Designing Registers and Counters

PRELAB!

Read the entire lab, and **complete** the prelab questions (Q1-Q5) on the answer sheet **before** coming to the laboratory.

1.0 Objectives

In this Lab you will design shift registers and counters, and observe their functionality.

2.0 Shift Register

A shift register is a specialized register that takes an input serially and shifts it from one bit position to the next bit position. A full explanation of shift registers is available in Chapter 5.8 of the textbook. Figure 5.17a shows a 4-bit shift register built using D flip-flops.

For this step in the lab you will design a 4-bit shift register using D flip-flops. You may use Figure 5.17a as a reference. You will use the D flip-flop of the **primitives** library to build a shift register. Create a new project ***lab10step1*** and open a new .bdf file and name it ***lab10step1***. Insert a symbol for the D flip-flop (*dff*). Set the preset ***PRN*** and the clear ***CLRN*** inputs of this flip-flop to high. One way to do this is to wire both ports to a **vcc** symbol.

Use the DE2-115 board to verify your shift register is operating correctly. Create an output pin for the output of each D flip-flop, label the first ***Q1***, second ***Q2***, third ***Q3*** and the last ***Q4***. Use toggle switches for the ***In*** and ***Clk*** pins, and use green LEDs to represent the outputs. Fill in the sequence table on the answer sheet and demonstrate your circuit to the TA.

Note: Mechanical switches have a bad electrical property called bouncing. As the two metal conductors in the switch get close to each other an electrical charge can jump across the gap between the conductors. This can happen several times before the two conductors make complete physical contact. This may cause a digital circuit to react as if the switch was opened and closed multiple times. An engineer must remove this property (debounce the switch) in order to achieve the desired action of the switch. This can be done using hardware in the circuit, or by adding a delay to switch reads in software. For this lab you just need to be aware of the problem and make sure that with every manual clock pulse you are not seeing more than one action from your circuit.

3.0 Counters

3.1 Synchronous Up-Counters

Counters are either synchronous (common clock signal) or asynchronous. A discussion of synchronous counters may be found in Chapter 5.9.2 of your textbook. Figure 5.23 describes how a 4-bit counter can be built using D flip-flops.

Create a new project ***lab10step2a*** and open a new .bdf file and name it ***lab10step2a***. Use the same **D** flip-flops you used in the last step, and additional gates, to build a synchronous 4-bit up-counter. Use the Figure 5.23 in your text as a reference.

Use the DE2-115 board to verify your up-counter is operating correctly. Use toggle switches for the ***Enable*** and ***Clk*** pins, and use green LEDs to represent the outputs. Once you are confident your circuit is functioning properly, demonstrate your circuit to the TA.

Create a new project ***lab10step2b*** and open a new .bdf file and name it ***lab10step2b***. Use **T** flip-flops, and additional gates, to build a synchronous 4-bit up-counter. Use Figure 5.21a in your text as a reference. You can get T flip-flops (*tff*) from the **primitives** library the same way you got the D flip-flops. Set the preset and the clear inputs of this flip-flop to high.

Use the DE2-115 board to verify your up-counter is operating correctly. Use a toggle switch for the ***Clk*** pin, (the first T flip-flop input should be tied to **vcc**), and use green LEDs to represent the outputs. Once you are confident your circuit is functioning properly, demonstrate your circuit to the TA.

3.2 Asynchronous Counters

In this step ***lab10step3a***, you will build a 4-bit asynchronous **up**-counter. Figure 5.19a in your textbook shows a 3-bit asynchronous up-counter using T flip-flops. Extend this circuit to build a 4-bit asynchronous up-counter. You can use an inverter on the Q output to get the ~Q from the flip-flops.

Create a new project and use the DE2-115 board to verify your up-counter is operating correctly. Use a toggle switch for the ***Clk*** pin, (the first T flip-flop input should be tied to **vcc**), and use a seven segment display to represent the outputs. Once you are confident your circuit is functioning properly, demonstrate your circuit to the TA.

In this step ***lab10step3b***, you will build a 4-bit asynchronous **down**-counter using T flip-flops. Figure 5.20a in your textbook shows a 3-bit asynchronous down-counter using T flip-flops. Extend this circuit to build a 4-bit asynchronous down-counter.

Create a new project and use the DE2-115 board to verify your down-counter is operating correctly. Use a toggle switch for the ***Clk*** pin, (the first T flip-flop input should be tied to **vcc**), and use a seven segment display to represent the outputs. Once you are confident your circuit is functioning properly, demonstrate your circuit to the TA.

4.0 Complete

You are done with this lab. Close all lab files, exit Quartus Prime, log off the computer, power down the DE2-115 board, and hand in your answers. **Don't forget to write down your name and lab section number**.