

CS226 LAB 9

Question 1

Design

// listing all inputs and outputs, by convention outputs go first

```
module p1(out,binary);  
    output [3:0] out;  
    input [3:0] binary;  
    and gray4(out[3],binary[3],binary[3]);  
    xor gray3(out[2],binary[3],binary[2]);  
    xor gray2(out[1],binary[2],binary[1]);  
    xor gray1(out[0],binary[1],binary[0]);  
endmodule
```

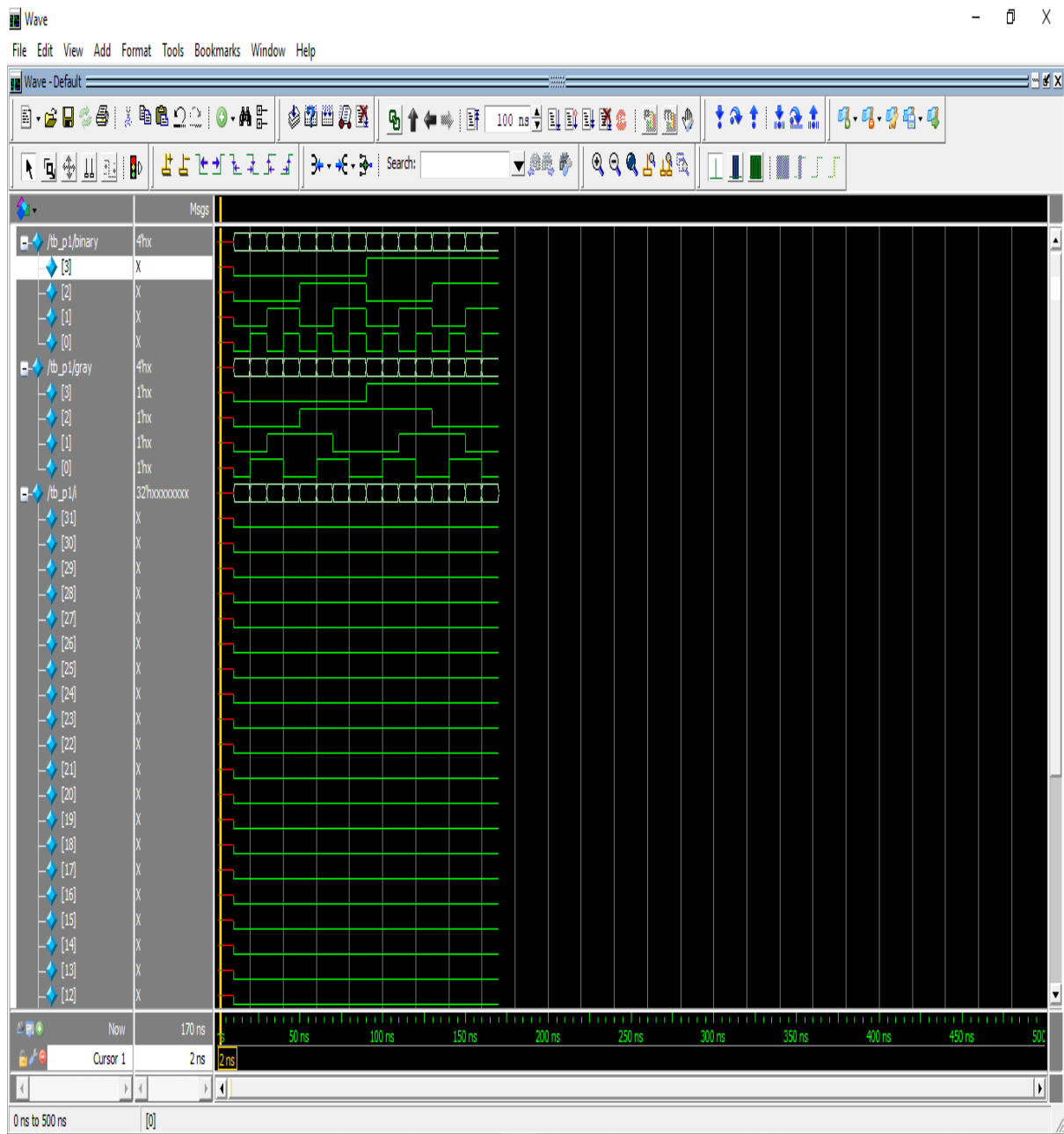
Testbench

```
module tb_p1();  
    reg [3:0] binary;  
    wire [3:0] gray;  
    integer i;  
    p1 Graycode (gray,binary);  
    initial  
    begin  
        #10 $monitor("binary = %b",binary, " => Graycode = %b",gray);  
        for(i=0;i<=15;i=i+1)  
            begin  
                binary=i;  
                #10;  
            end  
    end  
endmodule
```

Transcript

```
# binary = 0000 => Graycode = 0000
# binary = 0001 => Graycode = 0001
# binary = 0010 => Graycode = 0011
# binary = 0011 => Graycode = 0010
# binary = 0100 => Graycode = 0110
# binary = 0101 => Graycode = 0111
# binary = 0110 => Graycode = 0101
# binary = 0111 => Graycode = 0100
# binary = 1000 => Graycode = 1100
# binary = 1001 => Graycode = 1101
# binary = 1010 => Graycode = 1111
# binary = 1011 => Graycode = 1110
# binary = 1100 => Graycode = 1010
# binary = 1101 => Graycode = 1011
# binary = 1110 => Graycode = 1001
# binary = 1111 => Graycode = 1000
```

Wave



Question 2

Design

// listing all inputs and outputs, by convention outputs go first

```
module p2(ans,operation,x,y);
```

```
    output[15:0] ans;
```

```
    input [15:0] x,y;
```

```

    input [2:0] operation;

    reg [15:0] ans;

    always @ (operation)
    case (operation)

    // ALU is implemented using numbers

        3'b000: ans <= x+y;

        3'b001: ans <= x-y;

        3'b010: ans <= x&y;

        3'b011: ans <= x^y;

        3'b100: ans <= x|y;

        3'b101: ans <= x+1;

        3'b110: ans <= x<<1;

        3'b111: ans <= x>>1;

        default: ans <= 16'd0;

    endcase
endmodule

```

Testbench

```

module tb_p2(); //test_bench

    wire[15:0] ans;

    reg [15:0] x,y;

    reg [2:0] operation;

    integer i;

    p2 UUT (ans, operation, x, y);

    initial

    begin //checking for random values of A,B

        for( i = 0; i <= 7; i = i + 1)

            begin

                x=$urandom%2**15;

                y=$urandom%2**15;

                operation=i;

```

```

    $monitor("operation = %b", i, " , first number = %b", x, " , second number = %b", y, " => result=
    %b", ans);

    #10;

    $display("-----");

end

end

endmodule

