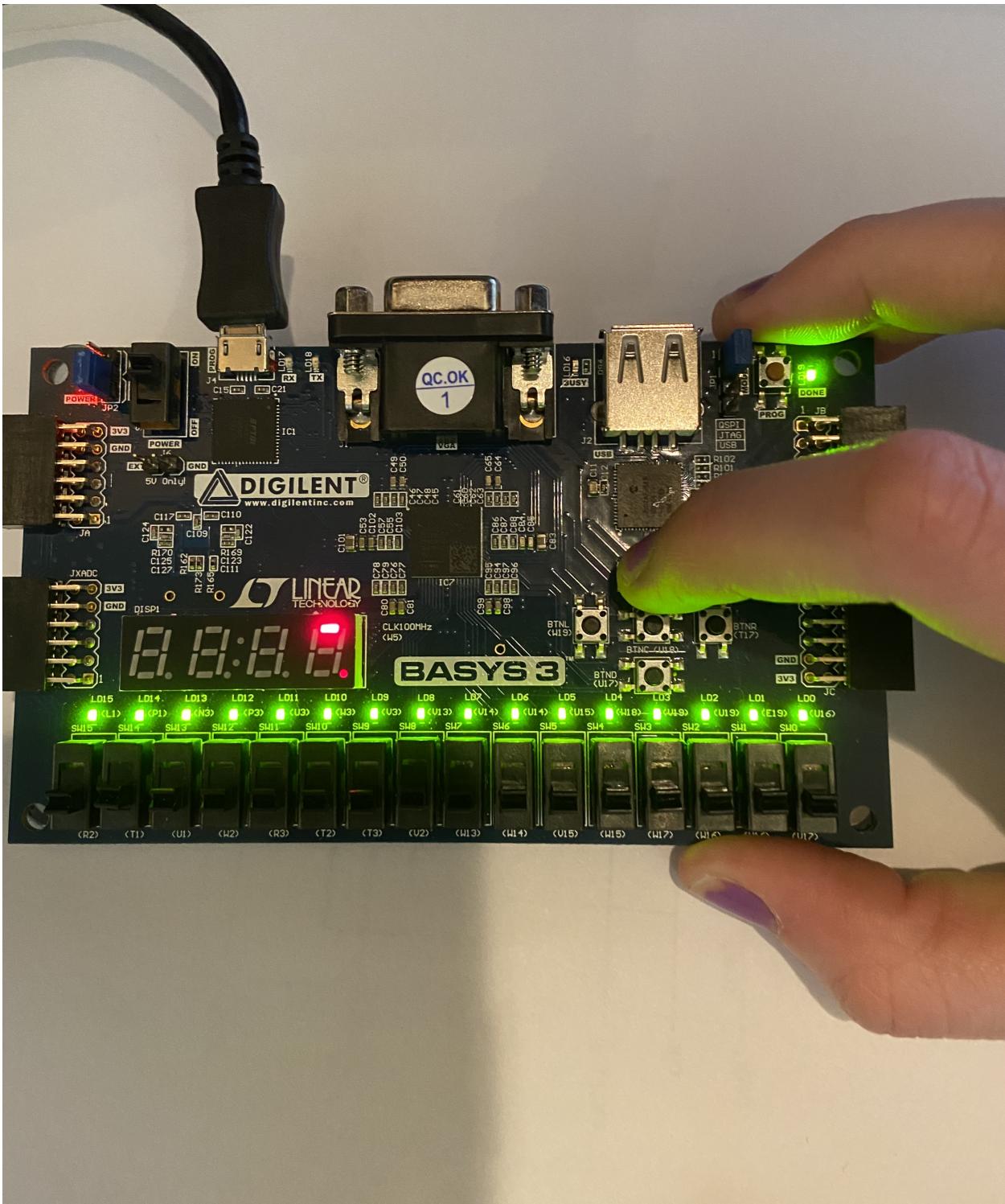


Figure 5: Game Results Simulation 3 - Win

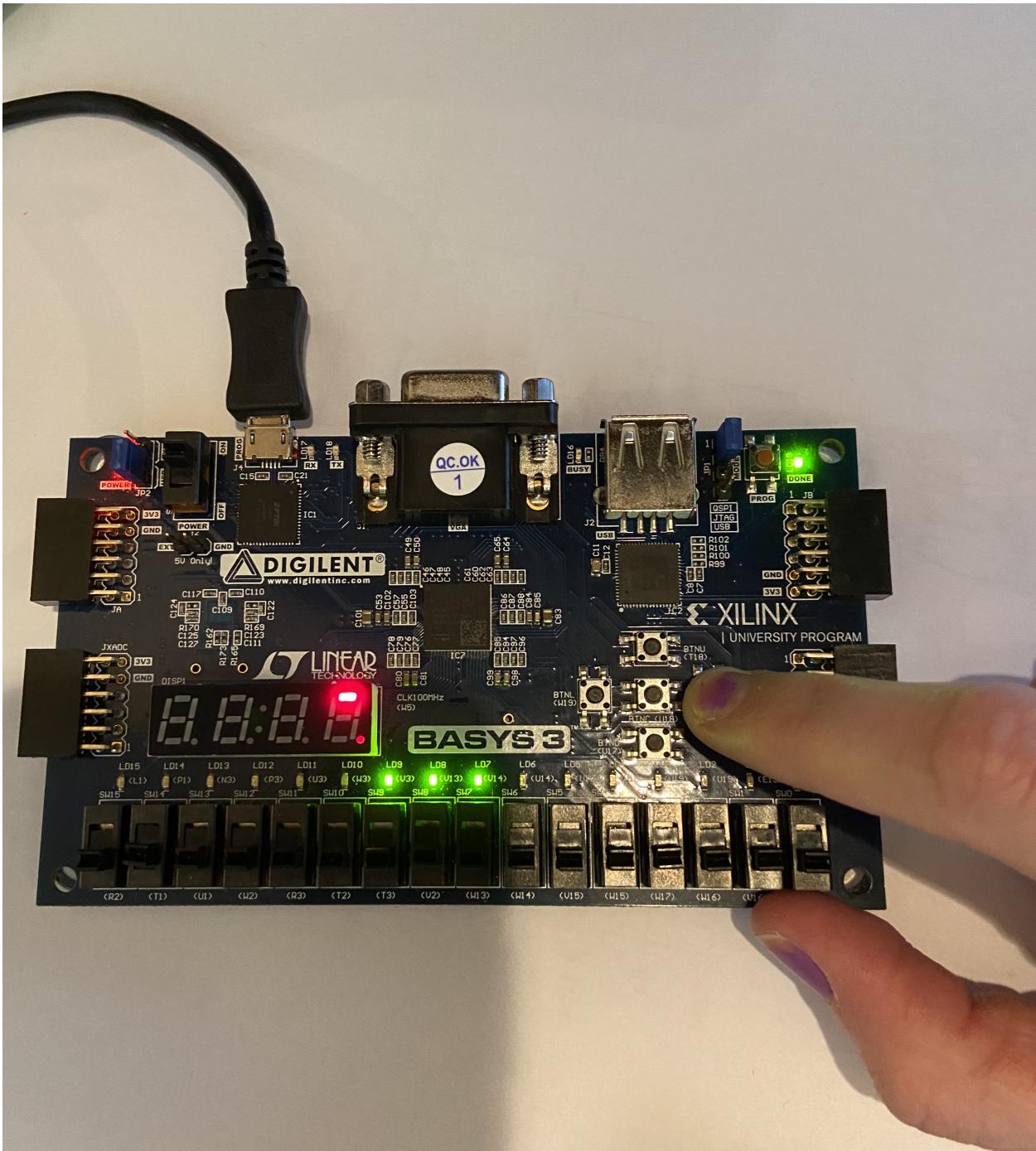


Figure 6: Game Results Simulation 4 - Lose

## Code

Code for source files for debounce, guess FSM, and guessing game and the test bench files for the debounce and guess FSM.

