CS223 Laboratory Assignment 1

Digital Circuits: Logic to Gates

Lab dates and times:

Section 1: Mon 08:30-12:20 in EA-Z04
Section 2: Tue 08:30-12:20 in EA-Z04
Section 3: Thu 08:30-12:20 in EA-Z04
Section 4: Mon 13:30-17:20 in EA-Z04
Section 5: Fri 08:30-12:20 in EA-Z04
Section 6: Tue 13:30-17:20 in EA-Z04

Location: EA Z04 (in the EA building, straight ahead past the elevators)
Groups: Each student will do the lab individually. Group size = 1

Preliminary Work (20 points)

(You should do this part before coming to lab).

Physical gates are built out of transistors and require physical signals that use correct voltage levels for inputs and produce physical signals with correct voltage levels for outputs. To work correctly, the transistor circuits that comprise a gate must have connections to a voltage supply and to the ground. For example, in the case of 74-series logic circuits used in this lab, the supply voltage (Vcc) must be 5 volts. In these integrated circuit packages, several gates are contained. Search Google specifying that gate number and its function (e.g. "7486 XOR gate") for pin connection diagrams, such as the pin diagram shown in Figure 1. You must have the pin diagrams for each gate you want to use, in order to do the following tasks. You can find the pinout of the rest of the 74-series gates here: http://www.qsl.net/on7pc/datasheet/ttl7400/7400family.pdf. Other gates you need today are 7408 quad 2-input AND, 7432 quad 2-input OR, and an INVERTER.