```

Transcript

```

# operation = 00000000000000000000000000000000 , first number = 0010001110111000 , second
number = 0000110000100110 => result= 0010111111011110

# -----

# operation = 00000000000000000000000000000001 , first number = 0110001110110110 , second
number = 0000100011000110 => result= 0101101011110000

# -----

# operation = 00000000000000000000000000000010 , first number = 0000111101110010 , second
number = 0111001100101110 => result= 0000001100100010

# -----

# operation = 00000000000000000000000000000011 , first number = 0101010100111010 , second
number = 0001110001101010 => result= 0100100101010000

# -----

# operation = 00000000000000000000000000000100 , first number = 0111101001101111 , second
number = 0001101001010110 => result= 0111101001111111

# -----

# operation = 00000000000000000000000000000101 , first number = 0111011111010100 , second
number = 0100000010101110 => result= 0111011111010101

# -----

# operation = 00000000000000000000000000000110 , first number = 0011011111011011 , second
number = 0000111000000101 => result= 0110111110110110

# -----

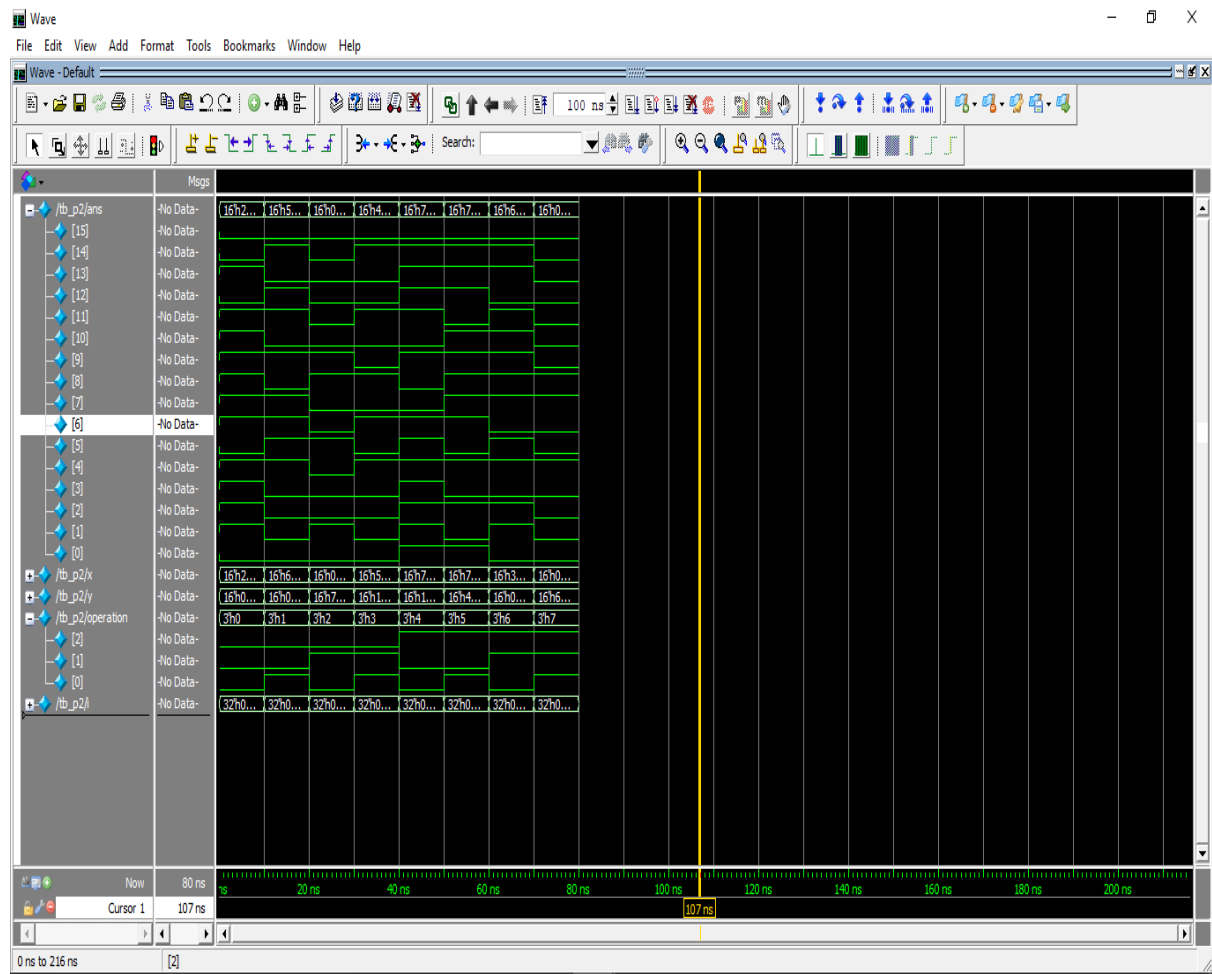
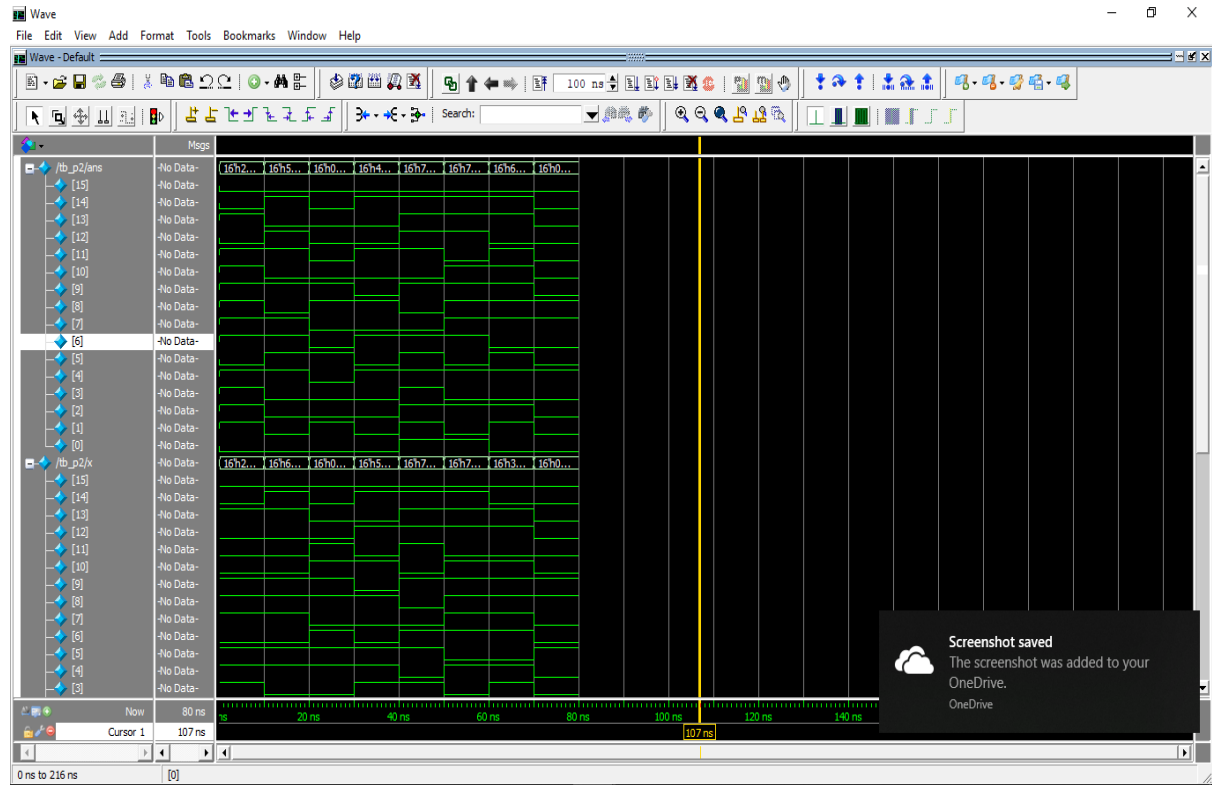
# operation = 00000000000000000000000000000111 , first number = 0000001100100000 , second
number = 0110010111100101 => result= 0000000110010000

# -----

```

```
# operation = 00000000000000000000000001000 , first number = 0000001100100000 , second  
number = 0110010111100101 => result= 0000000110010000
```

Wave



QUESTION 3

DESIGN

```
module p3(out,D,S);
```

```
// listing all inputs and outputs, by convention outputs go first
```

```
output out;
```

```
input [15:0]D;
```

```
input [3:0]S;
```

```
//behavioral approach
```

```
assign out = D[S];
```

```
endmodule
```

TESTBENCH

```
module tb_p3();
```

```
reg[15:0] D;
```

```
reg[3:0] S;
```

```
wire Z;
```

```
integer i;
```

```
p3 UUT(Z, D, S);
```

```
initial
```

```
begin
```

```
#10 $monitor(" D = %b", D, " , S = %b", S, " , Z = ", Z);
```

```
for( i = 1; i <= 65535; i = i * 2)
```

```
begin
```

```
D = i;
```

```
S = 0; #10;
```

```
S = 1; #10;
```



```

S = 2; #10;
S = 3; #10;
S = 4; #10;
S = 5; #10;
S = 6; #10;
S = 7; #10;
S = 8; #10;
S = 9; #10;
S = 10; #10;
S = 11; #10;
S = 12; #10;
S = 13; #10;
S = 14; #10;
S = 15; #10;
$display("-----");
end
end
endmodule

```

TRANSCRIPT

```

# D = 00000000000000001 , S = 0000 , Z = 1
# D = 00000000000000001 , S = 0001 , Z = 0
# D = 00000000000000001 , S = 0010 , Z = 0
# D = 00000000000000001 , S = 0011 , Z = 0
# D = 00000000000000001 , S = 0100 , Z = 0
# D = 00000000000000001 , S = 0101 , Z = 0
# D = 00000000000000001 , S = 0110 , Z = 0
# D = 00000000000000001 , S = 0111 , Z = 0
# D = 00000000000000001 , S = 1000 , Z = 0
# D = 00000000000000001 , S = 1001 , Z = 0

```

```

# D = 0000000000000001 , S = 1010 , Z = 0
# D = 0000000000000001 , S = 1011 , Z = 0
# D = 0000000000000001 , S = 1100 , Z = 0
# D = 0000000000000001 , S = 1101 , Z = 0
# D = 0000000000000001 , S = 1110 , Z = 0
# D = 0000000000000001 , S = 1111 , Z = 0
# -----
# D = 0000000000000010 , S = 0000 , Z = 0
# D = 0000000000000010 , S = 0001 , Z = 1
# D = 0000000000000010 , S = 0010 , Z = 0
# D = 0000000000000010 , S = 0011 , Z = 0
# D = 0000000000000010 , S = 0100 , Z = 0
# D = 0000000000000010 , S = 0101 , Z = 0
# D = 0000000000000010 , S = 0110 , Z = 0
# D = 0000000000000010 , S = 0111 , Z = 0
# D = 0000000000000010 , S = 1000 , Z = 0
# D = 0000000000000010 , S = 1001 , Z = 0
# D = 0000000000000010 , S = 1010 , Z = 0
# D = 0000000000000010 , S = 1011 , Z = 0
# D = 0000000000000010 , S = 1100 , Z = 0
# D = 0000000000000010 , S = 1101 , Z = 0
# D = 0000000000000010 , S = 1110 , Z = 0
# D = 0000000000000010 , S = 1111 , Z = 0
# -----
# D = 0000000000000100 , S = 0000 , Z = 0
# D = 0000000000000100 , S = 0001 , Z = 0
# D = 0000000000000100 , S = 0010 , Z = 1
# D = 0000000000000100 , S = 0011 , Z = 0
# D = 0000000000000100 , S = 0100 , Z = 0
# D = 0000000000000100 , S = 0101 , Z = 0
# D = 0000000000000100 , S = 0110 , Z = 0

