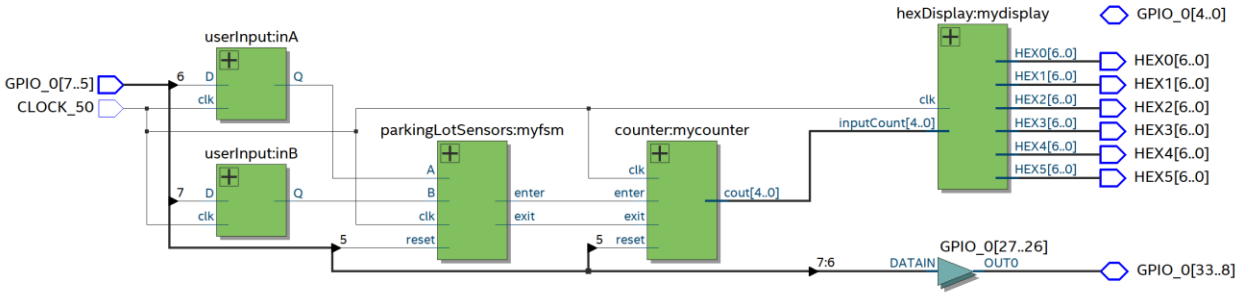
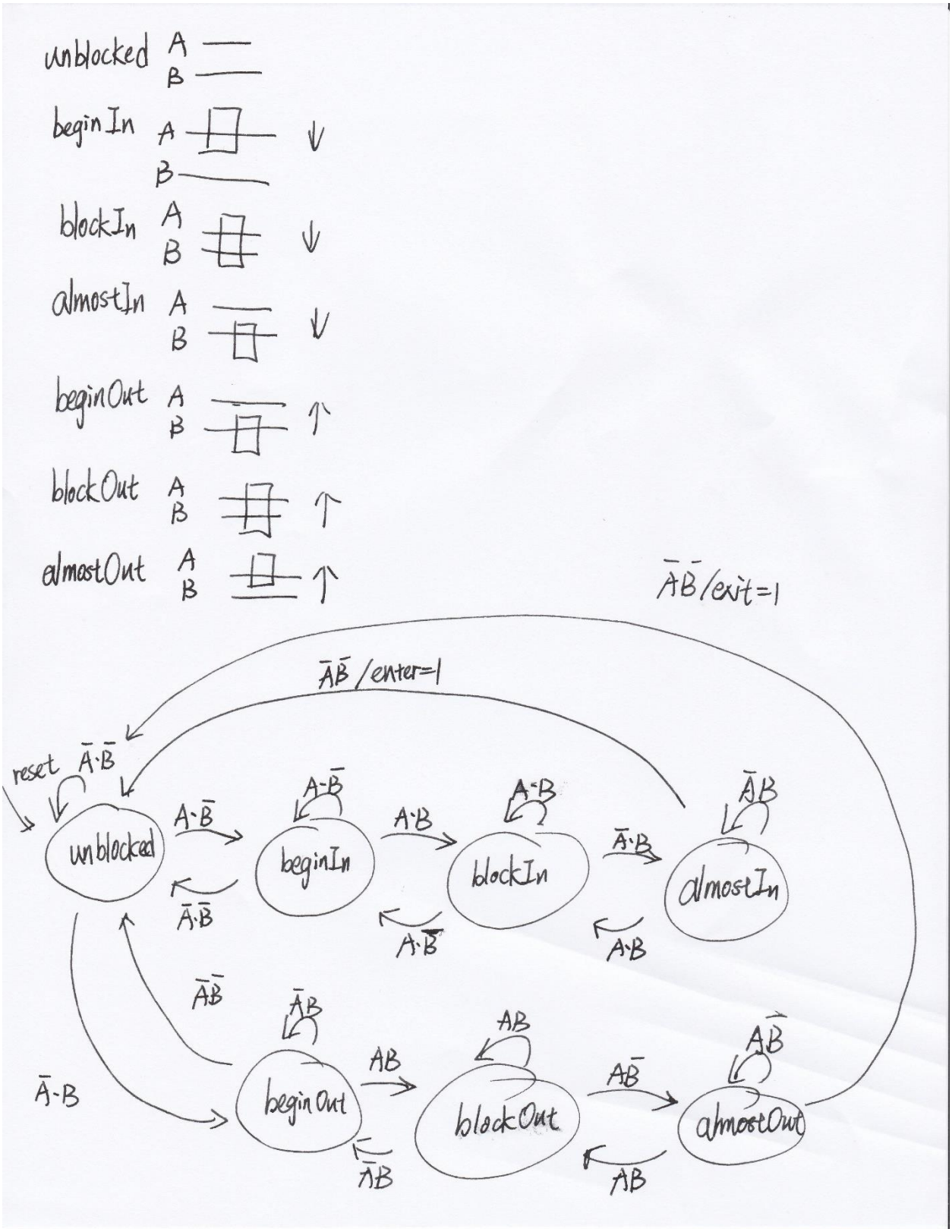
Alan Li
EE 371
January 15th, 2022
Lab 1 Report

Section 1: Procedure





Upon reading the lab assignment, I first designed how many states there should be. There are two sensor in the system. I assume that when car enters, it will trigger sensorA first, then both sensorA and

B, then only sensorB, then none of them. So the sequence for a car entering without changing direction is 00,10,11,01,00. Similarly, the sequence for car exiting without changing direction is 00,01,11,10,00.