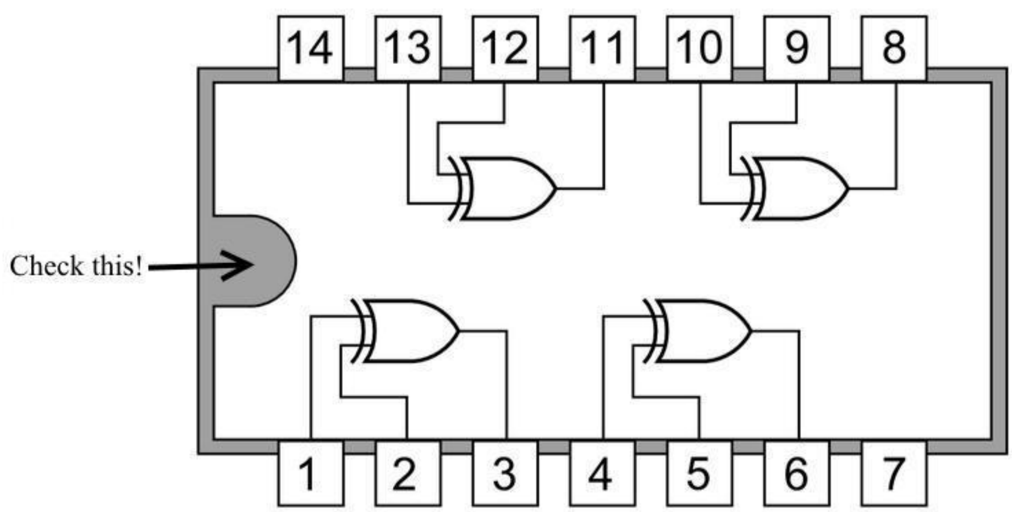

Fig 1: 7486 Quad 2-input XOR gates

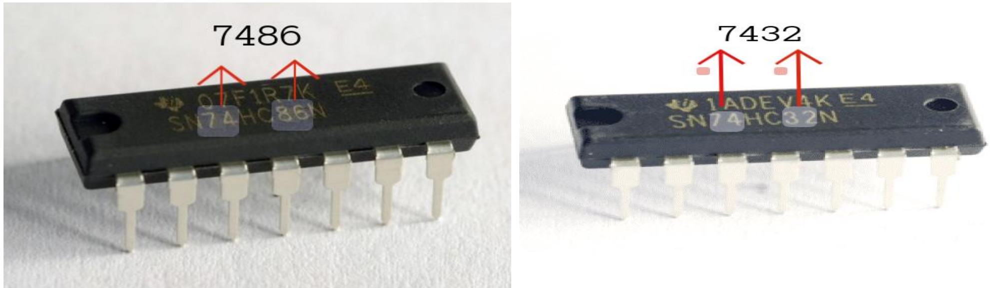

Fig 2: IC-7486 X-OR Gate & IC-7432 OR Gate

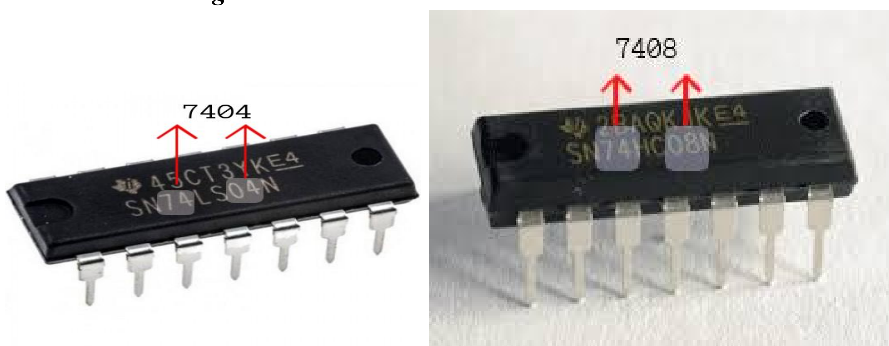

Fig 3: IC-7404 invertor Gate & IC-7408 and Gate

First, read the document posted in Moodle for CS223 labs: “Circuit Schematic versus Logic Diagram”. Then, using the logic diagram in Figure 4 (below) as a starting point, draw a *circuit schematic* of the digital circuit "you will build. This should include **pin numbers** marked on the inputs and outputs of all the gates, **part numbers** (IC’s code) of the IC package marked on each gate, plus **power and ground connections** marked on the side of the drawing. After that, draw other schematics.