```

```
# D = 0000000000000100 , S = 0111 , Z = 0
# D = 0000000000000100 , S = 1000 , Z = 0
# D = 0000000000000100 , S = 1001 , Z = 0
# D = 0000000000000100 , S = 1010 , Z = 0
# D = 0000000000000100 , S = 1011 , Z = 0
# D = 0000000000000100 , S = 1100 , Z = 0
# D = 0000000000000100 , S = 1101 , Z = 0
# D = 0000000000000100 , S = 1110 , Z = 0
# D = 0000000000000100 , S = 1111 , Z = 0
# -----
# D = 0000000000001000 , S = 0000 , Z = 0
# D = 0000000000001000 , S = 0001 , Z = 0
# D = 0000000000001000 , S = 0010 , Z = 0
# D = 0000000000001000 , S = 0011 , Z = 1
# D = 0000000000001000 , S = 0100 , Z = 0
# D = 0000000000001000 , S = 0101 , Z = 0
# D = 0000000000001000 , S = 0110 , Z = 0
# D = 0000000000001000 , S = 0111 , Z = 0
# D = 0000000000001000 , S = 1000 , Z = 0
# D = 0000000000001000 , S = 1001 , Z = 0
# D = 0000000000001000 , S = 1010 , Z = 0
# D = 0000000000001000 , S = 1011 , Z = 0
# D = 0000000000001000 , S = 1100 , Z = 0
# D = 0000000000001000 , S = 1101 , Z = 0
# D = 0000000000001000 , S = 1110 , Z = 0
# D = 0000000000001000 , S = 1111 , Z = 0
# -----
# D = 0000000000010000 , S = 0000 , Z = 0
# D = 0000000000010000 , S = 0001 , Z = 0
# D = 0000000000010000 , S = 0010 , Z = 0
# D = 0000000000010000 , S = 0011 , Z = 0
```

```

# D = 0000000000010000 , S = 0100 , Z = 1
# D = 0000000000010000 , S = 0101 , Z = 0
# D = 0000000000010000 , S = 0110 , Z = 0
# D = 0000000000010000 , S = 0111 , Z = 0
# D = 0000000000010000 , S = 1000 , Z = 0
# D = 0000000000010000 , S = 1001 , Z = 0
# D = 0000000000010000 , S = 1010 , Z = 0
# D = 0000000000010000 , S = 1011 , Z = 0
# D = 0000000000010000 , S = 1100 , Z = 0
# D = 0000000000010000 , S = 1101 , Z = 0
# D = 0000000000010000 , S = 1110 , Z = 0
# D = 0000000000010000 , S = 1111 , Z = 0
# -----
# D = 0000000000100000 , S = 0000 , Z = 0
# D = 0000000000100000 , S = 0001 , Z = 0
# D = 0000000000100000 , S = 0010 , Z = 0
# D = 0000000000100000 , S = 0011 , Z = 0
# D = 0000000000100000 , S = 0100 , Z = 0
# D = 0000000000100000 , S = 0101 , Z = 1
# D = 0000000000100000 , S = 0110 , Z = 0
# D = 0000000000100000 , S = 0111 , Z = 0
# D = 0000000000100000 , S = 1000 , Z = 0
# D = 0000000000100000 , S = 1001 , Z = 0
# D = 0000000000100000 , S = 1010 , Z = 0
# D = 0000000000100000 , S = 1011 , Z = 0
# D = 0000000000100000 , S = 1100 , Z = 0
# D = 0000000000100000 , S = 1101 , Z = 0
# D = 0000000000100000 , S = 1110 , Z = 0
# D = 0000000000100000 , S = 1111 , Z = 0
# -----
# D = 0000000001000000 , S = 0000 , Z = 0

```

D = 0000000001000000 , S = 0001 , Z = 0
D = 0000000001000000 , S = 0010 , Z = 0
D = 0000000001000000 , S = 0011 , Z = 0
D = 0000000001000000 , S = 0100 , Z = 0
D = 0000000001000000 , S = 0101 , Z = 0
D = 0000000001000000 , S = 0110 , Z = 1
D = 0000000001000000 , S = 0111 , Z = 0
D = 0000000001000000 , S = 1000 , Z = 0
D = 0000000001000000 , S = 1001 , Z = 0
D = 0000000001000000 , S = 1010 , Z = 0
D = 0000000001000000 , S = 1011 , Z = 0
D = 0000000001000000 , S = 1100 , Z = 0
D = 0000000001000000 , S = 1101 , Z = 0
D = 0000000001000000 , S = 1110 , Z = 0
D = 0000000001000000 , S = 1111 , Z = 0

D = 0000000010000000 , S = 0000 , Z = 0
D = 0000000010000000 , S = 0001 , Z = 0
D = 0000000010000000 , S = 0010 , Z = 0
D = 0000000010000000 , S = 0011 , Z = 0
D = 0000000010000000 , S = 0100 , Z = 0
D = 0000000010000000 , S = 0101 , Z = 0
D = 0000000010000000 , S = 0110 , Z = 0
D = 0000000010000000 , S = 0111 , Z = 1
D = 0000000010000000 , S = 1000 , Z = 0
D = 0000000010000000 , S = 1001 , Z = 0
D = 0000000010000000 , S = 1010 , Z = 0
D = 0000000010000000 , S = 1011 , Z = 0
D = 0000000010000000 , S = 1100 , Z = 0
D = 0000000010000000 , S = 1101 , Z = 0
D = 0000000010000000 , S = 1110 , Z = 0

D = 0000000010000000 , S = 1111 , Z = 0

D = 0000000010000000 , S = 0000 , Z = 0

D = 0000000010000000 , S = 0001 , Z = 0

D = 0000000010000000 , S = 0010 , Z = 0

D = 0000000010000000 , S = 0011 , Z = 0

D = 0000000010000000 , S = 0100 , Z = 0

D = 0000000010000000 , S = 0101 , Z = 0

D = 0000000010000000 , S = 0110 , Z = 0

D = 0000000010000000 , S = 0111 , Z = 0

D = 0000000010000000 , S = 1000 , Z = 1

D = 0000000010000000 , S = 1001 , Z = 0

D = 0000000010000000 , S = 1010 , Z = 0

D = 0000000010000000 , S = 1011 , Z = 0

D = 0000000010000000 , S = 1100 , Z = 0

D = 0000000010000000 , S = 1101 , Z = 0

D = 0000000010000000 , S = 1110 , Z = 0

D = 0000000010000000 , S = 1111 , Z = 0

D = 0000000100000000 , S = 0000 , Z = 0

D = 0000000100000000 , S = 0001 , Z = 0

D = 0000000100000000 , S = 0010 , Z = 0

D = 0000000100000000 , S = 0011 , Z = 0

D = 0000000100000000 , S = 0100 , Z = 0

D = 0000000100000000 , S = 0101 , Z = 0

D = 0000000100000000 , S = 0110 , Z = 0

D = 0000000100000000 , S = 0111 , Z = 0

D = 0000000100000000 , S = 1000 , Z = 0

D = 0000000100000000 , S = 1001 , Z = 1

D = 0000000100000000 , S = 1010 , Z = 0

D = 0000000100000000 , S = 1011 , Z = 0

```

# D = 0000001000000000 , S = 1100 , Z = 0
# D = 0000001000000000 , S = 1101 , Z = 0
# D = 0000001000000000 , S = 1110 , Z = 0
# D = 0000001000000000 , S = 1111 , Z = 0
# -----
# D = 0000010000000000 , S = 0000 , Z = 0
# D = 0000010000000000 , S = 0001 , Z = 0
# D = 0000010000000000 , S = 0010 , Z = 0
# D = 0000010000000000 , S = 0011 , Z = 0
# D = 0000010000000000 , S = 0100 , Z = 0
# D = 0000010000000000 , S = 0101 , Z = 0
# D = 0000010000000000 , S = 0110 , Z = 0
# D = 0000010000000000 , S = 0111 , Z = 0
# D = 0000010000000000 , S = 1000 , Z = 0
# D = 0000010000000000 , S = 1001 , Z = 0
# D = 0000010000000000 , S = 1010 , Z = 1
# D = 0000010000000000 , S = 1011 , Z = 0
# D = 0000010000000000 , S = 1100 , Z = 0
# D = 0000010000000000 , S = 1101 , Z = 0
# D = 0000010000000000 , S = 1110 , Z = 0
# D = 0000010000000000 , S = 1111 , Z = 0
# -----
# D = 0000100000000000 , S = 0000 , Z = 0
# D = 0000100000000000 , S = 0001 , Z = 0
# D = 0000100000000000 , S = 0010 , Z = 0
# D = 0000100000000000 , S = 0011 , Z = 0
# D = 0000100000000000 , S = 0100 , Z = 0
# D = 0000100000000000 , S = 0101 , Z = 0
# D = 0000100000000000 , S = 0110 , Z = 0
# D = 0000100000000000 , S = 0111 , Z = 0
# D = 0000100000000000 , S = 1000 , Z = 0