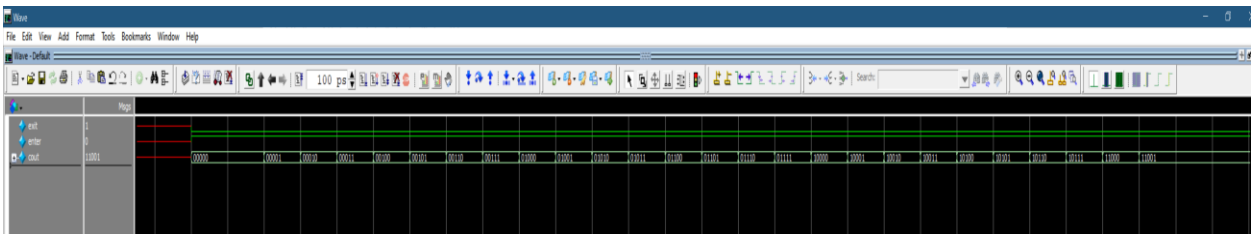
The reason I designed “in” and “out” in the system is that I want to tackle the changing direction issue. For example, there are two cases where only sensor A is triggered: a car just start to come in, or a car almost leave. It would be impossible for the system to decide which situation this is without adding the “in” and “out” cases. In that case, when the car comes in and then backs up after triggering sensor A, the system will recognize this and not marking it as an exit.

The rest of the system has 5 modules, userInput reduce the possibility the metastability, hexDisplay will display numbers and letters as the assignment states. The counter counts how many cars have entered or left. The parkingLotSensor is the most important part as it tells the rest of the module if there is an enter or exit signal.

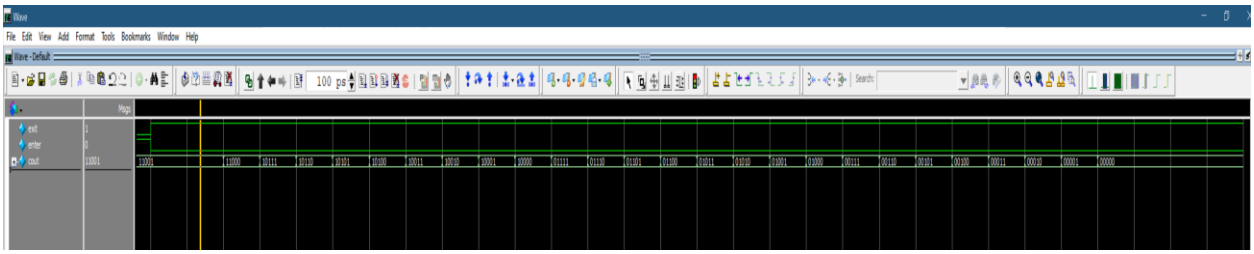
Section 2 Results:

I did not design simulation for userInput as it is unnecessary.

For counter module I simulate enter signal for 30 times and then exit counter for 30 time. Since the parking lot only has a capacity of 25, the counter should stay at 25 and then drop to 25 and stay there.

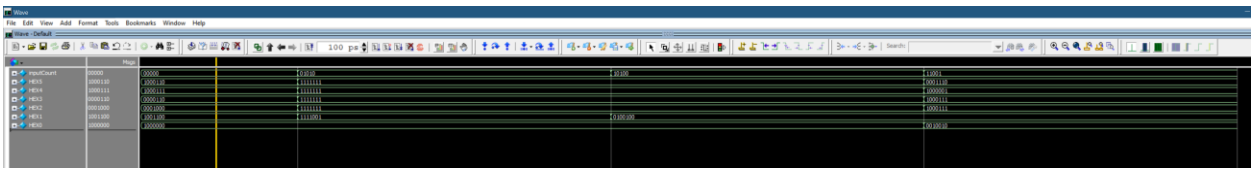


The counter keeps adding up until it reached 11001(25 in decimal)

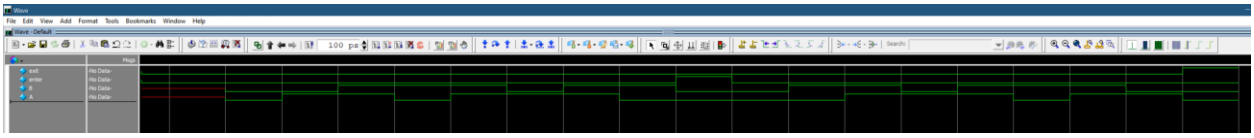


The counter decreases until reaches 0.