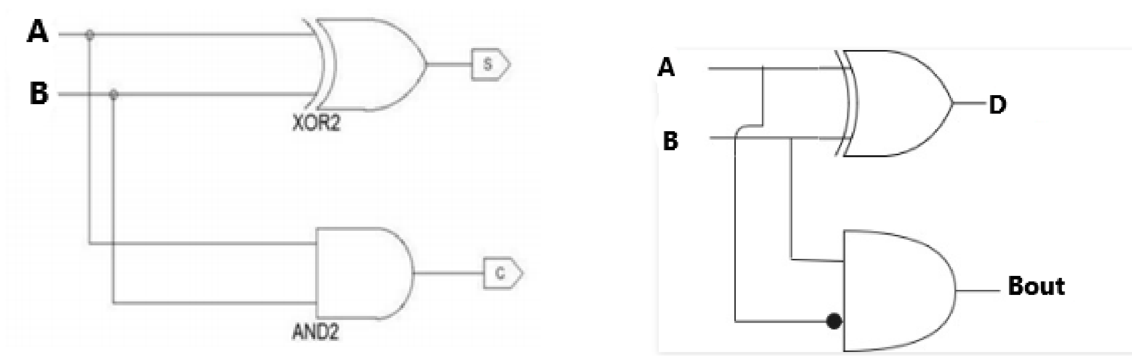

Figure 4. Half Adder & Subtractor

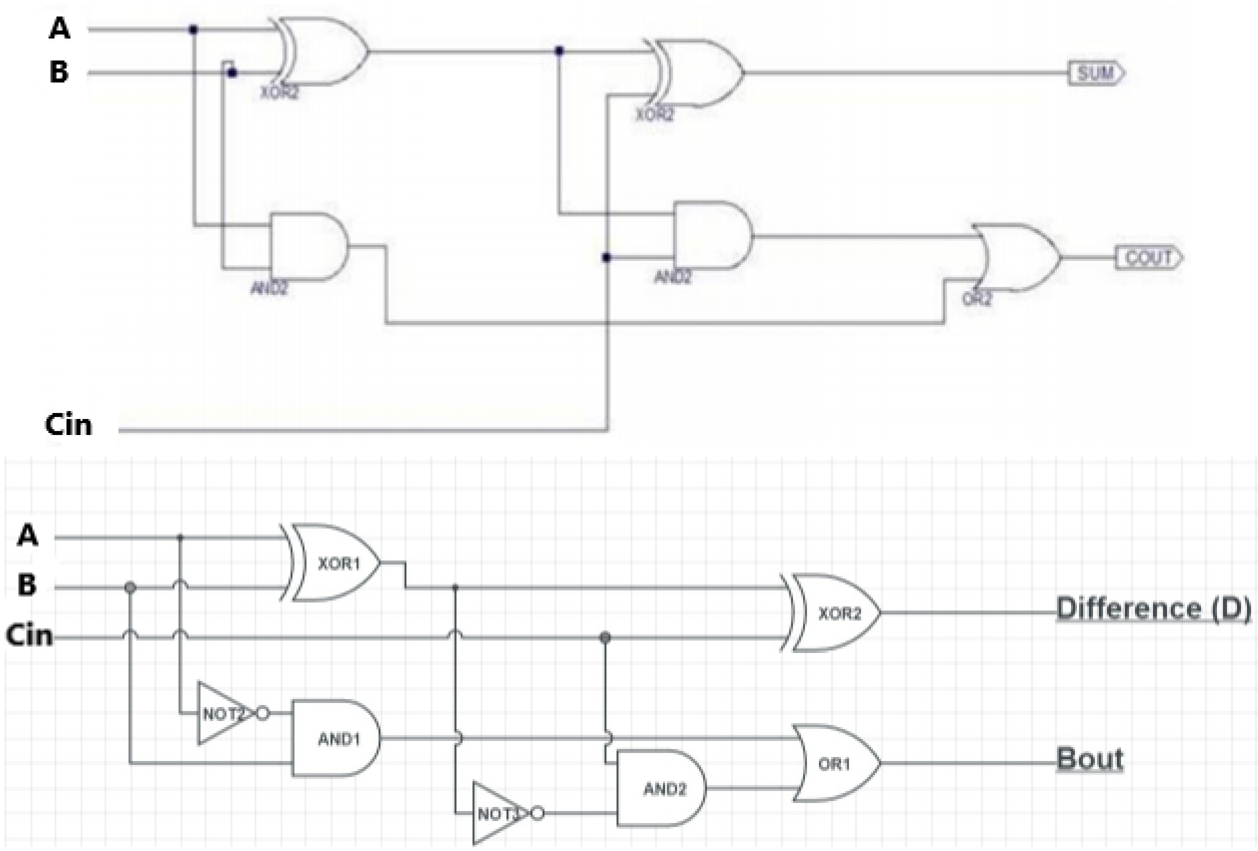

Figure 5. Full Adder & Subtractor

In the above subtractors, the two digits can be represented with A and B. These two digits can be subtracted and give the resultant bits as the difference (D) and borrow (B).

1-Draw a schematic for three input XOR gates using two-input XOR gates.

Recommendations

In CS223 labs, you build circuits by ICs and later by FPGA. It is better to obey some simple rules to avoid damaging electronic parts or confusing yourself with debugging your circuit.

Avoid touching IC or FPGA pins directly by your hand. Static electricity of your body can damage them permanently.

The whiteboard on which you set up your circuit, is called “breadboard”. Search on the internet and find out how its pins are connected internally.

Postpone connecting power pins (Vcc and ground) to the last step. Check circuit connections and if everything seems ok then connect power pins.

For easier debugging of circuits, always follow a wire color convention. For example, always use black or white wire for ground and red wire for Vcc.

If LED's light is weak, or if the IC's package is very hot (you can touch plastic part) you have a problem with the power pin connections (short circuit, connecting Vcc wire to ground pin,...).

Part 1: Practice with Logic Gates (35 points)

1. Ask the TA or Tutor to come and check your first schematic. *Do not proceed to the next step until* you have verified that your circuit schematic is correct, and the TA or Tutor has approved it.

2. Using your circuit schematic, build the circuit step-by-step, following the Digital Circuit Suggestions given in Moodle and recommendations on page-2. Connect the inputs to switches on the logic board. Connect the outputs of your logic circuit to LEDs on the logic board. Don't forget to connect +VCC power and GND ground to the VCC and GND pins on both IC packages. Make a test probe by connecting another LED on the logic board to one end of a long wire, whose other end will be used to touch circuit points and "see" the logic values. A full voltage level ~5 V will cause the LED to shine brightly; a 0 V level will not light up the LED. A low light output from the LED means that the voltage being sensed is in between logic 0 and logic 1, meaning something is WRONG with your circuit.

3. Now draw the truth table for the 2-input 2-output logic circuits that you have made, and fill in the left-hand (input) side in standard binary counting order. For each row, apply the input combinations by adjusting the switches, and measure the output. Use this information to complete the truth table, filling in the right-hand (output) side.

