



Lab 2: Matrix Multiplication Simulation

Chun-Jen Tsai and Lan-Da Van

Department of Computer Science

National Yang Ming Chiao Tung University

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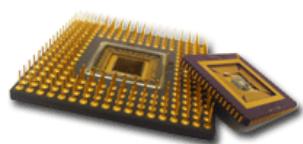


Lab 2: Matrix Multiplication Simulation

Lab 2

- ◆ In this lab, you will design a circuit to do 3×3 matrix multiplications on Vivado Simulator.
 - Two register arrays of 3×3 matrices will be given to you in the sample Verilog simulation testbench.
 - You must design a Verilog module to compute their multiplication, and print the result from the testbench.
 - You must use **no more than 9 multipliers** to implement your circuit.

- ◆ The lab file submission deadline is on 09/22 by 6:00pm.





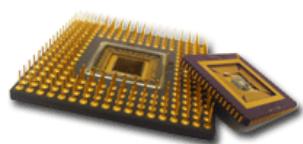
Input Matrix Format

Lab 2

- ◆ Each input matrix has 9 unsigned 8-bit elements of values between 0 ~ 255. Matrices A and B are declared in Verilog as follows:

```
reg [0:9*8-1] A = 72'h_4F_7E_57_0F_14_7B_21_4C_54;  
reg [0:9*8-1] B = 72'h_17_28_3A_40_2F_33_6C_22_77;
```

- Each matrix is stored in a 72-bit register, and each number in the matrix has 8 bits.
- The matrix is stored in row-major format.
- ◆ The output matrix has 9 unsigned 18-bit elements.



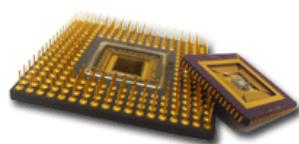


Specification of the Multiplier

Lab 2

- ◆ The matrix multiplier module is defined as follows:
 - You must follow this declaration to design your matrix multiplication module in order to use the sample simulation testbench.

```
module mmult(  
    input  clk,                      // Clock signal.  
    input  reset_n,                  // Reset signal (negative logic).  
    input  enable,                   // Activation signal for matrix  
                                    // multiplication (tells the circuit  
                                    // that A and B are ready for use).  
    input  [0:9*8-1] A_mat,          // A matrix.  
    input  [0:9*8-1] B_mat,          // B matrix.  
  
    output valid,                  // Signals that the output is valid  
                                    // to read.  
    output reg [0:9*18-1] C_mat // The result of A x B.  
);
```





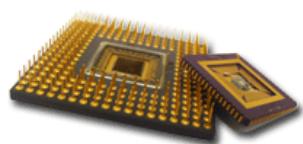
Computation of $A_{3\times 3} \times B_{3\times 3}$

Lab 2

- ◆ A 3×3 matrix multiplication is composed of 9 inner products:

$$\begin{pmatrix} a_{00} & a_{01} & a_{02} \\ a_{10} & a_{11} & a_{12} \\ a_{20} & a_{21} & a_{22} \end{pmatrix} \times \begin{pmatrix} b_{00} & b_{01} & b_{02} \\ b_{10} & b_{11} & b_{12} \\ b_{20} & b_{21} & b_{22} \end{pmatrix} = \begin{pmatrix} c_{00} & c_{01} & c_{02} \\ c_{10} & c_{11} & c_{12} \\ c_{20} & c_{21} & c_{22} \end{pmatrix}$$

- ◆ You can compute the outputs in each column of the C matrix in parallel in one clock cycle.
 - At each clock cycle, you use nine multipliers.
 - Three columns of the C matrix takes three cycles to compute!



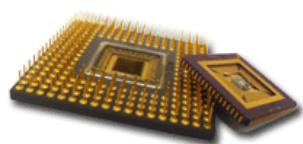


Testbench of the mmult() Module

Lab 2

- ◆ We provide a testbench for you to test the mmult() module.

- ◆ The testbench is composed of three parts:
 - Simulation of the clock and reset signals
 - Instantiation of the mmult() module and generation of its input signals
 - Print the output matrix to the console window





Simulation of Cock and Reset Signals

Lab 2

- ◆ Digital systems usually requires clock and reset signals.

```
reg clk = 1;          // Clock signal
reg reset_n = 1;    // Reset signal

// 100MHz clock generator
always
#5 clk = !clk;

// Declare the event
event reset_trigger;

initial begin
  forever begin
    // Check whether the event
    // "reset_trigger" is triggered or not
    @ (reset_trigger);
    @ (negedge clk);
    reset_n = 0;
    @ (negedge clk);
    reset_n = 1;
  end
end
```

```
// To issue a reset, you must
// trigger a reset event by the
// following code:

initial begin
  // Wait for 10 ns and then trigger
  // the event "reset_trigger".
  #10 -> reset_trigger;
end
```



Instantiation & Invocation of mmult()

Lab 2

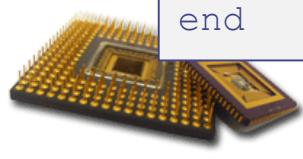
```
reg [0:9*8-1] A, B; // 3x3 matrices
wire [0:9*18-1] C;
reg enable;
wire valid;

// Instantiates a 3x3 matrix multiplier
mmult uut(
    .clk(clk), .reset_n(reset_n), .enable(enable),
    .A_mat(A), .B_mat(B), .valid(valid), .C_mat(C)
);

initial begin
    // Add stimulus here
    A = 72'h4F_7E_57_0F_14_7B_21_4C_54;
    B = 72'h17_28_3A_40_2F_33_6C_22_77;

    // Wait for 10 ns and then trigger the event "reset_trigger".
    #10 -> reset_trigger;

    // Wait for 100 ns for global reset to finish
    #100 enable = 1;
end
```