For hexDisplay I simulate the counter to be at 0,10,20 and 25 respectively. And the waveform shows that the HEX displays the right number

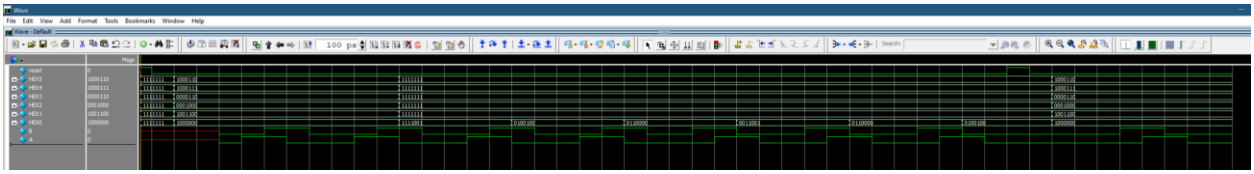


For the parkingLotSensor I designed the simulator which the car will change direction multiple times and eventually enter or exit the parking lot. So, there should only be one enter and exit signal. The waveform shows the same result.



We can see the enter signal at 900ps and exit signal at 1900ps

For the top-level module, I simulate 4 cars enters then 3 cars exit. After that I reset the system and give one exit signal, this shouldn't happen in real life, but the system should know how to handle it. The counter will stay at zero and the hex display should display "clear0"



Overall, the system satisfies every requirement in the lab assignment. The system can handle the car changing direction issue. The system can display both numbers and letters. The counter has upper and lower limit for parking lot capacity.