```

```

# D = 0000100000000000 , S = 1001 , Z = 0
# D = 0000100000000000 , S = 1010 , Z = 0
# D = 0000100000000000 , S = 1011 , Z = 1
# D = 0000100000000000 , S = 1100 , Z = 0
# D = 0000100000000000 , S = 1101 , Z = 0
# D = 0000100000000000 , S = 1110 , Z = 0
# D = 0000100000000000 , S = 1111 , Z = 0
# -----
# D = 0001000000000000 , S = 0000 , Z = 0
# D = 0001000000000000 , S = 0001 , Z = 0
# D = 0001000000000000 , S = 0010 , Z = 0
# D = 0001000000000000 , S = 0011 , Z = 0
# D = 0001000000000000 , S = 0100 , Z = 0
# D = 0001000000000000 , S = 0101 , Z = 0
# D = 0001000000000000 , S = 0110 , Z = 0
# D = 0001000000000000 , S = 0111 , Z = 0
# D = 0001000000000000 , S = 1000 , Z = 0
# D = 0001000000000000 , S = 1001 , Z = 0
# D = 0001000000000000 , S = 1010 , Z = 0
# D = 0001000000000000 , S = 1011 , Z = 0
# D = 0001000000000000 , S = 1100 , Z = 1
# D = 0001000000000000 , S = 1101 , Z = 0
# D = 0001000000000000 , S = 1110 , Z = 0
# D = 0001000000000000 , S = 1111 , Z = 0
# -----
# D = 0010000000000000 , S = 0000 , Z = 0
# D = 0010000000000000 , S = 0001 , Z = 0
# D = 0010000000000000 , S = 0010 , Z = 0
# D = 0010000000000000 , S = 0011 , Z = 0
# D = 0010000000000000 , S = 0100 , Z = 0
# D = 0010000000000000 , S = 0101 , Z = 0

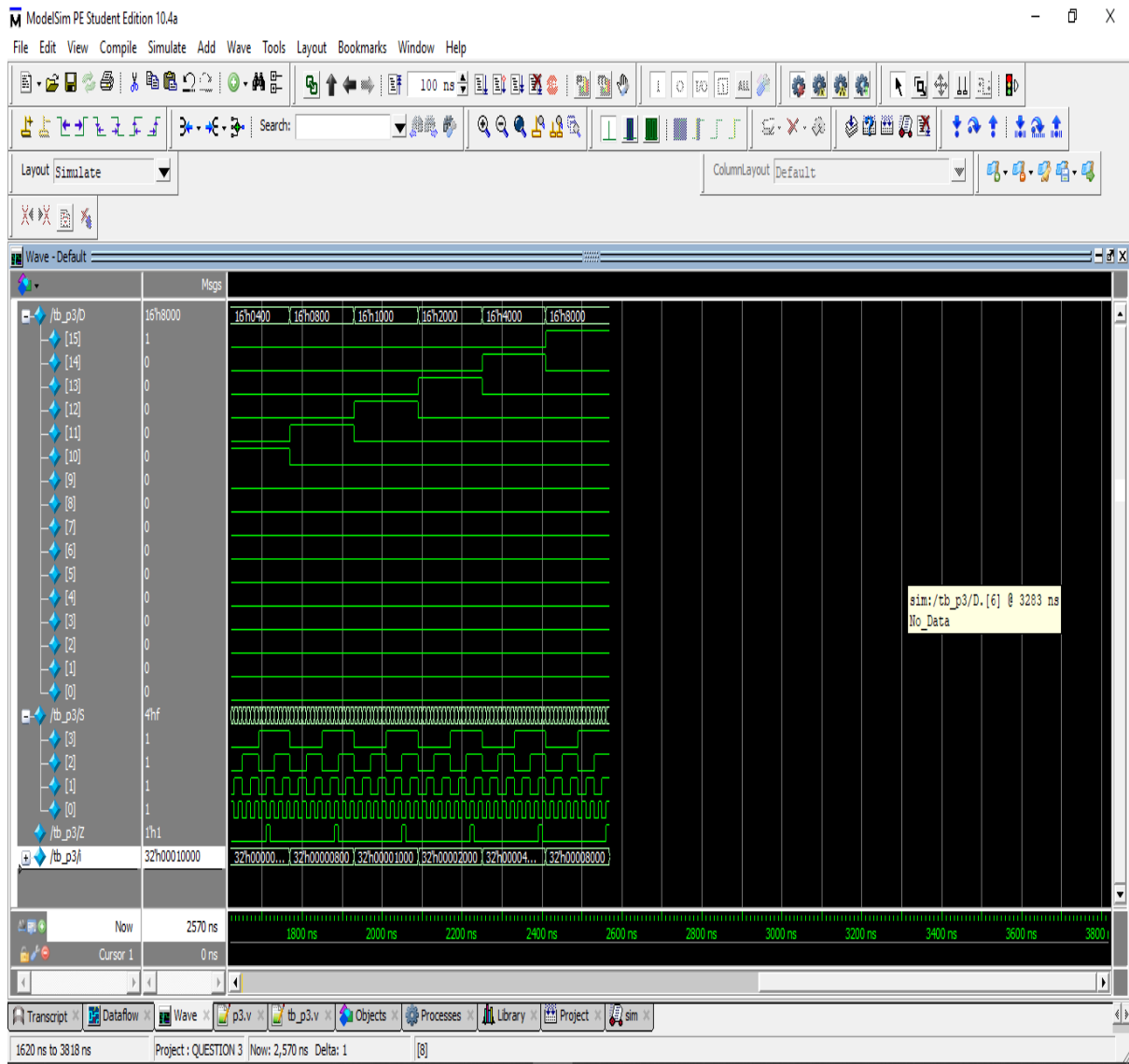
```



```
# D = 0010000000000000 , S = 0110 , Z = 0
# D = 0010000000000000 , S = 0111 , Z = 0
# D = 0010000000000000 , S = 1000 , Z = 0
# D = 0010000000000000 , S = 1001 , Z = 0
# D = 0010000000000000 , S = 1010 , Z = 0
# D = 0010000000000000 , S = 1011 , Z = 0
# D = 0010000000000000 , S = 1100 , Z = 0
# D = 0010000000000000 , S = 1101 , Z = 1
# D = 0010000000000000 , S = 1110 , Z = 0
# D = 0010000000000000 , S = 1111 , Z = 0
# -----
# D = 0100000000000000 , S = 0000 , Z = 0
# D = 0100000000000000 , S = 0001 , Z = 0
# D = 0100000000000000 , S = 0010 , Z = 0
# D = 0100000000000000 , S = 0011 , Z = 0
# D = 0100000000000000 , S = 0100 , Z = 0
# D = 0100000000000000 , S = 0101 , Z = 0
# D = 0100000000000000 , S = 0110 , Z = 0
# D = 0100000000000000 , S = 0111 , Z = 0
# D = 0100000000000000 , S = 1000 , Z = 0
# D = 0100000000000000 , S = 1001 , Z = 0
# D = 0100000000000000 , S = 1010 , Z = 0
# D = 0100000000000000 , S = 1011 , Z = 0
# D = 0100000000000000 , S = 1100 , Z = 0
# D = 0100000000000000 , S = 1101 , Z = 0
# D = 0100000000000000 , S = 1110 , Z = 1
# D = 0100000000000000 , S = 1111 , Z = 0
# -----
# D = 1000000000000000 , S = 0000 , Z = 0
# D = 1000000000000000 , S = 0001 , Z = 0
# D = 1000000000000000 , S = 0010 , Z = 0
```

D = 1000000000000000 , S = 0011 , Z = 0
D = 1000000000000000 , S = 0100 , Z = 0
D = 1000000000000000 , S = 0101 , Z = 0
D = 1000000000000000 , S = 0110 , Z = 0
D = 1000000000000000 , S = 0111 , Z = 0
D = 1000000000000000 , S = 1000 , Z = 0
D = 1000000000000000 , S = 1001 , Z = 0
D = 1000000000000000 , S = 1010 , Z = 0
D = 1000000000000000 , S = 1011 , Z = 0
D = 1000000000000000 , S = 1100 , Z = 0
D = 1000000000000000 , S = 1101 , Z = 0
D = 1000000000000000 , S = 1110 , Z = 0
D = 1000000000000000 , S = 1111 , Z = 1

