EE 2700
Digital Circuits

Lab 6 – 2-Bit Ripple Carry Adder

Objective: In this 2-week lab, the student will design, simulate, build and test a modular digital circuit that adds two 2-bit numbers plus a carry to form a 3-bit binary result (2 bits of sum and a carry). The student will also become familiar with modular circuit design.

Parts:
1-Proto board, Switches, LEDs and resistors (from lab 1)
1 74LS20 Dual 4-input NAND gate
4 74LS10 Triple 3-input NAND gates
Various NAND gates and inverters from previous labs

Preparation: (Week 1) Write the title and a short description of this lab in your lab book. Make sure the page is numbered and make an entry in the table of contents.

In this lab, we wish to design a circuit to add two 2-bit numbers plus a carry-in. Since there are only 5 total inputs, it seems reasonable to use VEMs for each of the three outputs. But if you do, you will quickly find that the logic expressions are quite complicated. A simpler approach to this problem is to divide and conquer. Recall how each bit of a binary sum depends on the two addends and the carry-in from the adjacent column on the right. We can take advantage of this property to build a multi-bit adder using multiple one-bit full adders similar to the one we built in lab 5 and connecting the carry-out from one to the carry-in of the other. (Figure 1). This configuration of full adders is known as a "ripple carry adder".

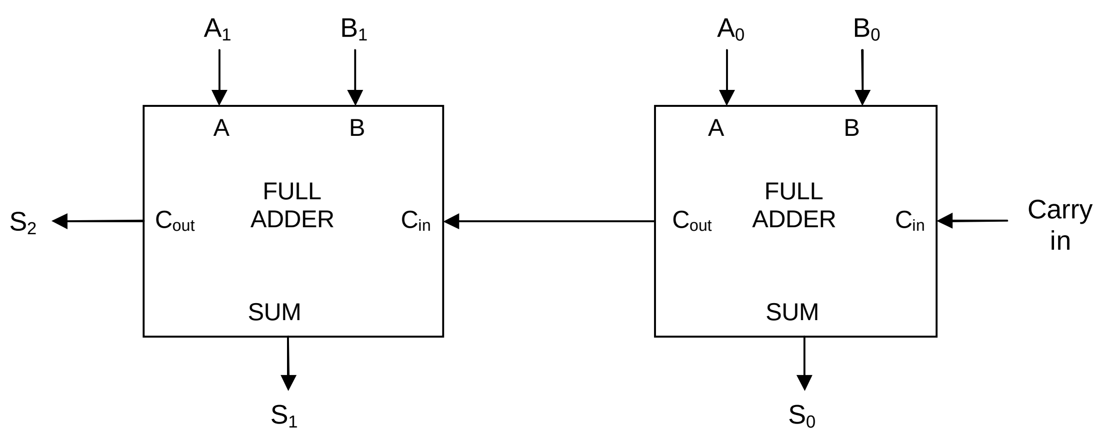

Figure 1 – Ripple Carry Adder

Procedure: (Week 1) Refer to the Karnaugh maps and logic equations you derived for lab 5. Using ISE, draw a schematic containing NAND gates and inverters to implement the 1-bit full adder. <u>If a gate performs a logical OR rather than an AND operation, use</u>

the appropriate OR symbol with bubbles on its inputs. For example, rather than use the built-in model “nand2”, use the other built-in model “or2b2”. Both represent the same physical gate but connote different logical operations. Add I/O markers to your schematic and save it. Write a test bench for your full adder that tests all 8 possible input combinations and simulate. Affix the schematic, test bench and simulation output to your lab book.

Create a schematic symbol for your full adder. (You may need to select the “Implementation” radio button.) Now create a new schematic for the 2-bit adder. Insert two instances of your 1-bit full adder and connect them as shown in Figure 1. The inputs and outputs to this schematic need to be busses, and the easiest way to handle that is by adding wires with I/O markers as shown in Figure 2.