Section 3: Appendix

```
1   // Alan Li
2   // 01/15/2022
3   // EE 371
4   // Lab #1
5
6   // counter takes 1-bit enter and exit as inputs and return 5-bit cout
    as output.
7   // The module functions as its name. When there is an enter signal, the
    cout increse by 1. When there is an exit signal, the cout decrease by 1.
8   // The range for the counter is from 0 to 25.
9
10  module counter(clk, reset, enter, exit, cout);
11
12     input logic clk, reset, enter, exit;
13     output logic [4:0] cout;
14     logic [4:0] ps, ns;
15
16     // Each decimal from 0 to 25 has been assigned with a 5-bit binary
    number.
17     parameter [4:0] zero = 5'b0,
18        one = 5'b1,
19        two = 5'b10,
20        three = 5'b11,
21        four = 5'b100,
22        five = 5'b101,
23        six = 5'b110,
24        seven = 5'b111,
25        eight = 5'b1000,
26        nine = 5'b1001,
27        ten = 5'b1010,
28        eleven = 5'b1011,
29        twelve = 5'b1100,
30        thirteen = 5'b1101,
31        fourteen = 5'b1110,
32        fifteen = 5'b1111,
33        sixteen = 5'b10000,
34        seventeen = 5'b10001,
35        eighteen = 5'b10010,
36        nineteen = 5'b10011,
37        twenty = 5'b10100,
38        twentyone = 5'b10101,
39        twentytwo = 5'b10110,
40        twentythree = 5'b10111,
41        twentyfour = 5'b11000,
42        twentyfive = 5'b11001;
43
44     // 25 states for the counter. Each state represent a different
    number.
45     // When there is a enter signal, the counter goes to next state
    which the number increase by one and vice versa.
46     // At state 0, if there is another exit signal(which should not
    happen in reality), the state will stay at zero.
47     // At state 25, if there is another enter signal, the state will
    stay at 25.
48        case(ps)
49           zero: if(enter)         ns = one;
50                 else              ns = zero;
51           one: if(enter)          ns = two;
```

```
52                      else if(exit)     ns = zero;
53                      else              ns = one;
54              two: if(enter)            ns = three;
55                      else if(exit)     ns = one;
56                      else              ns = two;
57              three:if(enter)           ns = four;
58                      else if(exit)     ns = two;
59                      else              ns = three;
60              four: if(enter)           ns = five;
61                      else if(exit)     ns = three;
62                      else              ns = four;
63
64              /*
65              five: if(exit)            ns = four;
66                      else              ns = five; // for demo purpose
67              */
68
69
70              five: if(enter)           ns = six;
71                      else if(exit)     ns = four;
72                      else              ns = five; // for lab design purpose
73
74              six: if(enter)            ns = seven;
75                      else if(exit)     ns = five;
76                      else              ns = six;
77              seven: if(enter)          ns = eight;
78                      else if(exit)     ns = six;
79                      else              ns = seven;
80              eight:if(enter)           ns = nine;
81                      else if(exit)     ns = seven;
82                      else              ns = eight;
83              nine: if(enter)           ns = ten;
84                      else if(exit)     ns = eight;
85                      else              ns = nine;
86              ten:  if(enter)           ns = eleven;
87                      else if(exit)     ns = nine;
88                      else              ns = ten;
89              eleven:if(enter)          ns = twelve;
90                      else if(exit)     ns = ten;
91                      else              ns = eleven;
92              twelve:if(enter)          ns = thirteen;
93                      else if(exit)     ns = eleven;
94                      else              ns = twelve;
95              thirteen:if(enter)        ns = fourteen;
96                      else if(exit)     ns = twelve;
97                      else              ns = thirteen;
98              fourteen: if(enter)       ns = fifteen;
99                      else if(exit)     ns = thirteen;
100                     else              ns = fourteen;
101             fifteen:if(enter)         ns = sixteen;
102                     else if(exit)     ns = fourteen;
103                     else              ns = fifteen;
104             sixteen: if(enter)        ns = seventeen;
105                     else if(exit)     ns = fifteen;
106                     else              ns = sixteen;
107             seventeen:if(enter)       ns = eighteen;
108                     else if(exit)     ns = sixteen;
109                     else              ns = seventeen;
```

```
110             eighteen:if(enter)      ns = nineteen;
111                   else if(exit)     ns = seventeen;
112                   else              ns = eighteen;
113             nineteen:if(enter)      ns = twenty;