WAVE



QUESTION 4

DESIGN

//_listing all inputs and outputs, by convention outputs go first

```
module mux(out,D,S);
```

```
    output out;
```

```
    input [1:0]D;
```

```
    input S;
```

```
    assign out = D[S];  
endmodule
```

```
module p4(out,D,S);  
    output out;  
    input [15:0]D;  
    input [3:0]S;  
    mux m1(out1,D[1:0],S[0]);  
    mux m2(out2,D[3:2],S[0]);  
    mux m3(out3,D[5:4],S[0]);  
    mux m4(out4,D[7:6],S[0]);  
    mux m5(out5,D[9:8],S[0]);  
    mux m6(out6,D[11:10],S[0]);  
    mux m7(out7,D[13:12],S[0]);  
    mux m8(out8,D[15:14],S[0]);  
    mux m9(out9,{out2,out1},S[1]);  
    mux m10(out10,{out4,out3},S[1]);  
    mux m11(out11,{out6,out5},S[1]);  
    mux m12(out12,{out8,out7},S[1]);  
    mux m13(out13,{out10,out9},S[2]);  
    mux m14(out14,{out12,out11},S[2]);  
    mux m15(out,{out14,out13},S[3]);  
endmodule
```

TESTBENCH

```
// listing all inputs and outputs, by convention outputs go first  
module tb_p4();  
    reg[15:0] D;
```

```

reg[3:0] S;

wire Z;

integer i;

p4 UUT(Z, D, S);

initial
begin
    #10 $monitor(" D = %b", D, " , S = %b", S, " , Z = ", Z);

    for( i = 1; i <= 65535; i = i * 2)
    begin
        D = i;

        S = 0; #10;

        S = 1; #10;

        S = 2; #10;

        S = 3; #10;

        S = 4; #10;

        S = 5; #10;

        S = 6; #10;

        S = 7; #10;

        S = 8; #10;

        S = 9; #10;

        S = 10; #10;

        S = 11; #10;

        S = 12; #10;

        S = 13; #10;

        S = 14; #10;

        S = 15; #10;

        $display("-----");
    end
end

endmodule

```

TRANSCRIPT

D = 0000000000000001 , S = 0000 , Z = 1

D = 0000000000000001 , S = 0001 , Z = 0

D = 0000000000000001 , S = 0010 , Z = 0

D = 0000000000000001 , S = 0011 , Z = 0

D = 0000000000000001 , S = 0100 , Z = 0

D = 0000000000000001 , S = 0101 , Z = 0

D = 0000000000000001 , S = 0110 , Z = 0

D = 0000000000000001 , S = 0111 , Z = 0

D = 0000000000000001 , S = 1000 , Z = 0

D = 0000000000000001 , S = 1001 , Z = 0

D = 0000000000000001 , S = 1010 , Z = 0

D = 0000000000000001 , S = 1011 , Z = 0

D = 0000000000000001 , S = 1100 , Z = 0

D = 0000000000000001 , S = 1101 , Z = 0

D = 0000000000000001 , S = 1110 , Z = 0

D = 0000000000000001 , S = 1111 , Z = 0

D = 0000000000000010 , S = 0000 , Z = 0

D = 0000000000000010 , S = 0001 , Z = 1

D = 0000000000000010 , S = 0010 , Z = 0

D = 0000000000000010 , S = 0011 , Z = 0

D = 0000000000000010 , S = 0100 , Z = 0

D = 0000000000000010 , S = 0101 , Z = 0

D = 0000000000000010 , S = 0110 , Z = 0

D = 0000000000000010 , S = 0111 , Z = 0

D = 0000000000000010 , S = 1000 , Z = 0

D = 0000000000000010 , S = 1001 , Z = 0

D = 0000000000000010 , S = 1010 , Z = 0

D = 0000000000000010 , S = 1011 , Z = 0

```

# D = 00000000000000010 , S = 1100 , Z = 0
# D = 00000000000000010 , S = 1101 , Z = 0
# D = 00000000000000010 , S = 1110 , Z = 0
# D = 00000000000000010 , S = 1111 , Z = 0
# -----
# D = 0000000000000100 , S = 0000 , Z = 0
# D = 0000000000000100 , S = 0001 , Z = 0
# D = 0000000000000100 , S = 0010 , Z = 1
# D = 0000000000000100 , S = 0011 , Z = 0
# D = 0000000000000100 , S = 0100 , Z = 0
# D = 0000000000000100 , S = 0101 , Z = 0
# D = 0000000000000100 , S = 0110 , Z = 0
# D = 0000000000000100 , S = 0111 , Z = 0
# D = 0000000000000100 , S = 1000 , Z = 0
# D = 0000000000000100 , S = 1001 , Z = 0
# D = 0000000000000100 , S = 1010 , Z = 0
# D = 0000000000000100 , S = 1011 , Z = 0
# D = 0000000000000100 , S = 1100 , Z = 0
# D = 0000000000000100 , S = 1101 , Z = 0
# D = 0000000000000100 , S = 1110 , Z = 0
# D = 0000000000000100 , S = 1111 , Z = 0
# -----
# D = 0000000000001000 , S = 0000 , Z = 0
# D = 0000000000001000 , S = 0001 , Z = 0
# D = 0000000000001000 , S = 0010 , Z = 0
# D = 0000000000001000 , S = 0011 , Z = 1
# D = 0000000000001000 , S = 0100 , Z = 0
# D = 0000000000001000 , S = 0101 , Z = 0
# D = 0000000000001000 , S = 0110 , Z = 0
# D = 0000000000001000 , S = 0111 , Z = 0
# D = 0000000000001000 , S = 1000 , Z = 0

```

```

# D = 0000000000001000 , S = 1001 , Z = 0
# D = 0000000000001000 , S = 1010 , Z = 0
# D = 0000000000001000 , S = 1011 , Z = 0
# D = 0000000000001000 , S = 1100 , Z = 0
# D = 0000000000001000 , S = 1101 , Z = 0
# D = 0000000000001000 , S = 1110 , Z = 0
# D = 0000000000001000 , S = 1111 , Z = 0
# -----
# D = 0000000000010000 , S = 0000 , Z = 0
# D = 0000000000010000 , S = 0001 , Z = 0
# D = 0000000000010000 , S = 0010 , Z = 0
# D = 0000000000010000 , S = 0011 , Z = 0
# D = 0000000000010000 , S = 0100 , Z = 1
# D = 0000000000010000 , S = 0101 , Z = 0
# D = 0000000000010000 , S = 0110 , Z = 0
# D = 0000000000010000 , S = 0111 , Z = 0
# D = 0000000000010000 , S = 1000 , Z = 0
# D = 0000000000010000 , S = 1001 , Z = 0
# D = 0000000000010000 , S = 1010 , Z = 0
# D = 0000000000010000 , S = 1011 , Z = 0
# D = 0000000000010000 , S = 1100 , Z = 0
# D = 0000000000010000 , S = 1101 , Z = 0
# D = 0000000000010000 , S = 1110 , Z = 0
# D = 0000000000010000 , S = 1111 , Z = 0
# -----
# D = 00000000000100000 , S = 0000 , Z = 0
# D = 00000000000100000 , S = 0001 , Z = 0
# D = 00000000000100000 , S = 0010 , Z = 0
# D = 00000000000100000 , S = 0011 , Z = 0
# D = 00000000000100000 , S = 0100 , Z = 0
# D = 00000000000100000 , S = 0101 , Z = 1

```



```

# D = 0000000000100000 , S = 0110 , Z = 0
# D = 0000000000100000 , S = 0111 , Z = 0
# D = 0000000000100000 , S = 1000 , Z = 0
# D = 0000000000100000 , S = 1001 , Z = 0
# D = 0000000000100000 , S = 1010 , Z = 0
# D = 0000000000100000 , S = 1011 , Z = 0
# D = 0000000000100000 , S = 1100 , Z = 0
# D = 0000000000100000 , S = 1101 , Z = 0
# D = 0000000000100000 , S = 1110 , Z = 0
# D = 0000000000100000 , S = 1111 , Z = 0
# -----
# D = 0000000001000000 , S = 0000 , Z = 0
# D = 0000000001000000 , S = 0001 , Z = 0
# D = 0000000001000000 , S = 0010 , Z = 0
# D = 0000000001000000 , S = 0011 , Z = 0
# D = 0000000001000000 , S = 0100 , Z = 0
# D = 0000000001000000 , S = 0101 , Z = 0
# D = 0000000001000000 , S = 0110 , Z = 1
# D = 0000000001000000 , S = 0111 , Z = 0
# D = 0000000001000000 , S = 1000 , Z = 0
# D = 0000000001000000 , S = 1001 , Z = 0
# D = 0000000001000000 , S = 1010 , Z = 0
# D = 0000000001000000 , S = 1011 , Z = 0
# D = 0000000001000000 , S = 1100 , Z = 0
# D = 0000000001000000 , S = 1101 , Z = 0
# D = 0000000001000000 , S = 1110 , Z = 0
# D = 0000000001000000 , S = 1111 , Z = 0
# -----
# D = 0000000010000000 , S = 0000 , Z = 0
# D = 0000000010000000 , S = 0001 , Z = 0
# D = 0000000010000000 , S = 0010 , Z = 0