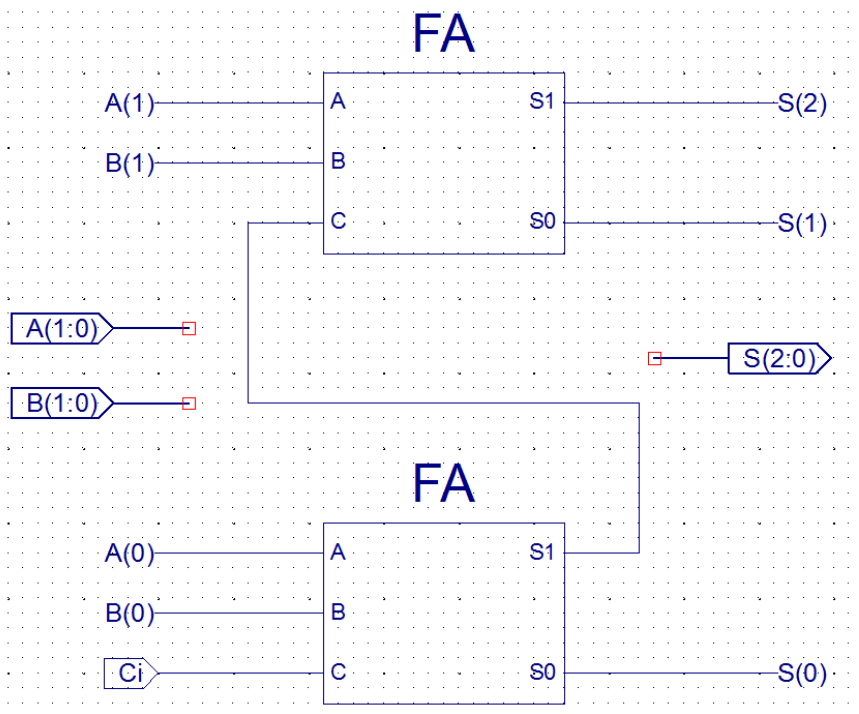

Figure 2 – Connecting Busses in ISE

Write a test bench to test all 32 possible input combinations. Simulate your circuit and verify the circuit functions properly (it is easier if, in the simulator, you set the radix for all busses to unsigned decimal). Again, affix the schematic, test bench and simulation output to your lab book.

Draw a complete schematic for the 2-bit adder in your lab book. Label each gate in your schematic with a designator and label each IC connection with a pin number. Remember to show power and ground connections. You may find it easier to print two copies of your 1-bit full adder schematic, cut off the node names, glue them onto a single page of your lab book, and add wires and labels as needed. Again, it is not necessary to include the switches, resistors and the LEDs that you built in lab 1.

Preparation: (Week 2) Assemble your circuit prior to your lab period. Connect inputs A_1, A_0, B_1, B_0 and Cin to your switches (you may have to wire a 5th switch). Connect outputs S_2, S_1 and S_0 to the inverters/LEDs you built in Lab 1.

Bring your lab book and assembled circuit to your lab period.

Procedure: Turn on the power supply and adjust it to 5 Volts. Carefully connect the positive (red) lead to the Vcc of your circuit and the negative (black) lead to the ground of your circuit.

Using the DIP switch, step through all 32 possible input combinations shown in your second simulation and verify that the output of the circuit matches the output of the simulation. Record the results of your tests in your lab book.

If the circuit does not function correctly, you will have to debug it and re-perform the test.

Write a short summary of your results then sign and date it. Demonstrate to your lab instructor that the circuit functions correctly.

Signoff: A lab score can only be given if the circuit is functional.

Rubric (20 points total)

- Lab book is bound, clearly legible and in ink. (1 point)
- Lab book contains a clear title and a short description of the lab. (1 point)
- Lab book contains K-maps and derived logic equations. (1 point)
- Lab book contains an ISE schematic for the 1-bit full adder. (1 point)
- Lab book contains test bench and simulation for the 1-bit adder. (2 points)
- Lab book contains an ISE schematic for the 2-bit adder. (1 point)
- Lab book contains test bench and simulation for the 2-bit adder. (2 points)
- Lab book contains a full schematic with chips and pins labeled (3 points)
- Lab book contains test results (comparison with simulation) (1 point)
- Lab book contains no obliterations. (1 point)
- Lab book contains a signed, dated summary (1 point)
- Each used page has a page number and is initialed* and dated* (1 point)
- The circuit is functional before the end of the 2nd lab period. (4 points)

Note: If the circuit is working at the end of the lab period but the lab book is not yet complete, the lab can be signed off as “working”, and no late penalty will be assessed if it is graded on or before the next lab period.

* It is not necessary to initial and date a page that contains a signature and date unless the dates are different.