CSSE1000/CSSE7035 - Prac 2

Combinational Circuits

Goal

- Construct a half-adder circuit and examine its operation.
- Construct a full-adder circuit and examine its operation.
- Construct a 4-bit binary adder circuit and examine its operation.
- Construct a 4-bit binary subtractor circuit and examine its operation.

See the following topics:

Back to Lab Experiment Index

Preparation - Complete the following questions in your Prac book before the session.

Half-Adder

A half-adder can be implemented with an exclusive-OR gate and an AND gate as shown in Figure 1.

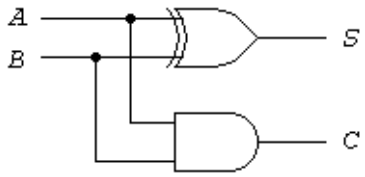

Figure 1. Implementation of a half-adder.

- Prepare a circuit schematic diagram of the half-adder. The two inputs will connect to toggle switches and the two outputs will connect to LEDs on the logic workstation.

Full-Adder

A full-adder can be implemented with two half-adders and one OR gate, as shown in Figure 2.

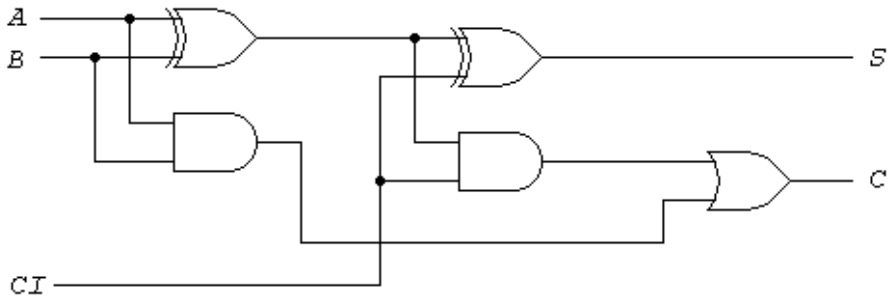

Figure 2. Implementation of a full-adder.

- Prepare a circuit schematic diagram of the full-adder. The three inputs will connect to toggle switches and the two outputs will connect to LEDs on the logic workstation.

Parallel Adder

- Prepare a circuit schematic diagram of the 74HCT283 4-bit binary adder. Represent the 74HCT283 in the circuit schematic diagram by its symbol (click to see example). The four *A* inputs and the four *B* inputs connect to toggle switches. The carry input connects to a pushbutton. The five outputs connect to LEDs.

Adder-Subtractor

The subtraction of two binary numbers can be done by taking the 2's complement of the subtrahend and adding it to the minuend, ie. $A - B = A + (-B)$ where $(-B)$ is the 2's complement representation of B.

From lecture, we know that the 2's complement can be obtained by taking the 1's complement and adding 1, ie, $(-B)$ = (1's complement of B) + 1. So $A - B = A +$ (1's complement of B) + 1

1's complement of B can be obtained using XOR gates - when one of the input to XOR gate is 1, it inverts the other input.

So in Figure 3, we are adding the 1's complement of *B* to the four bits of *A*. The four XOR gates complement the bits of *B* when the $M = 1$ and leave the bits of *B* unchanged when $M = 0$. Therefore M can be thought as a "mode switch".

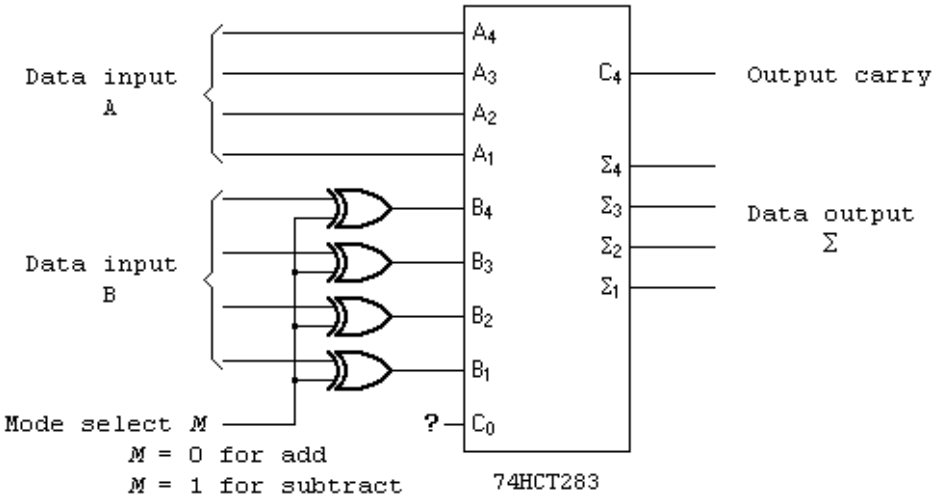

Figure 3. 4-bit adder-subtracter.

- Prepare a circuit schematic diagram of the 4-bit adder-subtractor. The *A* inputs and the *B* inputs will connect to toggle switches. The mode select input will connect to a pushbutton. Assume the five outputs will first be connected to LEDs.
- What should be connected to the carry-in pin? (HINT: It is not an extra toggle switch or push button for this connection - how can you utilise the existing signals to complete the functionality of this 4-bit adder-subtracter?)