```

```
# D = 0000000010000000 , S = 0011 , Z = 0
# D = 0000000010000000 , S = 0100 , Z = 0
# D = 0000000010000000 , S = 0101 , Z = 0
# D = 0000000010000000 , S = 0110 , Z = 0
# D = 0000000010000000 , S = 0111 , Z = 1
# D = 0000000010000000 , S = 1000 , Z = 0
# D = 0000000010000000 , S = 1001 , Z = 0
# D = 0000000010000000 , S = 1010 , Z = 0
# D = 0000000010000000 , S = 1011 , Z = 0
# D = 0000000010000000 , S = 1100 , Z = 0
# D = 0000000010000000 , S = 1101 , Z = 0
# D = 0000000010000000 , S = 1110 , Z = 0
# D = 0000000010000000 , S = 1111 , Z = 0
# -----
# D = 0000000100000000 , S = 0000 , Z = 0
# D = 0000000100000000 , S = 0001 , Z = 0
# D = 0000000100000000 , S = 0010 , Z = 0
# D = 0000000100000000 , S = 0011 , Z = 0
# D = 0000000100000000 , S = 0100 , Z = 0
# D = 0000000100000000 , S = 0101 , Z = 0
# D = 0000000100000000 , S = 0110 , Z = 0
# D = 0000000100000000 , S = 0111 , Z = 0
# D = 0000000100000000 , S = 1000 , Z = 1
# D = 0000000100000000 , S = 1001 , Z = 0
# D = 0000000100000000 , S = 1010 , Z = 0
# D = 0000000100000000 , S = 1011 , Z = 0
# D = 0000000100000000 , S = 1100 , Z = 0
# D = 0000000100000000 , S = 1101 , Z = 0
# D = 0000000100000000 , S = 1110 , Z = 0
# D = 0000000100000000 , S = 1111 , Z = 0
# -----
```

D = 0000001000000000 , S = 0000 , Z = 0
D = 0000001000000000 , S = 0001 , Z = 0
D = 0000001000000000 , S = 0010 , Z = 0
D = 0000001000000000 , S = 0011 , Z = 0
D = 0000001000000000 , S = 0100 , Z = 0
D = 0000001000000000 , S = 0101 , Z = 0
D = 0000001000000000 , S = 0110 , Z = 0
D = 0000001000000000 , S = 0111 , Z = 0
D = 0000001000000000 , S = 1000 , Z = 0
D = 0000001000000000 , S = 1001 , Z = 1
D = 0000001000000000 , S = 1010 , Z = 0
D = 0000001000000000 , S = 1011 , Z = 0
D = 0000001000000000 , S = 1100 , Z = 0
D = 0000001000000000 , S = 1101 , Z = 0
D = 0000001000000000 , S = 1110 , Z = 0
D = 0000001000000000 , S = 1111 , Z = 0

D = 0000010000000000 , S = 0000 , Z = 0
D = 0000010000000000 , S = 0001 , Z = 0
D = 0000010000000000 , S = 0010 , Z = 0
D = 0000010000000000 , S = 0011 , Z = 0
D = 0000010000000000 , S = 0100 , Z = 0
D = 0000010000000000 , S = 0101 , Z = 0
D = 0000010000000000 , S = 0110 , Z = 0
D = 0000010000000000 , S = 0111 , Z = 0
D = 0000010000000000 , S = 1000 , Z = 0
D = 0000010000000000 , S = 1001 , Z = 0
D = 0000010000000000 , S = 1010 , Z = 1
D = 0000010000000000 , S = 1011 , Z = 0
D = 0000010000000000 , S = 1100 , Z = 0
D = 0000010000000000 , S = 1101 , Z = 0

```
# D = 000001000000000000 , S = 1110 , Z = 0
# D = 000001000000000000 , S = 1111 , Z = 0
# -----
# D = 000010000000000000 , S = 0000 , Z = 0
# D = 000010000000000000 , S = 0001 , Z = 0
# D = 000010000000000000 , S = 0010 , Z = 0
# D = 000010000000000000 , S = 0011 , Z = 0
# D = 000010000000000000 , S = 0100 , Z = 0
# D = 000010000000000000 , S = 0101 , Z = 0
# D = 000010000000000000 , S = 0110 , Z = 0
# D = 000010000000000000 , S = 0111 , Z = 0
# D = 000010000000000000 , S = 1000 , Z = 0
# D = 000010000000000000 , S = 1001 , Z = 0
# D = 000010000000000000 , S = 1010 , Z = 0
# D = 000010000000000000 , S = 1011 , Z = 1
# D = 000010000000000000 , S = 1100 , Z = 0
# D = 000010000000000000 , S = 1101 , Z = 0
# D = 000010000000000000 , S = 1110 , Z = 0
# D = 000010000000000000 , S = 1111 , Z = 0
# -----
# D = 000100000000000000 , S = 0000 , Z = 0
# D = 000100000000000000 , S = 0001 , Z = 0
# D = 000100000000000000 , S = 0010 , Z = 0
# D = 000100000000000000 , S = 0011 , Z = 0
# D = 000100000000000000 , S = 0100 , Z = 0
# D = 000100000000000000 , S = 0101 , Z = 0
# D = 000100000000000000 , S = 0110 , Z = 0
# D = 000100000000000000 , S = 0111 , Z = 0
# D = 000100000000000000 , S = 1000 , Z = 0
# D = 000100000000000000 , S = 1001 , Z = 0
# D = 000100000000000000 , S = 1010 , Z = 0
```

```

# D = 0001000000000000 , S = 1011 , Z = 0
# D = 0001000000000000 , S = 1100 , Z = 1
# D = 0001000000000000 , S = 1101 , Z = 0
# D = 0001000000000000 , S = 1110 , Z = 0
# D = 0001000000000000 , S = 1111 , Z = 0
# -----
# D = 0010000000000000 , S = 0000 , Z = 0
# D = 0010000000000000 , S = 0001 , Z = 0
# D = 0010000000000000 , S = 0010 , Z = 0
# D = 0010000000000000 , S = 0011 , Z = 0
# D = 0010000000000000 , S = 0100 , Z = 0
# D = 0010000000000000 , S = 0101 , Z = 0
# D = 0010000000000000 , S = 0110 , Z = 0
# D = 0010000000000000 , S = 0111 , Z = 0
# D = 0010000000000000 , S = 1000 , Z = 0
# D = 0010000000000000 , S = 1001 , Z = 0
# D = 0010000000000000 , S = 1010 , Z = 0
# D = 0010000000000000 , S = 1011 , Z = 0
# D = 0010000000000000 , S = 1100 , Z = 0
# D = 0010000000000000 , S = 1101 , Z = 1
# D = 0010000000000000 , S = 1110 , Z = 0
# D = 0010000000000000 , S = 1111 , Z = 0
# -----
# D = 0100000000000000 , S = 0000 , Z = 0
# D = 0100000000000000 , S = 0001 , Z = 0
# D = 0100000000000000 , S = 0010 , Z = 0
# D = 0100000000000000 , S = 0011 , Z = 0
# D = 0100000000000000 , S = 0100 , Z = 0
# D = 0100000000000000 , S = 0101 , Z = 0
# D = 0100000000000000 , S = 0110 , Z = 0
# D = 0100000000000000 , S = 0111 , Z = 0

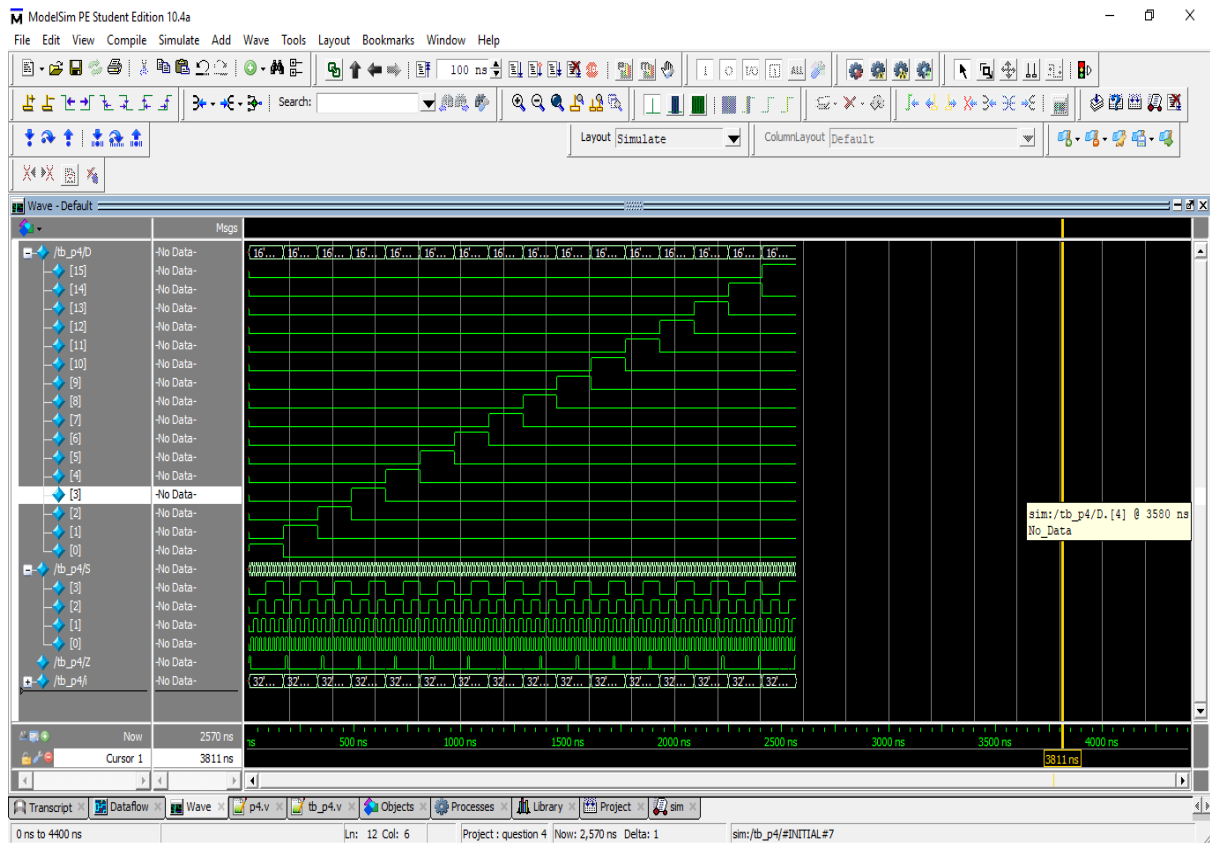
```

```

# D = 0100000000000000 , S = 1000 , Z = 0
# D = 0100000000000000 , S = 1001 , Z = 0
# D = 0100000000000000 , S = 1010 , Z = 0
# D = 0100000000000000 , S = 1011 , Z = 0
# D = 0100000000000000 , S = 1100 , Z = 0
# D = 0100000000000000 , S = 1101 , Z = 0
# D = 0100000000000000 , S = 1110 , Z = 1
# D = 0100000000000000 , S = 1111 , Z = 0
# -----
# D = 1000000000000000 , S = 0000 , Z = 0
# D = 1000000000000000 , S = 0001 , Z = 0
# D = 1000000000000000 , S = 0010 , Z = 0
# D = 1000000000000000 , S = 0011 , Z = 0
# D = 1000000000000000 , S = 0100 , Z = 0
# D = 1000000000000000 , S = 0101 , Z = 0
# D = 1000000000000000 , S = 0110 , Z = 0
# D = 1000000000000000 , S = 0111 , Z = 0
# D = 1000000000000000 , S = 1000 , Z = 0
# D = 1000000000000000 , S = 1001 , Z = 0
# D = 1000000000000000 , S = 1010 , Z = 0
# D = 1000000000000000 , S = 1011 , Z = 0
# D = 1000000000000000 , S = 1100 , Z = 0
# D = 1000000000000000 , S = 1101 , Z = 0
# D = 1000000000000000 , S = 1110 , Z = 0
# D = 1000000000000000 , S = 1111 , Z = 1
# -----