114                   else if(exit)     ns = eighteen;
115                   else              ns = nineteen;
116             twenty:if(enter)        ns = twentyone;
117                   else if(exit)     ns = nineteen;
118                   else              ns = twenty;
119             twentyone:if(enter)     ns = twentytwo;
120                   else if(exit)     ns = twenty;
121                   else              ns = twentyone;
122             twentytwo:if(enter)     ns = twentythree;
123                   else if(exit)     ns = twentyone;
124                   else              ns = twentytwo;
125             twentythree:if(enter)   ns = twentyfour;
126                   else if(exit)     ns = twentytwo;
127                   else              ns = twentythree;
128             twentyfour:if(enter)    ns = twentyfive;
129                   else if(exit)     ns = twentythree;
130                   else              ns = twentyfour;
131             twentyfive:if(exit)     ns = twentyfour;
132                   else              ns = twentyfive;
133             endcase
134       end
135
136       // when reset is pressed, the counter will reset to state 0.
137       always @(posedge clk) begin
138          if(reset) begin
139             ps <= zero;
140          end
141          else begin
142             cout <= ps;
143             ps <= ns;
144          end
145       end
146    endmodule
147
148    // counter_testbench tests all expected behavior that the parking lot
       occupancy counter system in the lab may encounter
149    module counter_testbench();
150       logic clk, reset, enter, exit;
151       logic [4:0]cout;
152
153       counter dut (.clk(clk), .reset(reset), .enter(enter), .exit(exit), .
       cout(cout));
154
155       parameter CLOCK_PERIOD = 100;
156
157       initial begin
158          clk <= 0;
159          forever #(CLOCK_PERIOD/2) clk <= ~clk;
160       end
161
162       // 30 cars enters, the counter will reach 25 and stay there
163       // 30 cars exit(for simulation), the counter will reach 0 and stay
       there
164       initial begin
```

```
165         reset <= 1;             @(posedge clk);
166         reset <= 0;             @(posedge clk);
167         enter <= 1; exit <= 0; repeat(30) @(posedge clk);
168         enter <= 0; exit <= 1; repeat(30) @(posedge clk);
169         $stop;
170       end
171   endmodule
172
173
174
```

```
1   // Alan Li
2   // 01/15/2022
3   // EE 371
4   // Lab #1
5
6   // DE1_Soc takes 34-bit GPIO_0 and return 1-bit enterIndicator and
    exitIndicator, 5-bit countIndicator and inputA, inputB
7   // This serves as the top-level module for the parking lot occupancy
    counter system
8
9   module DE1_SoC(CLOCK_50, GPIO_0, HEX5, HEX4, HEX3, HEX2, HEX1, HEX0);
10
11     // GPIO_0[5] is connected to the reset switch, GPIO_0[6] is
    connected to the sensorA switch, GPIO_0[7] is connected to the sensorB
    switch
12     inout logic [33:0] GPIO_0;
13     input logic CLOCK_50;
14     output logic [6:0] HEX5, HEX4, HEX3, HEX2, HEX1, HEX0;
15     logic enterIndicator, exitIndicator;
16     logic [4:0] countIndicator;
17     logic inputA, inputB;
18
19
20     assign GPIO_0[26] = GPIO_0[6]; // when switch A(sensor A) is
    enabled/triggered the corresponding LED turns on
21     assign GPIO_0[27] = GPIO_0[7]; // when switch B(sensor B) is
    enabled/triggered the corresponding LED turns on
22
23     // userInput inA and inB takes GPIO[6] and GPIO[7] as input
    parameters and return Q as inputA and inputB respectively
24     userInput inA (.clk(CLOCK_50), .D(GPIO_0[6]), .Q(inputA));
25     userInput inB (.clk(CLOCK_50), .D(GPIO_0[7]), .Q(inputB));
26
27     // parkingLotSensors myfsm takes CLOCK_50 as clk, GPIO[5], inputA,
    input B as parameters to reset, A, B
28     // and returns enter and exit as enterIndicator and exitIndicator
    respectively
29     parkingLotSensors myfsm (.clk(CLOCK_50), .reset(GPIO_0[5]), .A(inputA
    ), .B(inputB), .enter(enterIndicator), .exit(exitIndicator));
30
31     // counter mycounter takes CLOCK_50 as clk, GPIO_0[5],
    enterIndicator and exitIndicator as reset, enter and exit
32     // it returns enter, exit and cout as countIndicator[4:0]
33     counter mycounter (.clk(CLOCK_50), .reset(GPIO_0[5]), .enter(
    enterIndicator), .exit(exitIndicator), .cout(countIndicator[4:0]));
34
35     // hexDisplay mydisplay takes CLOCK_50 as clk, countIndicator[4:0]
    as inputCount
36     // and returns HEX5, HEX4, HEX3, HEX2, HEX1, HEX0 as HEX5, HEX4,
    HEX3, HEX2, HEX1, HEX0 respectively
37     hexDisplay mydisplay (.clk(CLOCK_50), .inputCount(countIndicator[4:0
    ]),
38                           .HEX5(HEX5), .HEX4(HEX4), .HEX3(HEX3), .HEX2(
    HEX2), .HEX1(HEX1), .HEX0(HEX0));
39  endmodule
40
41
42  // DE1_SoC_testbench tests all expected behavior that the parking lot
```

```
    occupancy counter system in the lab may encounter
43  module DE1_SoC_testbench();
44
45     logic clk, reset, A, B;
46     logic [6:0] HEX5, HEX4, HEX3, HEX2, HEX1, HEX0;
47
48     DE1_SoC dut (.CLOCK_50(CLOCK_50), .GPIO_0(GPIO_0),
49                             .HEX5(HEX5), .HEX4(HEX4), .HEX3(HEX3), .HEX2(