4. Compare your measured truth table that you just obtained from the circuit, with the below one. If there are no discrepancies, then it means that your logic circuit has worked as predicted. Ask the TA or Tutor to come and verify this. When the TA or Tutor has checked your circuit, you are done with this part.

A	B	S	C
0	0	0	0
0	1	1	0
1	0	1	0
1	1	0	1

A	B	D	Bout
0	0	0	0
0	1	1	1
1	0	1	0
1	1	0	0

Figure 6. Half Adder & Subtractor Truth Tables

Part 2: Understanding and Building a Full Adder & Subtractor (45 points)

1. In part 1 you implemented half adder & subtractor. Here you will do the same for full-adder & subtractor, a circuit for two bits and carry-in/borrow-in bit. As you did in part 1, ask the TA or Tutor to come and check your second schematic. *Do not proceed to the next step until* you have verified that your circuit schematic is correct, and the TA or Tutor has approved it.

2. Using your circuit schematic, build the circuit, following the Digital Circuit Suggestions given in Moodle. Connect the inputs to switches on the logic board. Connect the outputs of your logic circuit to LEDs on the logic board. Don't forget to connect +VCC power and GND ground to the VCC and GND pins on all the IC packages.

3. In this section of the lab the module given in Figure 7 will be implemented such that for a given C and D, output Y will be a certain function of A and B. When C=0 and D=0, the *first lab calculator* given in Figure 7 acts as an AND gate, therefore, Y=AB. When, C=0 and D=1, the *first lab calculator* acts as a NOR gate. When C=1 and D=0, the *first lab calculator* acts as a half-adder. When C=1 and D=1 the *first lab calculator* acts as a half-subtractor. The function codes are summarized in the table below.

0	0	A.B	AND	0
0	1	$\overline{(A + B)}$	NOR	0
1	0	A+B	Half Adder	Carry Out
1	1	A-B	Half Subtractor	Borrow out

Represent the output Y and Z as a function of A, B, C, and D on a truth table.
Write the minimum logic expression, as a sum-of-products for the functions Y and Z.
Draw logic diagrams for the above expressions using ANDs, ORs, XORs, and Inverters.

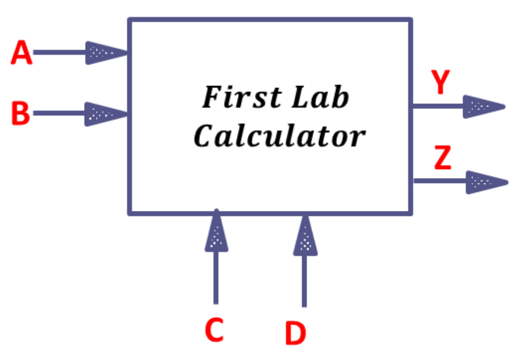

Figure 7: First Lab Calculator

Clean Up

1) Clean up your lab station, and return all the parts, wires, the Beti trainer board, etc. Leave your lab workstation for others the way you would like to find it.

2) CONGRATULATIONS! You are finished with Lab #1 and are one step closer to becoming a computer engineer.

NOTES

--Advance work on this lab, and all labs is strongly suggested.

--Be sure to read and follow the Policies for CS223 labs, posted in Moodle.

LAB POLICIES

1. There are three computers in each row in the lab. Don't use middle <u>computers</u>, unless you are allowed by the lab coordinator.

2. You borrow a lab board containing the development board, connectors, etc. in the beginning. The lab coordinator takes your signature. When you are done, return it to his/her, otherwise, you will be responsible and lose points.

3. Each lab board has a number. You <u>must</u> always use the same board throughout the semester.

4. You must be in the lab, working on the lab, from the time lab starts until you finish and leave. (bathroom and snack breaks are the exception to this rule). Absence from the lab, at any time, is counted as absence from the whole lab that day.

5. No cell phone usage during lab. Tell friends not to call during the lab hours--you are busy learning how digital circuits work!

6. Internet usage is permitted only to lab-related technical sites. No Facebook, Twitter, email, news, video games, etc--you are busy learning how digital circuits work!

7. If you are late more than 15 minutes for the lab session, you will lose the preliminary work's credits and if you are late more than 45 minutes you will lose that lab.

8. When you are done, <u>DO NOT</u> return IC parts into the IC boxes where you've taken them first. Just put them inside your Lab-board box. The lab coordinator will check and return them later.