```

WAVE



QUESTION 5

DESIGN

// listing all inputs and outputs, by convention outputs go first

```
module p5(out,D);
```

```
    output [63:0]out;
```

```
    reg [63:0]out;
```

```
    input [5:0]D;
```

```
    always@(D)
```

```
    //behavioral approach
```

```
begin
```

```
    out=0;
```

```
    out[D]=1;
```

```
end
```

```
endmodule
```

TESTBENCH

```
// listing all inputs and outputs, by convention outputs go first
module tb_p5();

    wire [63:0]Z;

    reg [5:0]D;

    integer i;

    p5 UUT (Z,D);

    initial

    begin

        #10 $monitor("D = %b",D, " , Z=%b",Z);

        for(i=0;i<=63;i=i+1)

            begin

                D=i; #10;

            end

        end

    end

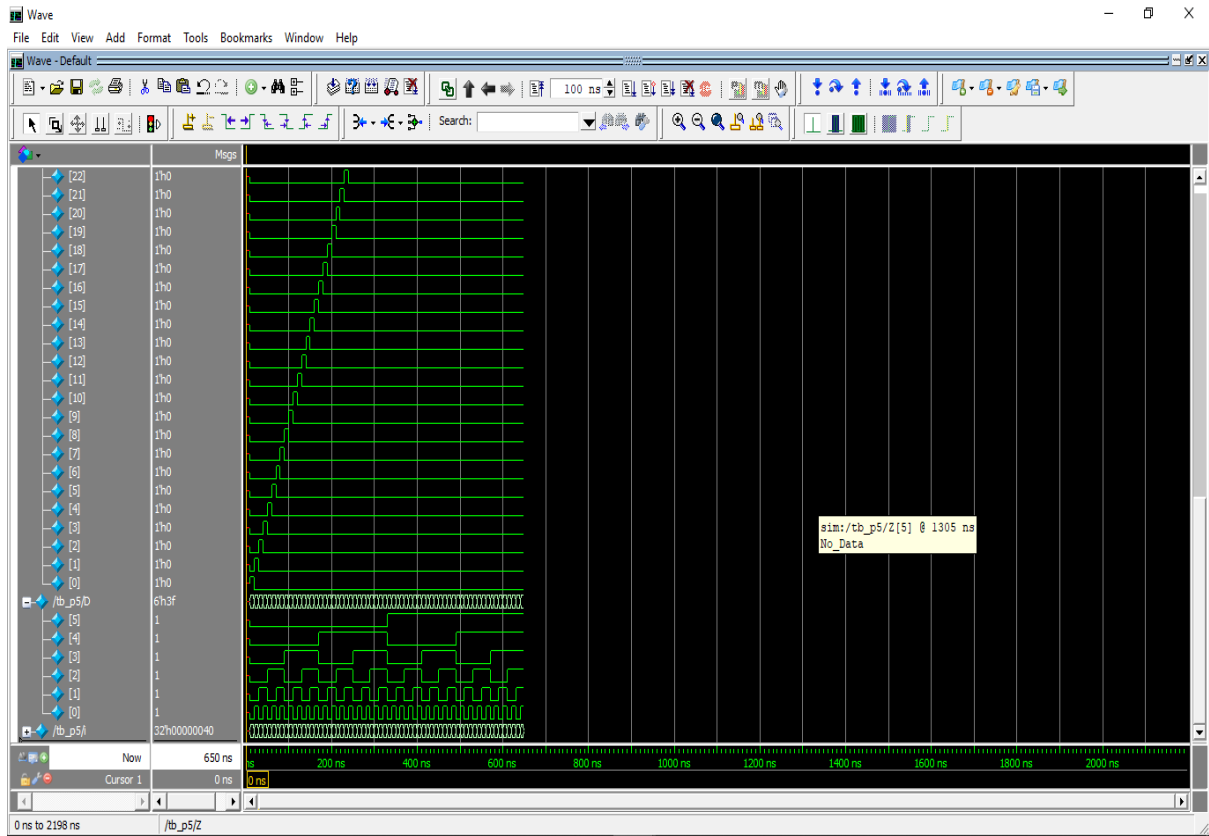
endmodule
```

TRANSCRIPT

[illegible]

[illegible]

WAVE



QUESTION 6

DESIGN

// listing all inputs and outputs, by convention outputs go first

```
module decoder(Y0, Y1, Y2, Y3, Y4, Y5, Y6, Y7, C, B, A, enable);
```

```
    output Y7, Y6, Y5, Y4, Y3, Y2, Y1, Y0;
```

```
    input A, B, C;
```

```
    input enable;
```

```
//behavioral approach
```

```
    assign {Y7,Y6,Y5,Y4,Y3,Y2,Y1,Y0} = ( {enable,A,B,C} == 4'b1000) ? 8'b0000_0001 : ( {enable,A,B,C} ==
4'b1001) ? 8'b0000_0010 : ( {enable,A,B,C} == 4'b1010) ? 8'b0000_0100 : ( {enable,A,B,C} ==
4'b1011) ? 8'b0000_1000 : ( {enable,A,B,C} == 4'b1100) ? 8'b0001_0000 : ( {enable,A,B,C} ==
4'b1101) ? 8'b0010_0000 : ( {enable,A,B,C} == 4'b1110) ? 8'b0100_0000 : ( {enable,A,B,C} ==
4'b1111) ? 8'b1000_0000 : 8'b0000_0000;
```

```
endmodule
```

```

module p6(out,in);
    output [63:0] out;
    input [5:0] in;
    decoder maingate (a,b,c,d,e,f,g,h,in[3],in[4],in[5],1);
    decoder d1
    (out[0],out[1],out[2],out[3],out[4],out[5],out[6],out[7],in[0],in[1],in[2],a);
    decoder d2
    (out[8],out[9],out[10],out[11],out[12],out[13],out[14],out[15],in[0],in[1],in[2],b);
    decoder d3
    (out[16],out[17],out[18],out[19],out[20],out[21],out[22],out[23],in[0],in[1],in[2],c);
    decoder d4
    (out[24],out[25],out[26],out[27],out[28],out[29],out[30],out[31],in[0],in[1],in[2],d);
    decoder d5
    (out[32],out[33],out[34],out[35],out[36],out[37],out[38],out[39],in[0],in[1],in[2],e);
    decoder d6
    (out[40],out[41],out[42],out[43],out[44],out[45],out[46],out[47],in[0],in[1],in[2],f);
    decoder d7
    (out[48],out[49],out[50],out[51],out[52],out[53],out[54],out[55],in[0],in[1],in[2],g);
    decoder d8
    (out[56],out[57],out[58],out[59],out[60],out[61],out[62],out[63],in[0],in[1],in[2],h);
endmodule

