

Laboratory 6

(Due date: **002/003**: November 26th, **004**: November 27th, **005**: November 28th)

OBJECTIVES

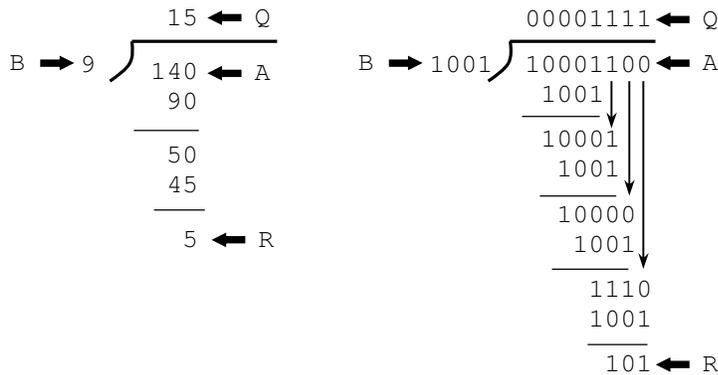
- ✓ Describe Finite State Machines (FSMs) in VHDL.
- ✓ Implement a Digital System: Control Unit and Datapath Unit.

VHDL CODING

- ✓ Refer to the [Tutorial: VHDL for FPGAs](#) for parametric code for: register, shift register, counter, adder.

ITERATIVE DIVIDER IMPLEMENTATION (100/100)

- Given two unsigned numbers A and B , we want to design a circuit that produces the quotient Q and a remainder R . $A = B \times Q + R$. The algorithm that implements the traditional long-hand division is as follows:

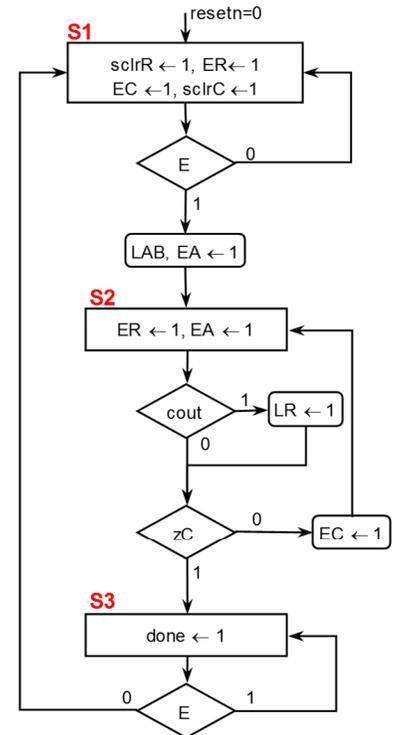
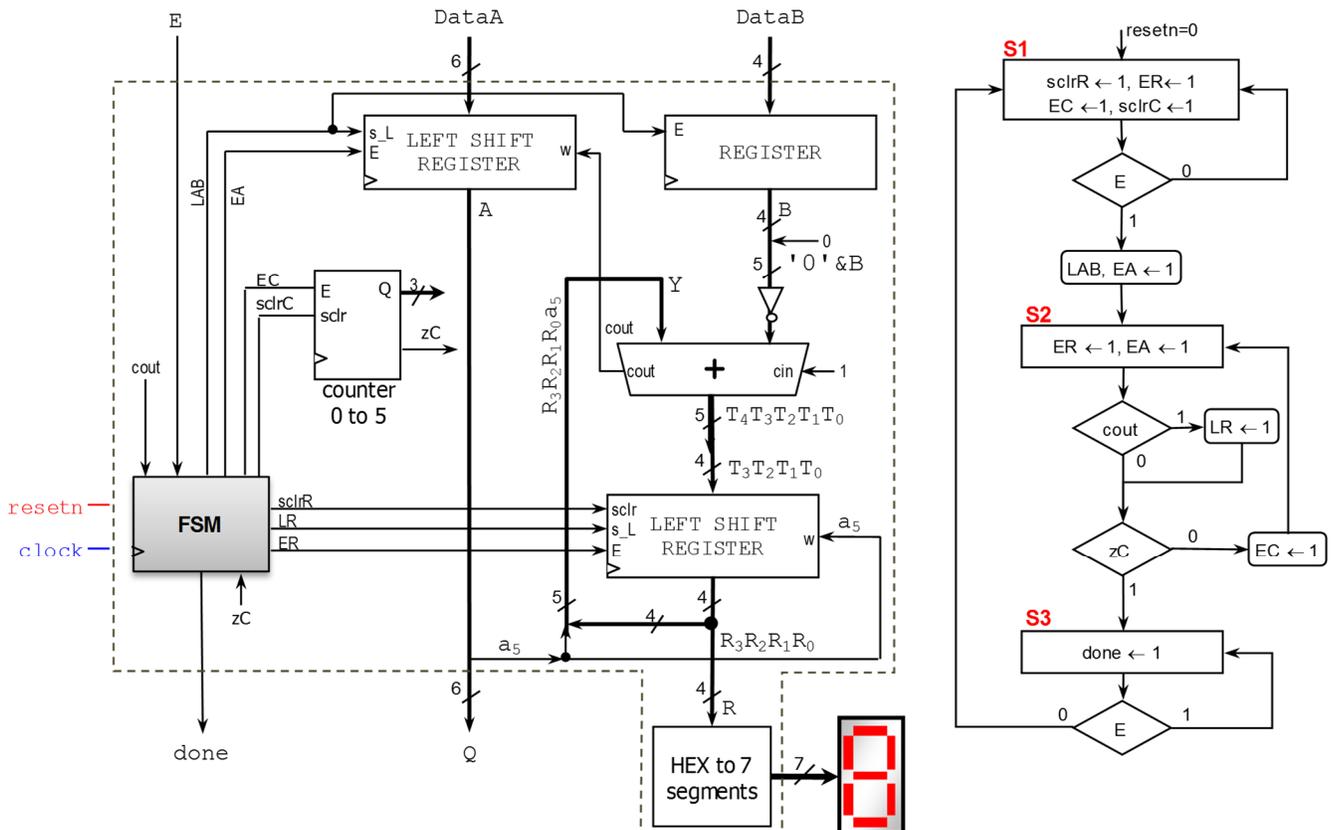