Listing 1: debounce Code

```
'timescale 1ns / 1ps
// ELC 2137, John Miller, 2019-11-08

module debounce #(parameter N=21)
(input clk, reset,
input in,
output reg out,
output reg tick);

// define states as local parameters (constants)
localparam [1:0]
zero    = 2'b00,
wait1   = 2'b01,
one     = 2'b11,
wait0   = 2'b10;

// internal signals
reg [1:0] state, state_next;
reg [N-1:0] counter, counter_next;

// state memory (register)
always_ff @(posedge clk or posedge reset)
if (reset) begin
state    <= zero;
counter <= {N{1'b1}};
end
else begin
state    <= state_next;
counter <= counter_next;
end

// combined next-state and output logic
always_comb begin
// default behavior
state_next    = state;
counter_next  = counter;
tick = 0;

case(state)
zero: begin
out = 0;
counter_next = {N{1'b1}};
if (in)
state_next = wait1;
end

wait1: begin
```

```
out = 0;      // Moore output
counter_next = counter - 1;
if (counter == 0) begin
  tick = 1'b1; // Mealy output
  state_next = one;
end
else if (~in)
  state_next = zero;
end

one: begin
  out = 1;
  counter_next = {N{1'b1}};
  if (~in)
    state_next = wait0;
end

wait0: begin
  out = 1;
  counter_next = counter - 1;
  if (counter == 0)
    state_next = zero;
  else if (in)
    state_next = one;
end
endcase
end

endmodule // debounce
```

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Listing 2: guess FSM Code

---

```
'timescale 1ns / 1ps
//Megan Gordon
//ELC 2137 4-21-2020

module guess_FSM #(parameter N=21)
(input clk, reset,
input [3:0] b,
output reg [3:0] y,
output reg win,
output reg lose);

// define states as local parameters (constants)
localparam [2:0]
s0 = 3'b000,
s1 = 3'b001,
s2 = 3'b010,
s3 = 3'b011,
swin = 3'b100,
slose = 3'b101;

// internal signals
reg [2:0] state, state_next;

// state memory (register)
always_ff @(posedge clk or posedge reset)
if (reset) begin
state <= s0;
end
else begin
state <= state_next;
end

// combined next-state and output logic
always_comb begin
// default behavior
state_next = state;

case(state)
s0: begin
win=0;
lose=0;
y = 4'b0001;
if (~b[0])
state_next = s1;
else if (~b[3]&~b[2]&~b[1]&b[0])
state_next = swin;
else if (b[3]|b[2]|b[1])
state_next = slose;
end

s1: begin
y = 4'b0010;
```

```

if (~b[1])
state_next = s2;
else if (~b[3]&~b[2]&b[1]&~b[0])
state_next = swin;
else if (b[3]|b[2]|b[0])
state_next = slose;
end

s2: begin
y = 4'b0100;
if (~b[2])
state_next = s3;
else if (~b[3]&b[2]&~b[1]&~b[0])
state_next = swin;
else if (b[3]|b[1]|b[0])
state_next = slose;
end

s3: begin
y = 4'b1000;
if (~b[3])
state_next = s0;
else if (b[3]&~b[2]&~b[1]&~b[0])
state_next = swin;
else if (b[2]|b[1]|b[0])
state_next = slose;
end

swin: begin
win=1;
lose=0;
if (b[3]|b[2]|b[1]|b[0])
state_next = swin;
else if (~b[3]&~b[2]&~b[1]&~b[0])
state_next = s0;
end

slose: begin
lose=1;
win=0;
if (b[3]|b[2]|b[1]|b[0])
state_next = slose;
else if (~b[3]&~b[2]&~b[1]&~b[0])
state_next = s0;
end

endcase
end

endmodule

```

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Listing 3: guessing game Code