    HEX2), .HEX1(HEX1), .HEX0(HEX0));
50
51     //Set up the clock.
52     parameter CLOCK_PERIOD = 100;
53
54     initial begin
55        clk <= 0;
56        forever #(CLOCK_PERIOD/2) clk <= ~clk;
57
58     end
59
60     initial begin
61        reset <= 1;       @(posedge clk);   // cycle through car entering
62        reset <= 0;       @(posedge clk);
63                          @(posedge clk);
64                          @(posedge clk);
65        {A,B} <= 2'b00;   @(posedge clk);
66        {A,B} <= 2'b10;   @(posedge clk);
67        {A,B} <= 2'b11;   @(posedge clk);
68        {A,B} <= 2'b01;   @(posedge clk);
69        {A,B} <= 2'b00;   @(posedge clk);
70
71        {A,B} <= 2'b00;   @(posedge clk);
72        {A,B} <= 2'b10;   @(posedge clk);
73        {A,B} <= 2'b11;   @(posedge clk);
74        {A,B} <= 2'b01;   @(posedge clk);
75        {A,B} <= 2'b00;   @(posedge clk);
76
77        {A,B} <= 2'b00;   @(posedge clk);
78        {A,B} <= 2'b10;   @(posedge clk);
79        {A,B} <= 2'b11;   @(posedge clk);
80        {A,B} <= 2'b01;   @(posedge clk);
81        {A,B} <= 2'b00;   @(posedge clk);
82
83        {A,B} <= 2'b00;   @(posedge clk);
84        {A,B} <= 2'b10;   @(posedge clk);
85        {A,B} <= 2'b11;   @(posedge clk);
86        {A,B} <= 2'b01;   @(posedge clk);
87        {A,B} <= 2'b00;   @(posedge clk);   // 4 cars entered
88
89        {A,B} <= 2'b00;   @(posedge clk);
90        {A,B} <= 2'b01;   @(posedge clk);
91        {A,B} <= 2'b11;   @(posedge clk);
92        {A,B} <= 2'b10;   @(posedge clk);
93        {A,B} <= 2'b00;   @(posedge clk);
94
95        {A,B} <= 2'b00;   @(posedge clk);
96        {A,B} <= 2'b01;   @(posedge clk);
97        {A,B} <= 2'b11;   @(posedge clk);
98        {A,B} <= 2'b10;   @(posedge clk);
```

```
 99          {A,B} <= 2'b00;   @(posedge clk);
100
101          {A,B} <= 2'b00;   @(posedge clk);
102          {A,B} <= 2'b01;   @(posedge clk);
103          {A,B} <= 2'b11;   @(posedge clk);
104          {A,B} <= 2'b10;   @(posedge clk);
105          {A,B} <= 2'b00;   @(posedge clk);   // 3 cars exiting
106
107          reset <= 1;       @(posedge clk);   // cycle through car exiting
108          reset <= 0;       @(posedge clk);
109                            @(posedge clk);
110                            @(posedge clk);
111          {A,B} <= 2'b00;   @(posedge clk);
112          {A,B} <= 2'b01;   @(posedge clk);
113          {A,B} <= 2'b11;   @(posedge clk);
114          {A,B} <= 2'b10;   @(posedge clk);
115          {A,B} <= 2'b00;   @(posedge clk);
116                            @(posedge clk);
117          $stop;
118       end
119    endmodule
120
```

```
1   // Alan Li
2   // 01/15/2022
3   // EE 371
4   // Lab #1
5
6   // hexDisplay takes 5-bit inputCount as inputs and return 7-bits HEX5,
    HEX4, HEX3, HEX2, HEX1, HEX0 as output.
7   // Upon start, the HEX display will display "clear0", when enter signal
    is given, the HEX display the counter on HEX1 and HEX0. The counter
    will keep adding up until reach 25.
8   // Then the hex display will diaplay "FULL25".
9   // If the counter reach 0, the hex display will display "clear0" as
    there is no car in the parking lot
10
11  module hexDisplay(clk, inputCount, HEX5, HEX4, HEX3, HEX2,HEX1, HEX0);
12     input clk;
13     input logic [4:0] inputCount;
14     output logic [6:0] HEX5, HEX4, HEX3, HEX2, HEX1, HEX0;
15
16     // 7-bit parameter for the display to display different numbers or
    characters
17     //                              6543210
18     parameter [6:0]   zero =   7'b1000000,
19                       one =    7'b1111001,
20                       two =    7'b0100100,
21                       three =  7'b0110000,
22                       four =   7'b0011001,
23                       five =   7'b0010010,
24                       six =    7'b0000010,
25                       seven =  7'b1111000,
26                       eight =  7'b0000000,
27                       nine =   7'b0011000,
28                       F =      7'b0001110, //FULL
29                       U =      7'b1000001,
30                       L =      7'b1000111,
31
32                       C =      7'b1000110, //CLEAR
33                       E =      7'b0000110,
34                       A =      7'b0001000,
35                       R =      7'b1001100,
36                       blk =    7'b1111111;
37
38
39     // The hex are driven off upon start.
40     // The hex will display counters when enter or exit signal is given
41     // When the counter is 0, it will display "clear0". When full it
    will display "full25"
42     always_comb begin
43        HEX5 = blk;
44        HEX4 = blk;
45        HEX3 = blk;
46        HEX2 = blk;
47        HEX1 = blk;
48        HEX0 = blk;
49        case(inputCount)
50           0: begin HEX5 = C; HEX4 = L; HEX3 = E; HEX2 = A; HEX1 = R; HEX0
     = zero; end
51           1: begin HEX5 = blk; HEX4 = blk; HEX3 = blk; HEX2 = blk; HEX1 =
```

```
      blk; HEX0 = one; end
52            2: begin HEX5 = blk; HEX4 = blk; HEX3 = blk; HEX2 = blk; HEX1 =
      blk; HEX0 = two; end
