



# Lab 1: Sequential Multiplier

Lan-Da Van and Chun-Jen Tsai

Department of Computer Science

National Yang Ming Chiao Tung University

Taiwan, R.O.C.

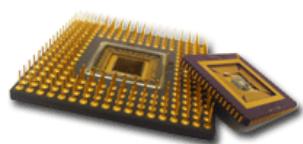
*Fall, 2025*



# 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 09/15 by 6:00pm.





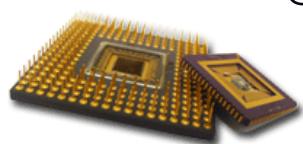
# Write Simulation for a Multiplier

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.





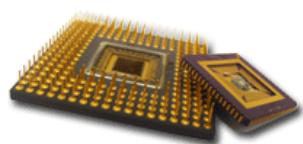
# Sequential Binary Multiplier Behavior

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	
+	<hr/>	00010111
		000110110101 → product





# C Model of the Multiplier

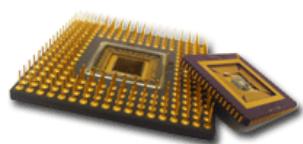
Lab 1

- ◆ 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

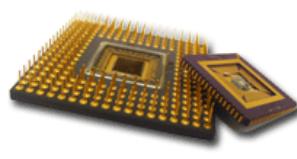
Lab 1

```
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
```

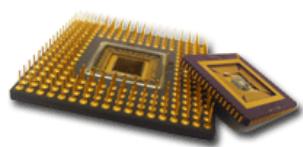




# Verilog Module of the Multiplier with Comment (1/2)

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.
*/
```



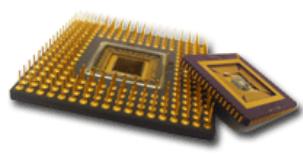
# Verilog Module of the Multiplier with Comment (2/2)

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
        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|   counter = 0: prod = 00000000000000000000
    -----
    000000110110101| → product
    */
    counter <= counter + shift; //counter+1 when counter < 7
end
end
endmodule

```

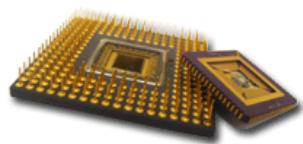
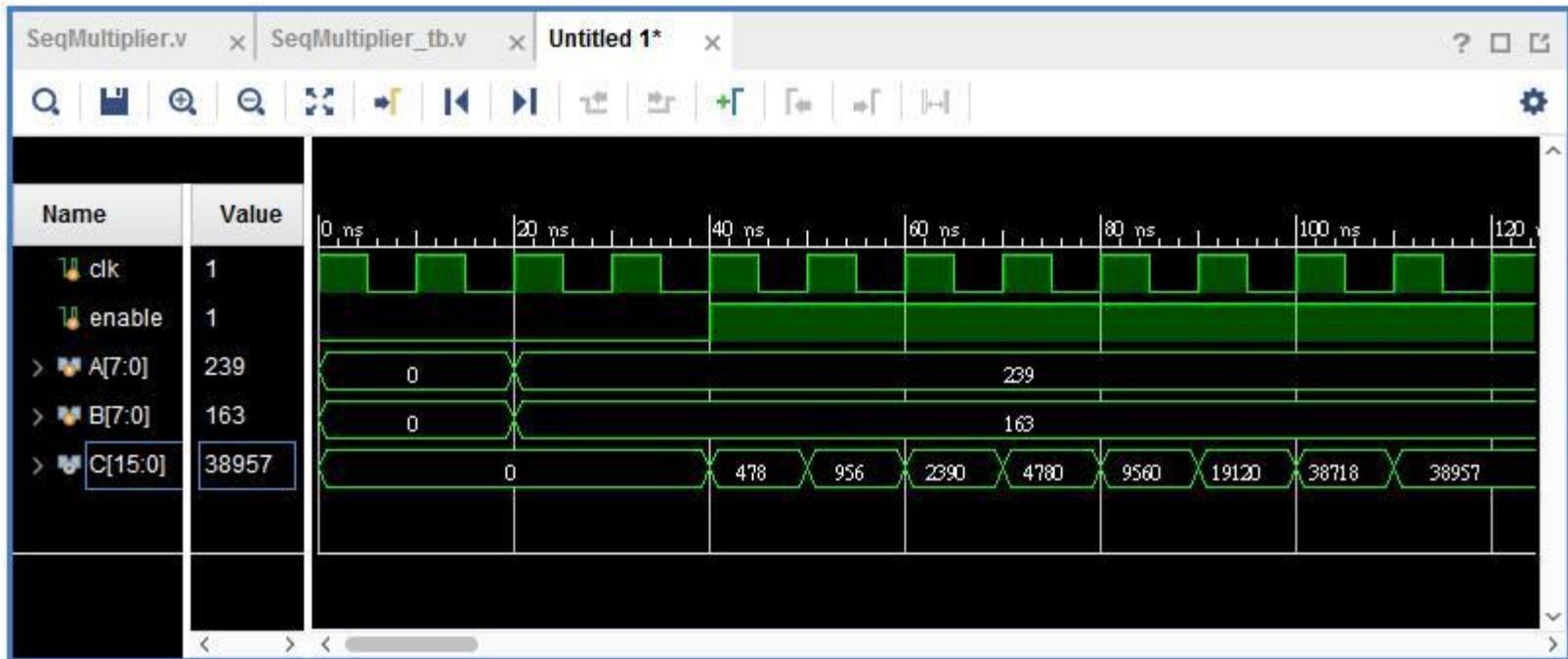




# Example of Simulated Waveforms

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.

