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Laboratory #9: Registers

For lab sections June 6-9, 2017

I. OBJECTIVES

In this laboratory you will:

- Use flip-flops to build a register.
- Understand the operation of shift registers.
- Use multiplexers to design a multi-function shift register.

PROBLEM STATEMENT

A flip-flop stores one bit of data when an active clock edge appears at the clock input. The most common type of flip-flop is the D-type, which simply transfers the value of the D input to the Q output when the active clock edge occurs.

An *n*-bit data storage register stores *n* bits in *n* flip-flops. The flip-flops in the register have a common clock connection so that all *n* bits are changed at the same time on the same active clock edge.

An *n*-bit shift register will shift the *n* bits which are stored in the *n* flip-flops my loading each flip-flop with the output of its adjacent flip-flop. The shift register can shift bits to the left or to the right. One flip-flop will have no adjacent flip-flop to capture its bit, and its output bit will be lost. One flip-flop will have no adjacent flip-flop to provide its input bit and will be left vacant by the shift operation. Its input is specified by an external input. The flip-flops in the register have a common clock connection so that all *n* bits are changed at the same time on the same active clock edge.

Universal shift registers which can load input data or shift data left or shift data right are an important component of processor systems and of communication between processors and devices and sensors. The shift registers can be used to convert data to serial or parallel form for communciation between procesisng units and communication links. They can be used for arithmetic operations that multiply or divide by 2.

II. PRE-LAB

(i) Draw a schematic of a 4-bit storage register using flip-flops.
The register is clocked by a signal CLK.
The data into the register is a 4-bit input word X ($X_3X_2X_1X_0$).
The output is a 4-bit word Z ($Z_3Z_2Z_1Z_0$).

(ii) Modify the register in (i) to be a 4-bit shift right register that can shift stored data by one bit to the right. Draw this schematic clearly indicating what is connected to each of the data inputs of the flip-flops.

(iii)Modify the register in (i) to be a 4-bit shift left register that can shift that can shift stored data by one bit to the left. Draw this schematic clearly indicating what is connected to each of the data inputs of the flip-flops.

(iv) How could you put the three schematics together to make a universal load/bidirectionalshift register? The controls for this universal register are

- a signal Load which is high when the register needs a parallel load and low when the register shifts
- a signal ShiftL which is high when the register shifts left and low when the register shifts right.

Draw the schematic for your universal shift register.

III. PROCEDURE

Part 1: Data Storage Register
Schematic:

1. Draw the schematic for your design using the Altera libraries. Find a D-type flipflop in libraries→primitives→storage→dff. This flip_flop has D, CLCK, preset, and clear inputs and a Q output, but it does not have a QN. Be sure that all inputs to your components are controlled and are not left floating.

Inputs/Outputs:

2. Connect the 4-bit input X ($X_3X_2X_1X_0$) of your circuit to switches on the board.
3. In order to observe the inputs of your circuit you will connect them to LEDs and also to seven segment hexadecimal displays.
4. Connect the output of the Register to LEDs and also to a seven segment display.
5. Connect the clock input CLK to a push button switch.

Testing:

6. Download your circuit to the FPGA.
7. Check that the operation is correct using a test plan. Try various inputs and ensure that the register is loading your data correctly. Make sure that the least significant bit of your input is also the least significant bit in the 4-but word controlling the seven-segment display.

Part 2: Shift Registers

8. Repeat steps 1 through 7 for the two types of shift register you have designed. Consider what value you will shift into the vacant bit of the shift-register.

Part 3: Universal Register

9. Repeat steps 1 through 7 for universal shift register you designed.
    a. Connect two switches to be the Load and ShiftL control signals.
    b. To aid in testing, connect the D inputs to your four flip-flops to LEDs. Then you will be able to see both the current outputs of the flip-flops and also what the outputs of the flip-flops will be after you push the clock button.
10. Input an even number and observe what happens to this number as you shift left. Repeat for an odd number.
11. Input an even number and observe what happens to this number as you shift right. Repeat for an odd number.

Part 4: Arithmetic Operations using Shift

1. Use this universal shift register to design part of an Arithmetic Logic Unit (ALU) that can perform different arithmetic operations on a 4-bit unsigned number based on a 2-bit operation code as shown in teh table below. Hint: Use shift operations to do the multiplication and division.

Opcode Input	**OUTPUT Z**
O_1O_0	
0 0	Z= Z
0 1	Z= X
1 0	Z=floor(Z/2)
1 1	Z= 2Z

IV. REPORT

1. Introduction, procedure, results, conclusions and references.
2. Include schematic, test plan, and results for each operation.
3. How would you modify the circuit to allow opcodes for both logical and circular shifts to the left and right? A shift left or right will always leave a “vacant” bit on one side and will shift a bit out to no destination on the other side. A logical shift will shift a zero into the vacant location and lose the bit that is shifted out of the other side of the register. A circular shift will shift the last bit out of one side of the shift register and back into the vacant bit on the other side (like PAC-MAN).
4. How would you use your circuit to load a 4-bit data word (parallel load) and create a serial bit sequence that could be the input to a serial communication circuit such as USB.
5. How would you add logic to allow for getting Z= 3X.