53            3: begin HEX5 = blk; HEX4 = blk; HEX3 = blk; HEX2 = blk; HEX1 =
      blk; HEX0 = three; end
54            4: begin HEX5 = blk; HEX4 = blk; HEX3 = blk; HEX2 = blk; HEX1 =
      blk;HEX0 = four; end
55            5: begin HEX5 = F; HEX4 = U; HEX3 = L; HEX2 = L;HEX1 = blk;
    HEX0 = five; end // for demo purpose
56
57            //5: begin HEX5 = blk; HEX4 = blk; HEX3 = blk; HEX2 = blk;
    HEX1 = blk;HEX0 = five; end
58            6: begin HEX5 = blk; HEX4 = blk; HEX3 = blk; HEX2 = blk; HEX1 =
      blk;HEX0 = six; end
59            7: begin HEX5 = blk; HEX4 = blk; HEX3 = blk; HEX2 = blk; HEX1 =
      blk;HEX0 = seven; end
60            8: begin HEX5 = blk; HEX4 = blk; HEX3 = blk; HEX2 = blk; HEX1 =
      blk;HEX0 = eight; end
61            9: begin HEX5 = blk; HEX4 = blk; HEX3 = blk; HEX2 = blk; HEX1 =
      blk;HEX0 = nine; end
62            10: begin HEX5 = blk; HEX4 = blk; HEX3 = blk; HEX2 = blk;HEX1 =
      one; HEX0 = zero; end
63            11: begin HEX5 = blk; HEX4 = blk; HEX3 = blk; HEX2 = blk;HEX1 =
      one; HEX0 = one; end
64            12: begin HEX5 = blk; HEX4 = blk; HEX3 = blk; HEX2 = blk;HEX1 =
      one; HEX0 = two; end
65            13: begin HEX5 = blk; HEX4 = blk; HEX3 = blk; HEX2 = blk;HEX1 =
      one; HEX0 = three; end
66            14: begin HEX5 = blk; HEX4 = blk; HEX3 = blk; HEX2 = blk;HEX1 =
      one; HEX0 = four; end
67            15: begin HEX5 = blk; HEX4 = blk; HEX3 = blk; HEX2 = blk;HEX1 =
      one; HEX0 = five; end
68            16: begin HEX5 = blk; HEX4 = blk; HEX3 = blk; HEX2 = blk;HEX1 =
      one; HEX0 = six; end
69            17: begin HEX5 = blk; HEX4 = blk; HEX3 = blk; HEX2 = blk;HEX1 =
      one; HEX0 = seven; end
70            18: begin HEX5 = blk; HEX4 = blk; HEX3 = blk; HEX2 = blk;HEX1 =
      one; HEX0 = eight; end
71            19: begin HEX5 = blk; HEX4 = blk; HEX3 = blk; HEX2 = blk;HEX1 =
      one; HEX0 = nine; end
72            20: begin HEX5 = blk; HEX4 = blk; HEX3 = blk; HEX2 = blk;HEX1 =
      two; HEX0 = zero; end
73            21: begin HEX5 = blk; HEX4 = blk; HEX3 = blk; HEX2 = blk;HEX1 =
      two; HEX0 = one; end
74            22: begin HEX5 = blk; HEX4 = blk; HEX3 = blk; HEX2 = blk;HEX1 =
      two; HEX0 = two; end
75            23: begin HEX5 = blk; HEX4 = blk; HEX3 = blk; HEX2 = blk;HEX1 =
      two; HEX0 = three; end
76            24: begin HEX5 = blk; HEX4 = blk; HEX3 = blk; HEX2 = blk;HEX1 =
      two; HEX0 = four; end
77            25: begin HEX5 = F; HEX4 = U; HEX3 = L; HEX2 = L;HEX1 = two;
    HEX0 = five; end
78          endcase
79        end
80
81  endmodule
82
83  // counter_testbench tests all expected behavior that the parking lot
```

```
      occupancy counter system in the lab may encounter
84    module hexDisplay_testbench();
85       logic clk;
86       logic [4:0] inputCount;
87       logic [6:0] HEX5, HEX4, HEX3, HEX2, HEX1, HEX0;
88
89       hexDisplay dut (.clk(clk), .inputCount(inputCount), .HEX5(HEX5), .
      HEX4(HEX4), .HEX3(HEX3), .HEX2(HEX2), .HEX1(HEX1), .HEX0(HEX0));
90
91       parameter CLOCK_PERIOD = 100;
92
93       initial begin
94          clk <= 0;
95          forever #(CLOCK_PERIOD/2) clk <= ~clk;
96       end
97
98       initial begin
99          inputCount <= 0;  @(posedge clk);
100         inputCount <= 10; @(posedge clk);
101         inputCount <= 20; @(posedge clk);
102         inputCount <= 25; @(posedge clk);
103         $stop;
104      end
105   endmodule
106
```

```
1  // Alan Li
2  // 01/15/2022
3  // EE 371
4  // Lab #1
5
6  // parkingLotSensors takes in 1-bit A, B and clk as inputs and return
   1-bit enter and exit as outputs.
7
8  module parkingLotSensors(clk, reset, A, B, enter, exit);
9     input logic A, B, clk, reset;
10    output logic enter, exit;
11
12    // States
13    enum {unblocked, beginIn, blockIn, almostIn, beginOut, blockOut,
   almostOut} ps, ns;
14
15    // The parking lot sensor can have six cases as list below. beginIn,
   blockin and almostIn are pairs with almostOut, blockOut and beginOut.
16    // Assume the entrance is north-south direction. If car is entering
   from North, it will trigger sensor A first.
17    // If car is exiting from South it will trigger sensor B first.
18    // For example, beginIn and almost out both indicate that only
   sensorA is blocked, they only differences is that beginIn means the car
   is going in the south direction and almostOut is car going north.
19    // This "case pair" is designed to tackle car changing direction
   issue.
20    always_comb
21       begin
22          enter = 0;
23          exit = 0;
24
25          case(ps)
26
27             unblocked:
28                if (A & ~B)          ns = beginIn;      // car begin to
   enter
29                else if (~A & B)     ns = beginOut;     // car begin to
   exit
30                // else if (~A & ~B)    ns = unblocked; // impossible
31                else                 ns = unblocked;    // nothing happens
32
33             beginIn:
34                if (A & B)           ns = blockIn;      // car is
   halfway entering
35                else if (~A & ~B)    ns = unblocked;    // car just
   enters then back up