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```
'timescale 1ns / 1ps
//Megan Gordon
//ELC 2137 4-22-2020

module guessing_game(
input btnU, btnD, btnR, btnL,
input clk,
input [15:0] sw,
input btnC,
output reg [6:0] seg,
output [3:0] an,
output reg [15:0] led);

//counter
wire [1:0] count1;
counter #(.N(2)) counter1(.clk(clk), .rst(btnC), .en(sw[0]), .count(count1)
);

//buttons U, D, R, and L debounced
wire tickU;
wire outU;
debounce #(.N(2)) dbU (.clk(clk), .reset(btnC), .in(btnU), .out(outU),
.tick(tickU));

wire tickD;
wire outD;
debounce #(.N(2)) dbD (.clk(clk), .reset(btnC), .in(btnD), .out(outD),
.tick(tickD));

wire tickR;
wire outR;
debounce #(.N(2)) dbR (.clk(clk), .reset(btnC), .in(btnR), .out(outR),
.tick(tickR));

wire tickL;
wire outL;
debounce #(.N(2)) dbL (.clk(clk), .reset(btnC), .in(btnL), .out(outL),
.tick(tickL));

//button debounce outputs to b input
wire [3:0] b;
assign outU = b[3]; //up button is b[3]
assign outR = b[2]; //right button is b[2]
assign outD = b[1]; //down button is b[1]
assign outL = b[0]; //left button is b[0]

wire clock;
mux2_4b mux1(.in0(clk) , .in1(count1) , .sel(sw[15]) ,.out(clock));

wire win, lose;
wire [3:0] y;
guess_FSM #(.N(21)) guess (.clk(clock), .reset(btnC), .b(b), .y(y), .win(
```

```
    win), .lose(lose));\n\nassign an[0] = 0; //only one digit needed\nassign an[3:1] = 3'b111;\n\nalways @*\nbegin\nif (y==4'b0001)\nseg = 7'b1111110; //top\nelse if (y==4'b0010)\nseg = 7'b1111001; //right\nelse if (y == 4'b0100)\nseg = 7'b1110111; //bottom\nelse if (y==4'b100)\nseg = 7'b1001111; //left\nend\n\nalways @*\nbegin\nif (win)\nled=16'b1111111111111111;\nelse if (lose)\nled=16'b0000001110000000;\nend\nendmodule
```

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Listing 4: debounce Test Bench Code

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```
'timescale 1ns / 1ps
// ELC 2137, John Miller, 2019-11-08

module debounce_test();

reg clk, reset, in;
wire out, tick;
integer i;

debounce #(N(2)) db (.clk(clk), .reset(reset), .in(in), .out(out),
.tick(tick));

always begin
#5 clk = ~clk;
end

initial begin
clk=0; reset=0; in=0; #5;
reset=1; #10;
reset=0; #5;
// bounce
for (i=0; i<10; i=i+1) begin
#20 in=~in;
end
// hold input = 1 for a while
in = 1; #200;
// bounce
for (i=0; i<10; i=i+1) begin
#20 in=~in;
end
// hold input = 0 for a while
in = 0; #200;
$finish;
end
endmodule // debounce_test
```

---

Listing 5: guess FSM Test Bench Code

---

```
'timescale 1ns / 1ps
//Megan Gordon
//ELC 2137 4-22-2020

module guess_FSM_test();

reg clk, reset;
wire [3:0] y;
reg [3:0] b;
wire win, lose;

guess_FSM #(N(21))guess1(.clk(clk), .reset(reset), .b(b), .y(y), .win(win),
), .lose(lose));

always begin
#1 clk = ~clk;
end

initial begin
clk=0; reset=0; b=4'b0000; #5;
reset=1; #5;
reset=0; #10;
b=4'b0010; #20
b=4'b0001; #20
b=4'b0010; #20
b=4'b0000; #20
b=4'b1000; #20
$finish;
end
endmodule // guess_FSM_test
```

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