```

TESTBENCH

// listing all inputs and outputs, by convention outputs go first

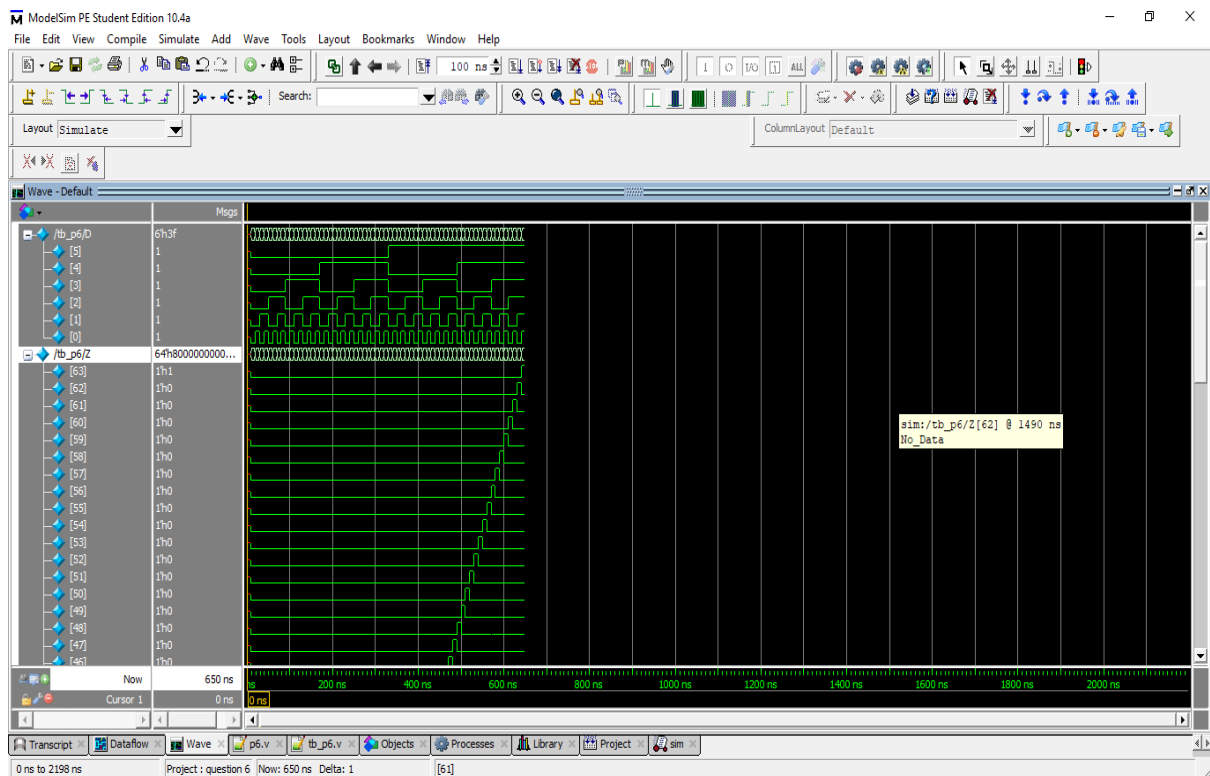
```

module tb_p6();
    reg [5:0]D;
    wire [63:0]Z;
    integer i;
    p6 UUT (Z,D);

```


[illegible]

WAVE



QUESTION 7

DESIGN

```
module decade_counter ( q, clk );  
    output reg [3:0] q=0;  
    input clk;  
    always @(posedge clk)  
        q <= q == 9 ? 0 : q + 1;  
endmodule
```

// listing all inputs and outputs, by convention outputs go first

```
module decoded_counter ( output ctrl, input clk );  
    reg [3:0] count_value=0;  
    always @(posedge clk)  
        count_value <= count_value + 1;  
    assign ctrl = count_value == 4'b0111 || count_value == 4'b1011;  
endmodule
```

TESTBENCH

```
module decade();  
    wire [3:0]q;  
    reg clk = 0;  
    integer i;  
    decade_counter UUT(q, clk);  
    initial begin  
        for(i = 0; i < 100; i = i + 1)  
            #10;  
    end  
    always @(i) clk = ~clk;
```



```

        initial begin
            #7;
            $monitor("clock=%d",q);
        end
    endmodule

module decoded();
    reg clk = 0;
    wire ctrl;
    integer i = -1;
    decoded_counter UUT(ctrl, clk);
    initial

        for(i = 0; i < 50; i = i + 1)
            #5;
            always @(i) clk = ~clk;
            always @(i/2)
                $display("ctrl = %b", ctrl);
Endmodule

```

TRANSCRIPT

Decade

clock= 1

clock= 2

clock= 3

clock= 4

clock= 5

clock= 6

clock= 7

clock= 8

clock= 9

clock= 0

clock= 1

clock= 2

clock= 3

clock= 4

clock= 5

clock= 6

clock= 7

clock= 8

clock= 9

clock= 0

clock= 1

clock= 2

clock= 3

clock= 4

clock= 5

clock= 6

clock= 7

clock= 8

clock= 9

clock= 0

clock= 1

clock= 2

clock= 3

clock= 4

clock= 5

clock= 6

clock= 7

clock= 8

clock= 9

clock= 0

clock= 1

clock= 2

clock= 3

clock= 4

clock= 5

clock= 6

clock= 7

clock= 8

clock= 9

clock= 0

clock= 1

Decoded

ctrl = 0

ctrl = 0

ctrl = 0

ctrl = 0

ctrl = 0

ctrl = 0

ctrl = 0

ctrl = 1

ctrl = 0

ctrl = 0

ctrl = 0

ctrl = 1

ctrl = 0

ctrl = 0

ctrl = 0

ctrl = 0

ctrl = 0

ctrl = 0

ctrl = 0

ctrl = 0

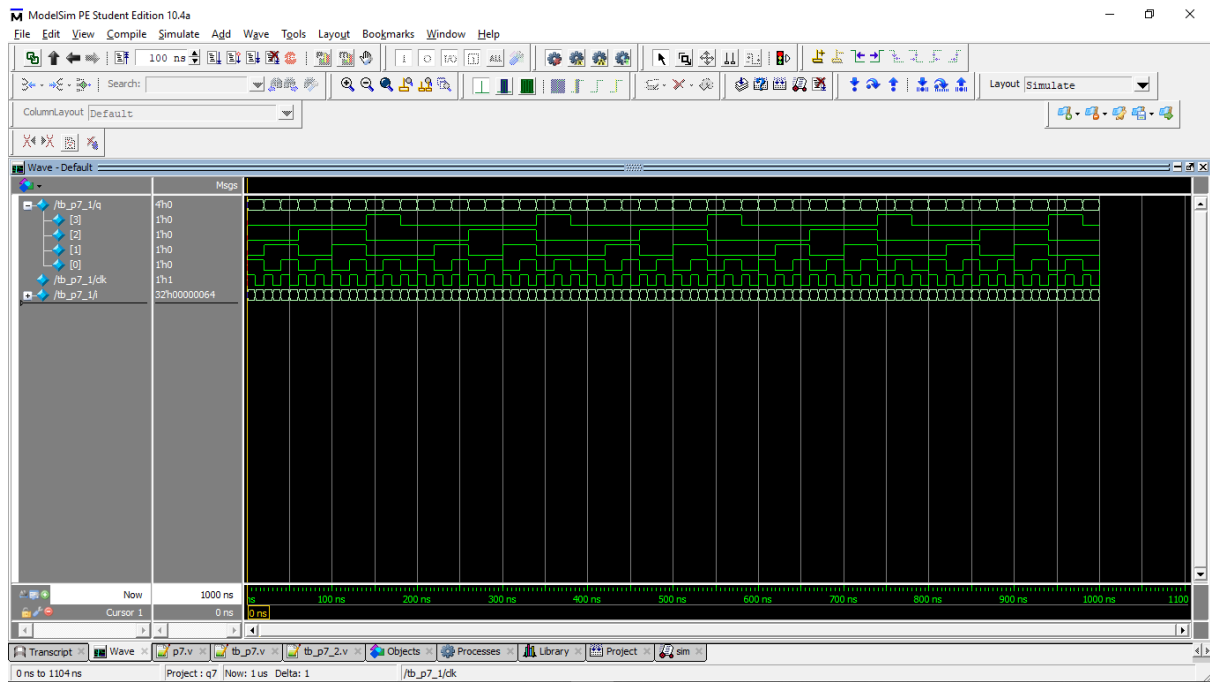
ctrl = 0

ctrl = 0

```
ctrl = 0
ctrl = 1
ctrl = 0
ctrl = 0
```

WAVE

Decade



Decoded