36                // else if (A & ~B)     ns = beginIn;   // impossible
37                else                 ns = beginIn;      // car does not
   move
38
39             blockIn:
40                if (~A & B)          ns = almostIn;     // car almost
   enters (trigger both sensors)
41                else if (A & ~B)     ns = beginIn;      // car backs up
42                // else if (A & B)      ns = blockIn;   // impossible
43                else                 ns = blockIn;      // car does not
   move
44
```

```
45                almostIn:
46                   if (~A & ~B)
47                      begin
48                                          ns = unblocked;    // car enters
49                                          enter = 1;
50                                          exit = 0;
51                      end
52                   else if (A % B)        ns = blockIn;      // car backs up
53                   // else if (~A & B)       ns = almostIn;  // impossible
54                   else                   ns = almostIn;     // car does not
      move
55
56                beginOut:
57                   if (A & B)             ns = blockOut;     // car is
      halfway exiting
58                   else if (~A & ~B)      ns = unblocked;    // car backs up
59                   // else if (~A & B)       ns = beginOut;  // impossible
60                   else                   ns = beginOut;     // car does not
      move
61
62                blockOut:
63                   if (A & ~B)            ns = almostOut;    // car almost
      exits (trigger both sensors)
64                   else if (~A & B)       ns = beginOut;     // car backs up
65                   // else if (A & B)        ns = blockOut;  // impossible
66                   else                   ns = blockOut;     // car does not
      move
67
68                almostOut:
69                   if (~A & ~B)                              // car exits
70                      begin
71                         ns = unblocked;
72                         enter = 0;
73                         exit = 1;
74                      end
75                   else if (A & B)        ns = blockOut;     // car backs up
76                   // else if (A & ~B)       ns = almostOut; // impossible
77                   else                   ns = almostOut;    // car does not
      move
78
79                /*
80                default:
81                   begin
82                      enter = 0;
83                      exit = 0;
84                   end
85                */
86             endcase
87          end
88
89
90       // if reset, the parking lot sensor goes to unblocked case
91       always_ff @(posedge clk)
92          begin
93             if (reset)
94                ps <= unblocked;
95             else ps <= ns;
96          end
```

```
 97  endmodule
 98
 99  // parkingLotSensor_testbench tests all expected behavior that the
     parking lot occupancy counter system in the lab may encounter
100  module parkingLotSensor_testbench();
101     logic clk, reset, A, B, enter, exit;
102
103     parkingLotSensors dut (.clk(clk), .reset(reset), .A(A), .B(B), .enter
     (enter), .exit(exit));
104
105     parameter CLOCK_PERIOD = 100;
106
107     initial begin
108        clk <= 0;
109        forever #(CLOCK_PERIOD/2) clk <= ~clk;
110     end
111
112     // I have already simulate the case where car enters and exits
     without changing directions in DE1_SoC
113     // For this testbench I will simulate the case where the car changes
     direction multiple times
114     initial begin
115        reset <= 1;          @(posedge clk);
116        reset <= 0;          @(posedge clk);
117        {A, B} <= 2'b00;     @(posedge clk);
118        {A, B} <= 2'b10;     @(posedge clk);
119        {A, B} <= 2'b11;     @(posedge clk);
120        {A, B} <= 2'b01;     @(posedge clk);
121        {A, B} <= 2'b11;     @(posedge clk);
122        {A, B} <= 2'b10;     @(posedge clk);
123        {A, B} <= 2'b11;     @(posedge clk);
124        {A, B} <= 2'b01;     @(posedge clk);
125        {A, B} <= 2'b00;     @(posedge clk); // simulation for car enters
126
127        {A, B} <= 2'b00;     @(posedge clk);
128        {A, B} <= 2'b01;     @(posedge clk);
129        {A, B} <= 2'b11;     @(posedge clk);
130        {A, B} <= 2'b10;     @(posedge clk);
131        {A, B} <= 2'b11;     @(posedge clk);
132        {A, B} <= 2'b01;     @(posedge clk);
133        {A, B} <= 2'b11;     @(posedge clk);
134        {A, B} <= 2'b10;     @(posedge clk);
135        {A, B} <= 2'b00;     @(posedge clk); // simulation for car exits
136        $stop;
137     end
138  endmodule
139
140
141
142
```

```
1   // Alan Li
2   // 01/15/2022
3   // EE 371
4   // Lab #1
5
6   // userInput take 1-bit D as user input and return Q as output
7   // This module utilize two DFF to reduce the possibility of
    metastability by adding latency
8
9   module userInput(clk, D, Q);
10     input clk, D;
11     output logic Q;
12     logic temp;
13
14     always_ff @(posedge clk) begin
15        temp <= D;
16        Q <= temp;
17     end
18
19  endmodule
```