



# Lab 1: Sequential Multiplier

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# Lab 1 Goal: Simulate an 8-bit Multiplier

Lab 1

- ◆ In this lab, you must simulate the operations of a sequential binary multiplier using the Vivado Simulator.
  - You should review your textbook on Digital Circuit Design by Mano. Some design guideline of the sequential binary multiplier is in Section 8.10 of Mano's book.
  - The multiplier is designed using only adder, shifter, multiplexor, and gate-level operators. You cannot use the multiplication operator of Verilog.
- ◆ The lab file submission deadline is on 9/26 by 6:00pm.





# Write Simulation for a Multiplier

Lab 1

- ◆ The input/output ports of the 8-bit multiplier is as follows:

```
module SeqMultiplier(  
    input wire clk,  
    input wire enable,  
    input wire [7:0] A,  
    input wire [7:0] B,  
    output wire [15:0] C  
);
```

'clk' is the system clock,  
'enable' activates the multiplication operation,  
'A' is the 8-bit unsigned multiplicand input,  
'B' is the 8-bit unsigned multiplier input, and  
'C' is the 16-bit unsigned product output.





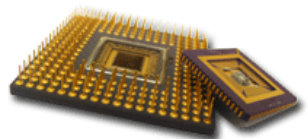
# Sequential Binary Multiplier Behavior

Lab 1

◆ Sequential binary multiplication of 10111 and 10011:

$$23 \times 19 = (437)_{10}$$

	00010111	→ multiplicand
×	00010011	→ multiplier
<hr/>		
	00000000	
	00000000	
	00000000	
	00010111	
	00000000	
	00000000	
	00010111	
+	00010111	
<hr/>		
	000110110101	→ product





# C Model of the Multiplier

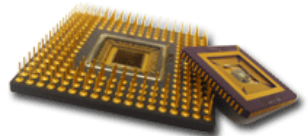
Lab 1

- ◆ The C code that performs the sequential multiplication:

```
typedef unsigned char Byte;
typedef unsigned short Word;

SeqMultiplier(Byte A, Byte B, Word *C)
{
    int idx;

    *C = 0;
    for (idx = 8; idx != 0; idx--)
    {
        *C = *C << 1;
        if ((B & 0x80) == 0x80)
        {
            *C += A;
        }
        B = B << 1;
    }
}
```





# Verilog Module of the Multiplier

Lab 1

```
module SeqMultiplier(input wire clk, input wire enable,
    input wire [7:0] A, input wire [7:0] B,
    output wire [15:0] C);

    reg [15:0] prod;
    reg [7:0] mult;
    reg [3:0] counter;
    wire shift;

    assign C = prod;
    assign shift = |(counter^7);

    always @(posedge clk) begin
        if (!enable) begin
            mult <= B;
            prod <= 0;
            counter <= 0;
        end
        else begin
            mult <= mult << 1;
            prod <= (prod + (A & {8{mult[7]}))) << shift;
            counter <= counter + shift;
        end
    end

endmodule
```





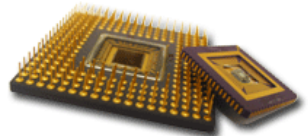
# Verilog Module of the Multiplier with Comment (1/2)

Lab 1

```

module SeqMultiplier(
    input wire clk,
    input wire enable,
    input wire [7:0] A,
    input wire [7:0] B,
    output wire [15:0] C
);
    reg [15:0] prod;
    reg [7:0] mult;
    reg [3:0] counter;
    wire shift;
    assign C = prod;
    assign shift = |(counter^7); //1 if counter<7; 0 if counter==7
    /*
    Every bit of counter exclusive or 7(4'b0111), and or together
    ex: When counter = 4'd2 = 4'b0010, then counter^7 = 4'b0101, shift = 0|1|0|1 = 1
    That is, only when counter^7 == 4'b0000 --> counter == 7 will shift be 0.
    */

```





# Verilog Module of the Multiplier with Comment (2/2)

Lab 1

```
always @(posedge clk) begin
    if (!enable) begin //Reset
        mult <= B; //We will change the value of it, so we put it in another register.
        prod <= 0;
        counter <= 0;
    end
    else begin
```

```
end
```

```
else begin
```

```
    mult <= mult << 1; //shift left
```

```
    prod <= (prod + (A & {8{mult[7]}})) << shift;
```

```
/*
```

Replication, {8{mult[7]}} == {mult[7], mult[7], mult[7], mult[7], mult[7], mult[7], mult[7], mult[7]}

Every bit of A will '&' (bit-wise operator) the highest bit of mult,

ex: 01000101 & 11111111 = 01000101 / 01000101 & 00000000 = 00000000

add the result to prod(product) and prod then shifts left.