Print the Output Matrix

Lab 2

- ◆ In the simulator, you can print the output to console:

```

always @(*) begin // @(*) means all the inputs are included.
@(posedge valid);

// Wait one clock cycle so that the output is saved in result[].
#10 $display("\nThe result of C = A x B is:\n");

for (idx = 0; idx < 9; idx = idx+1)      // E.g.
begin                                     // for idx = 0
    $write("%d ", result[idx*18 +: 18]); // result[0+:18] = result[0:17]
    if (idx%3 == 2) $write("\n");        // for idx = 1
end                                         // result[18+:18] = result[18:35]
$write("\n");                            // for idx = 2
                                         // result[35+:18] = result[36:53]

End

always @ (posedge clk) begin
    if (~reset_n) result <= 0;    // Reset the register "result"
    else if (valid) result <= C; // Write the output "C" into the register
                                // "result"
    else result <= result;       // Keep the value in the register "result"
end

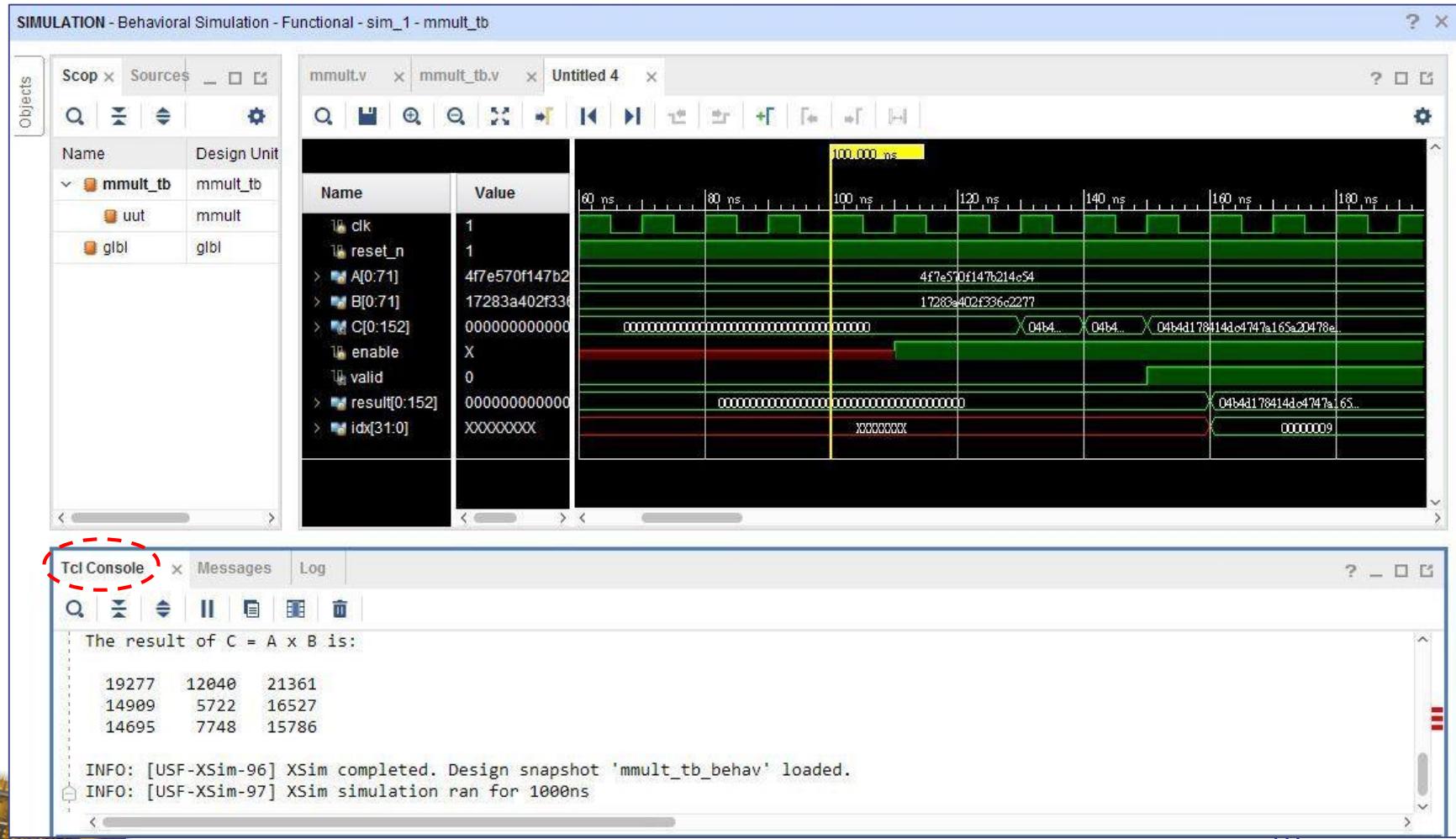
```



The Simulation Output

Lab 2

- ◆ The `$display()` function sends output to “**Tcl Console**”.





Lab 2 Demo Guide

Lab 2

- ◆ You can download the sample testbench file `mmult_tb.v` from E3, and create a Vivado project for it.
- ◆ You should upload your lab2 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.