ALGORITHM

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R = 0
for i = n-1 downto 0
  left shift R (input = ai)
  if R ≥ B
    qi = 1, R ← R-B
  else
    qi = 0
  end
end
end
    
```

- An iterative architecture is depicted in the figure for A with 6 bits and B with 4 bits. The register R stores the remainder. A division operation is started when $E = 1$ (where A and B values are captured). Then, at every clock cycle, we either: i) shift in the next bit of A , or ii) shift in the next bit of A and subtract B . The signal *done* is asserted to indicate that the operation has been completed and the result appears in Q and R .



- Modulo-6 counter: It includes: i) a synchronous input *sclr* that clears the count when $E = sclr = 1$, and ii) an output *zC* that is asserted when the count reaches 5. The counter increases its value when $E = 1$ and $sclr = 0$.
- Parallel Access Left-shift register: Note that one of the shift registers includes a synchronous input *sclr* that clears the register outputs when $E = sclr = 1$. Refer to 'Notes – Unit 6' for a description of the circuit and its operation.
- Each sequential component has *resetn* and *clock* inputs.

- The circuit is an example of a Digital System: It includes a Control Circuit (FSM) and a Datapath Circuit. The Datapath Circuit is made out of combinational and sequential components. The circuit is also called a Special-Purpose Processor. In this case, the special purpose is the unsigned division.
 - ✓ Create a new Vivado Project. Select the **XC7A100T-1CSG324 Artix-7 FPGA** device.
 - ✓ Write the VHDL code for the given circuit. Suggestion: create a separate file for modulo-6 counter, shift Register, shift register with *sclr* input, register, adder, hex to 7-segments decoder, FSM, and top file.
 - ✓ Write the VHDL testbench (you must generate a 100 MHz input clock for your simulations) to test the following cases:
 - DataA = 011101 (29), DataB = 1010 (10)
 - DataA = 110111 (55), DataB = 0110 (6)
 - DataA = 101101 (45), DataB = 0011 (3)
 - DataA = 101011 (43), DataB = 1110 (14)
 - DataA = 110011 (51), DataB = 0101 (5)
 - DataA = 011001 (25), DataB = 1001 (9)
 - ✓ Perform Functional Simulation and Timing Simulation of your design. **Demonstrate this to your TA.**
 - ✓ I/O Assignment: Create the XDC file. Nexys-4-DDR: Use SW0 to SW10 for the inputs, CLK100MHZ for the input *clock*, CPU_RESET push-button for *resetn*, a LED for 'done', six LEDs for *Q*, and the 7-segment display for *R*.
 - ✓ Generate and download the bitstream on the FPGA and test. **Demonstrate this to your TA.**

- Submit (as a .zip file) all the generated files: VHDL code files, VHDL testbench, and XDC file to Moodle (an assignment will be created). DO NOT submit the whole Vivado Project.

TA signature: _____

Date: _____