Can take page 31 of lab1's ppt as example:

```

      00010111 → multiplicand
x     00010011 → multiplier
-----
```

```
      00000000 <-- |
```

```
      00000000 . |
```

```
      00000000 . |
```

```
      00010111 . |
```

```
      00000000 |
```

```
      00000000 |
```

```
      00010111 |
```

```

+      00010111 |
-----
```

```
      000000110110101 | → product
```

```
counter = 0: prod = 0000000000000000
```

```
counter = 1: prod = 0000000000000000
```

```
counter = 2: prod = 0000000000000000
```

```
counter = 3: prod = 0000000000010111
```

```
counter = 4: prod = 0000000000101110
```

```
counter = 5: prod = 0000000001011100
```

```
counter = 6: prod = 0000000011001111
```

```
counter = 7: prod = 0000000110110101
```

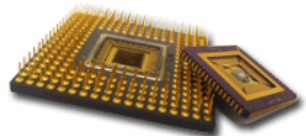
```
*/
```

```
    counter <= counter + shift; //counter+1 when counter < 7
```

```
end
```

```
end
```

```
endmodule
```



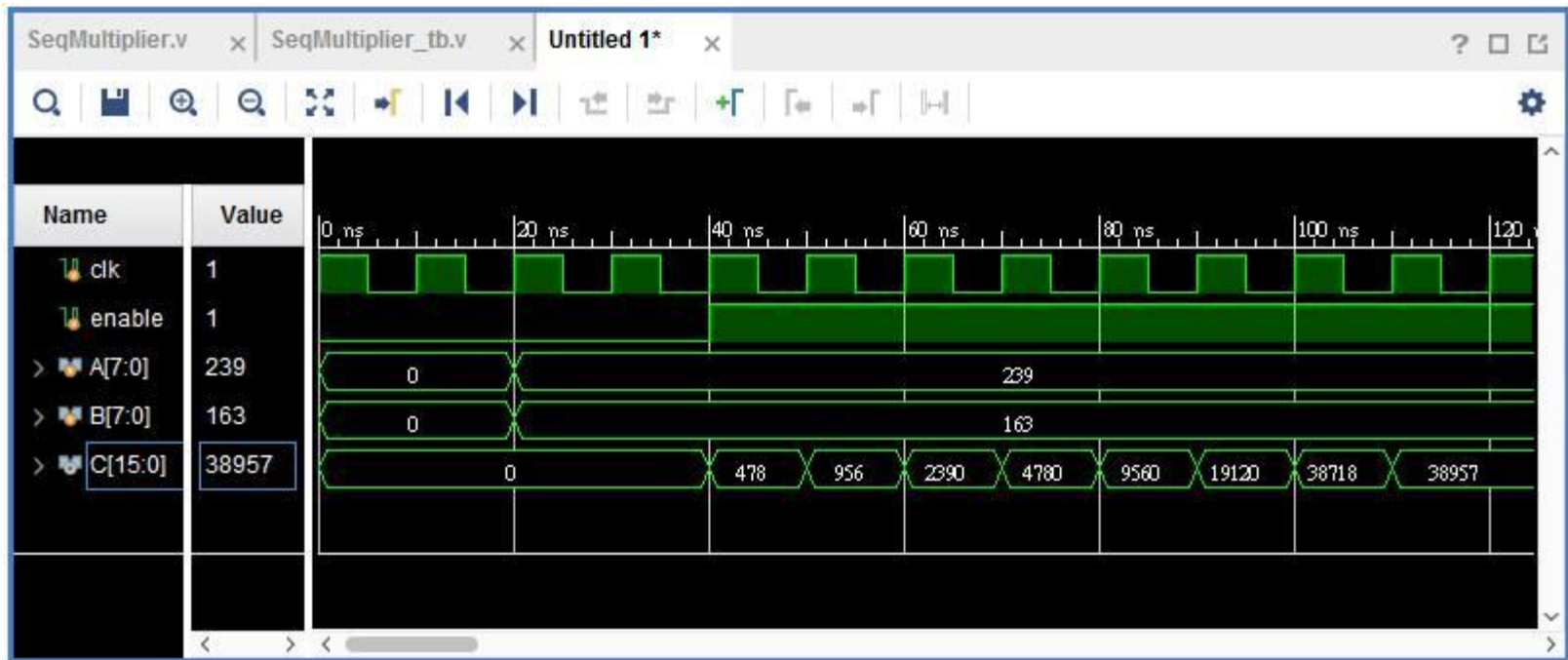




# Example of Simulated Waveforms

Lab 1

- ◆ An example of the timing diagram of  $239 \times 163 = 38957$





# Lab 1 Demo Guide

Lab 1

- ◆ You can design one 8X8 sequential multiplier in Verilog. You have to finish the design by one-bit by one-bit in shift and add way.
- ◆ You should complete the simulation and show some multiplication result waveforms.
- ◆ You should upload your Lab 1 solution to E3 before the deadline.
- ◆ During the demo time, TA will ask you to modify the testbench to show different results.
  - You can download your code from E3 during demo.