Logisim Simulator

Run the Logisim simulator at home or in the General Purpose South Computing Laboratories. If at home, you can download Logisim from the CSSE1000 software downloads page. Familiarise yourself with the tool and prepare a LogiSim model for the Full adder circuit.

1. Download and run the file. Save the file at a convenient location for future use. If in the labs, start LogiSim from Start -> Programs -> Logisim
2. Open the tutorial (Help -> Tutorial)
3. Work through the tutorial
4. Open the User's Guide (Help -> User's Guide)
5. Read through the "Libraries and attributes" section and experiment with these parts of the Logisim interface
6. Use Logisim to enter the circuit for a full-adder circuit (implement as drawn above, with two half adders and an or gate).
7. Save your work and bring to your files to your practical class

Back to Contents

Procedure

A tutor will mark your preparation, and in particular, provide feedback on your circuit schematic diagrams. (You can start constructing your circuit(s) before this happens.)

Familiarisation with equipment (if necessary):

- Attempt to use a wire stripper to customise the length of a wire.
- Revise how to use the logic probe - the yellow pen shape object attached to the logic workstation.
- What is the normal output (0 or 1) for a push-button when it is pressed? What is the normal output (0 or 1) for a push-button when it is not pressed ?

Standard Tasks - help will be provided by the tutor if required - don't hesitate to ask any questions.

1. Construct and test the half-adder circuit that you have prepared. Connect the two inputs to toggle switches and the two outputs to LEDs on the logic workstation. Complete the truth table with measured values.
2. Construct and test the full-adder circuit that you have prepared. Connect the three inputs to toggle switches and the two outputs to LEDs on the logic workstation. Complete the truth table with measured values. Confirm that it is consistent with the LogiSim model you have prepared.
3. Wire up the 74HCT283 based 4-bit parallel adder. Connect the input carry to a push-button. Perform the addition of various 4-bit binary numbers with the input carry set to logic 0 and check that the output sum and output carry give the proper values. Show that when the input carry is set to logic 1, it adds 1 to the output sum.
4. Construct the adder-subtractor circuit that you have prepared. Connect the *A* inputs to four toggle switches and the *B* inputs to another four toggle switches. Connect the mode select input to a pushbutton. Download the LogiSim Model we have prepared. Complete the model (i.e. wire up the carry-in pin appropriately). Confirm that this model is consistent with your hardware.
5. Investigate how to use the seven segment display on the logic workstations - the seven segment display shows the hexadecimal equivalent of the binary values. For example, an input of 0011 will show as 3. The left most digit of the binary number is referred to as 'MSB' (most significant bit), and the right most digit is the 'LSB' (least significant bit). To switch on/off the seven segment display, look for a switch on the right panel of the logic workstation. Wire up the outputs of your circuit for part 4 to seven segment display digit and retest. Leave the LEDs wired up as well. Check for consistency with this LogiSim Model. (Dont forget to wire up the carry in pin).
6. Demonstrate part 5 to the tutor and complete the tutor assigned task. Have your working LogiSim models open on the computer for demonstration. You will not be given the tutor task unless your circuit and simulation work and your workbook is complete to the satisfaction of the tutor.

*Important: **Do NOT use your fingers to remove the chip from the breadboard.** Use two pens as levers on both side to "pop" it out. This will avoid the nasty (and painful) metal pins in fingernails problem, and also avoid damages to the chip.*

Challenge Task (to be completed once you have your mark signed off by the tutor)

Design and construct a circuit that has a four bit input A, and four bit output X, that behaves as follows:

- If A is greater than 9 then X = A + 6;
- Otherwise, X = A

Wire up this circuit. What is this circuit potentially useful for (Hint: revise lecture material on BCD).

Assessment

This practical is marked out of 4 and worth 2% of your mark for CSSE1000:

- Preparation - All circuit schematic diagrams completed - ***1 Mark***
- Documentation - All testing results, including completed truth tables are documented in workbook - ***1 Mark***
- Demonstration - Part 5 demonstrated. Partial marks given if an earlier exercise is demonstrated - ***1 Mark***
- Tutor Task - Tutor task completed and documented in workbook - ***1 Mark***

Equipment

- Computer
- Logic Workstation
- Breadboard
- Hook up Wire
- Wire Strippers
- Components:

1 x 74HCT08	- Quad 2-input AND Gate	Datasheet
1 x 74HCT32	- Quad 2-input OR Gate	Datasheet
1 x 74HCT86	- Quad 2-input XOR Gate	Datasheet
1 x 74HCT283	- 4 bit Binary Full Adder with Fast Carry	Datasheet

Back to Contents

References

- Tanenbaum, Andrew S., *Structured Computer Organization*, 5th Ed., Prentice/Hall, 2006. ISBN: 0-13-148521-0
- Mano, M., *Digital Design*, Prentice/Hall, 1984. ISBN: 0-13-212325-8

Back to Contents

Last update: