ECE2810 Digital Systems Design Laboratory

Lab 2: Logic Gates / Simulation Software

School of Science and Engineering
The Chinese University of Hong Kong, Shenzhen

2023-2024 Term 2

1. Objectives

In Lab 2, we will spend the 2-week sessions on the following:

- Explore basic logic gates, including AND, NOT, OR, NAND, NOR, XOR, XNOR.
- Learn to use a digital logic simulation software, Multisim.
- Learn to build other basic logic gates by NAND, and to test its functional completeness.
- Learn to combine logic gates to form combined logic and verify it by both simulation and hardware.

2. Basic Logic Gates

In this laboratory, we will explore the logic gates, including AND, NOT, OR, NAND, NOR, and XNOR.

2.1. AND

There are different AND gates in terms of input numbers, as listed below. We are using CMOS in this laboratory, so mainly in HC series. There are also LS series.

- 74HC08: It has 4 2-input AND gates. Y=AB
- 74HC11: It has 3 3-input AND gates. Y=ABC
- 74HC21: It has 2 4-input AND gates. Y=ABCD

The truth table of a 2-input AND is as below.

A	B	Y
0	0	0
0	1	0
1	0	0
1	1	1

2.2. NOT

NOT gate simply inverts the logic input, i.e. $Y=\overline{A}$. 74HC04 has 6 channel NOT gates. The truth table is shown below.

A	Y
0	1
1	0

2.3. OR

Similar to AND gates, there are different ICs with OR functionality. Try to search on the internet with engines such as Google, Bing, or Baidu, etc., and fill the blanks below. It is not needed to include in the report.

- 74HC32: It has 4 2-input OR gates. Y=A+B
- 74HC____: It has 3 3-input OR gates. Y=A+B+C
- 74HC____: It has 2 4-input OR gates. Y=A+B+C+D

The truth table of a 2-input OR is as below.

A	B	Y
0	0	0
0	1	1
1	0	1
1	1	1

2.4. NAND

NAND is very commonly used. It has the property of functional completeness, i.e., any other logic function (AND, OR, etc.) can be implemented using only NAND gates.

74HC00 contains 4 2-input NAND gates, with the truth table below. $Y=\overline{AB}$. There are also NAND gates with more inputs. You can try to search for yourself when needed.

A	B	Y
0	0	1
0	1	1
1	0	1
1	1	0

2.5. NOR

NOR gate has logic function $Y=\overline{A+B}$. 74HC02 contains 4 2-input NOR gates, with the truth table below. There are also NOR gates with more inputs. You can try to search for yourself when needed.

A	B	Y
0	0	1
0	1	0
1	0	0
1	1	0

2.6. XOR

XOR gate has the logic function $Y=A\overline{B}+\overline{A}B$. If A and B are identical, Y=0. Otherwise, Y=1. 74HC86 has 4 2-input XOR.

A	B	Y
0	0	0
0	1	1
1	0	1
1	1	0

2.7. XNOR

XNOR gate has the logic function $Y=AB+\overline{A}\overline{B}$. It is the opposite of XOR. If A and B are identical, Y=1. Otherwise, Y=0. 74HC7266 has 4 2-input XNOR.

A	B	Y
0	0	1
0	1	0
1	0	0
1	1	1

3. Simulation software Multisim

Multisim is an industry-standard SPICE (Simulation Program with Integrated Circuit Emphasis) simulation environment. Multisim was originally developed by Electronics Workbench in Canada. Electronics Workbench was bought by National Instruments in 2007, and the Multisim product is now marketed and supported by National Instruments. It is widely used in academia and industry for circuits education, electronic schematic design, and SPICE simulation.

With simulations, you can save time and cost to evaluate whether your circuit can work or not. You can adjust the circuit easily if some error occurs. When everything works as expected, then you can implement the circuit with hardware.

A simple process of using Multisim is illustrated below.

3.1 Launch Multisim

Try to find NI Multisim in the startup menu. You will find an initial view of Multisim below.

There are 3 toolbars frequently used: component toolbar, simulation toolbar, and instrument toolbar.

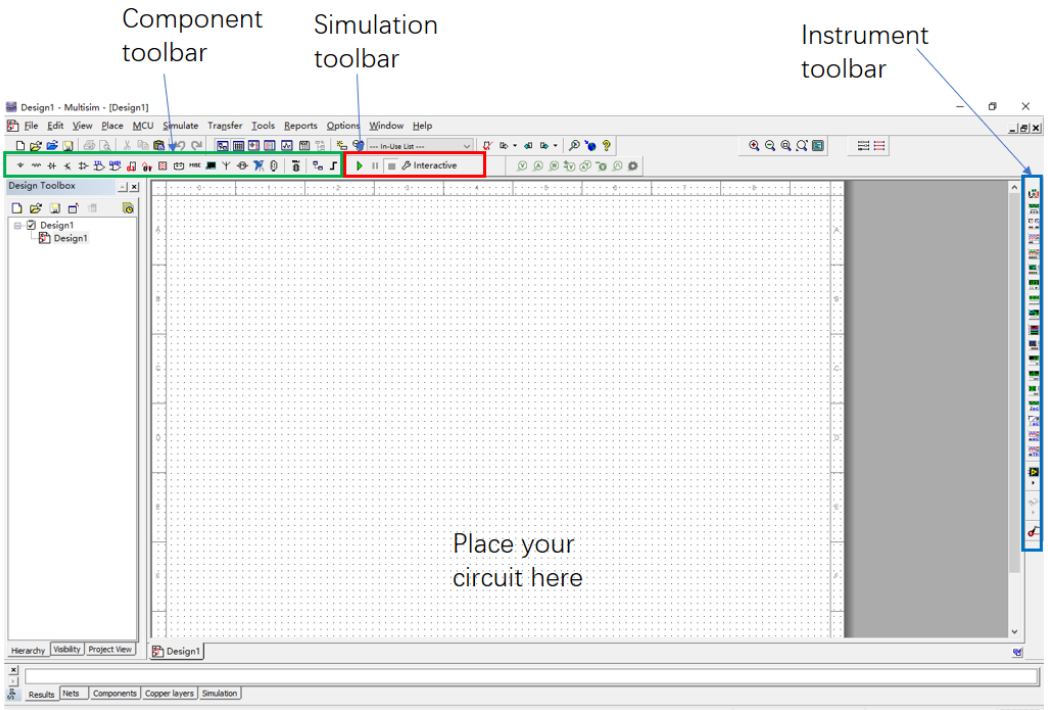

Fig. 1 Multisim layout

3.2 Open/Create Schematic

A blank schematic Circuit 1 is automatically created.

- To create a new schematic click on File => New => Blank => Create.
- To save the schematic, click File /Save As.
- To open an existing file click on File/ Open in the toolbar.

3.3 Place Components

To place components click on Place/Components. On the "Select a Component Window", click Group to select the components needed for the circuit. Click OK to place the component on the schematic.

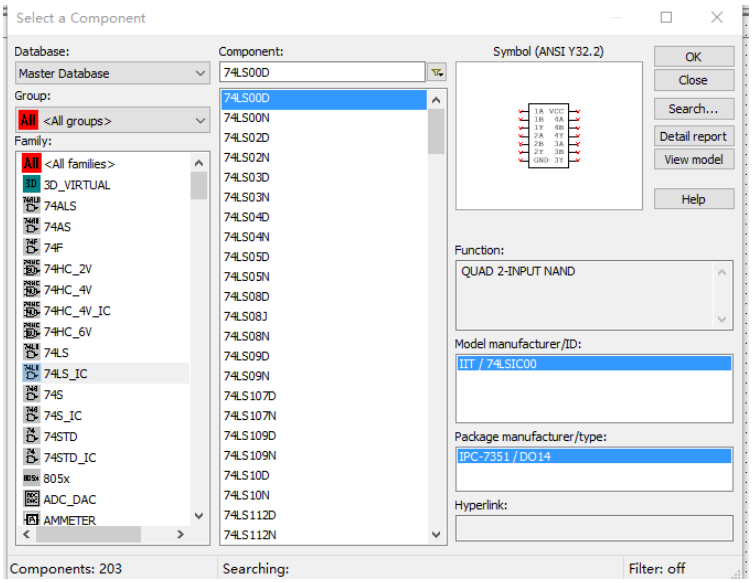

Fig. 2 "Select a Component" dialog box

Here below we will list how to find the components to build up one simple AND gate circuit.

- Vcc: Sources => POWER_SOURCES => VCC
- Resistor: Basic => RESISTOR => 1k (Add two 1k resistors into the circuit.)
- Ground: Sources => POWER_SOURCES => GROUND

You can click OK in the "Select a Component" window and directly place the components above into the circuit.

Add an 8 channel DIP switch, i.e., the switch you are using in SIM.

- DIP Switch: Basic => SWITCH> DIPSW8

For this switch, as the DIPSW8 has 8 channels, there is one step further, i.e. select A, and place this single switch channel. Then add the channel B channel as well.

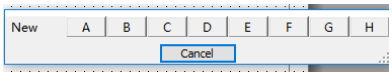

Fig. 3 DIPSW8

As 74HC08 has 4 AND gates, it is similar to DIPSW8. We need only 1 gate. You can select one from A-D.

- AND Gate: CMOS => 74HC_6V => 74HC08N_6V.

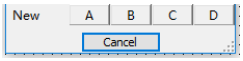

Fig. 4 74HC08N_6V

For measurement of output, there are several ways.

- Probe: Indicator => PROBE => PROBE
- Buzzer: Indicator => BUZZER => BUZZER

You can also find the multimeter and oscilloscope in the “Instrument toolbar”, click and add them into the circuit. Then, you will have some circuits like this.

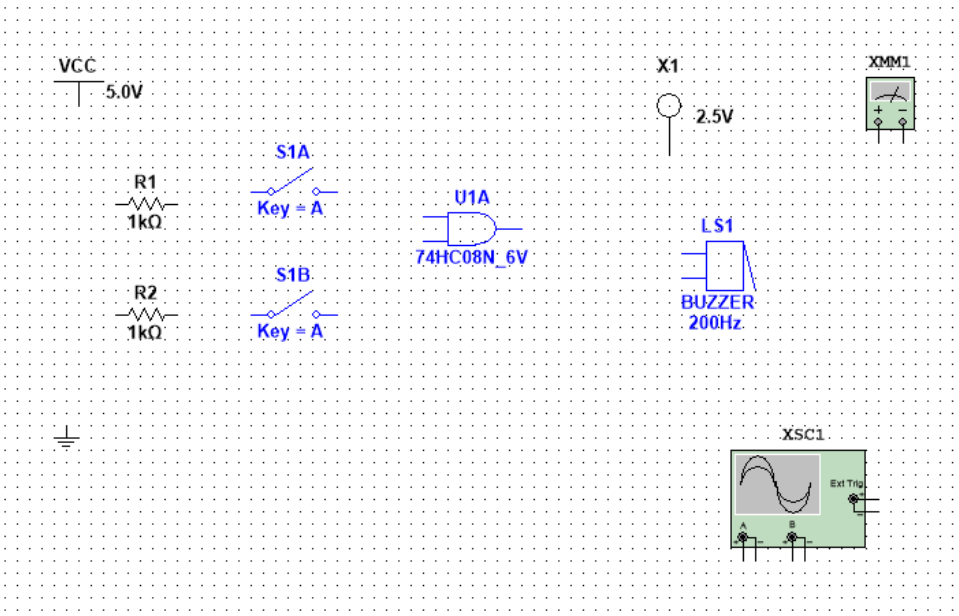

Fig. 5 All components

3.4 Rotate Components

It is better to align the two input channels (switch and resistor) vertically. Right-click on the resistors and switches, and rotate them 90 degrees. You need to do it individually for each component.

3.5 Connect components

Each component has some ends, you can left-click the ends to connect them. If any component or linkage looks not in a good place, you can drag and place it appropriately.

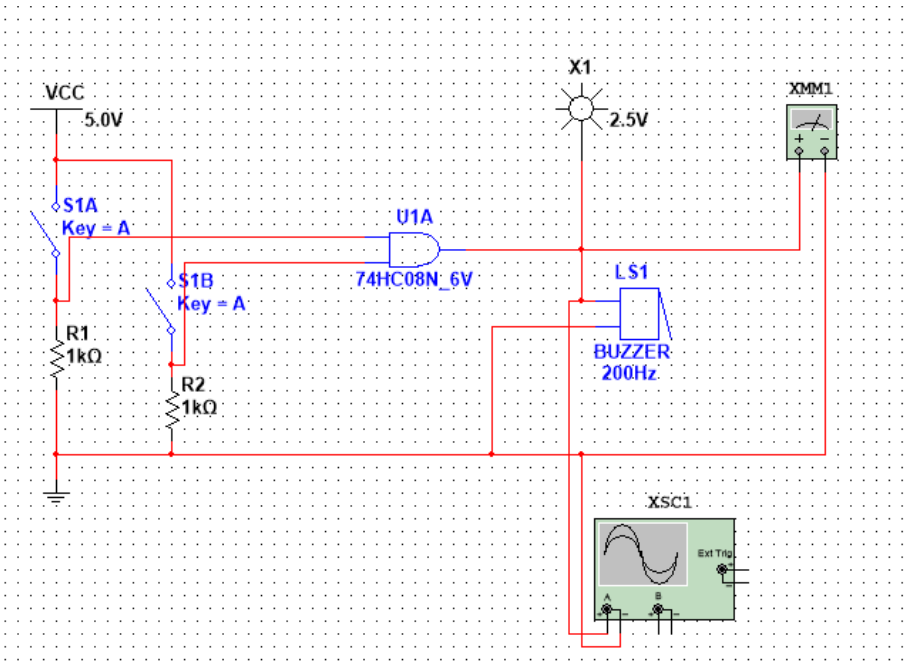

Fig. 6 Circuit completed

3.6. Adjust some component's parameters

- Hotkey of S1B: Now the two switches have the same hotkey "A" to turn it on or off. Double click S1B => Value => Key for toggle => B.
- Buzzer threshold voltage: Buzzer will give out a sound when the voltage is over a threshold. Double click buzzer => Value => Voltage(V) => Set to "3".

3.7. Run

Click "Run" in the "Simulation toolbar", or press F5 on the keyboard. This will run the simulation. Double click the multimeter and oscilloscope, you will view the curve. When you turn two switches on:

- The probe will be on;
- The buzzer will make a sound;
- The multimeter will show high voltage;
- The oscilloscope will show an appropriate curve.

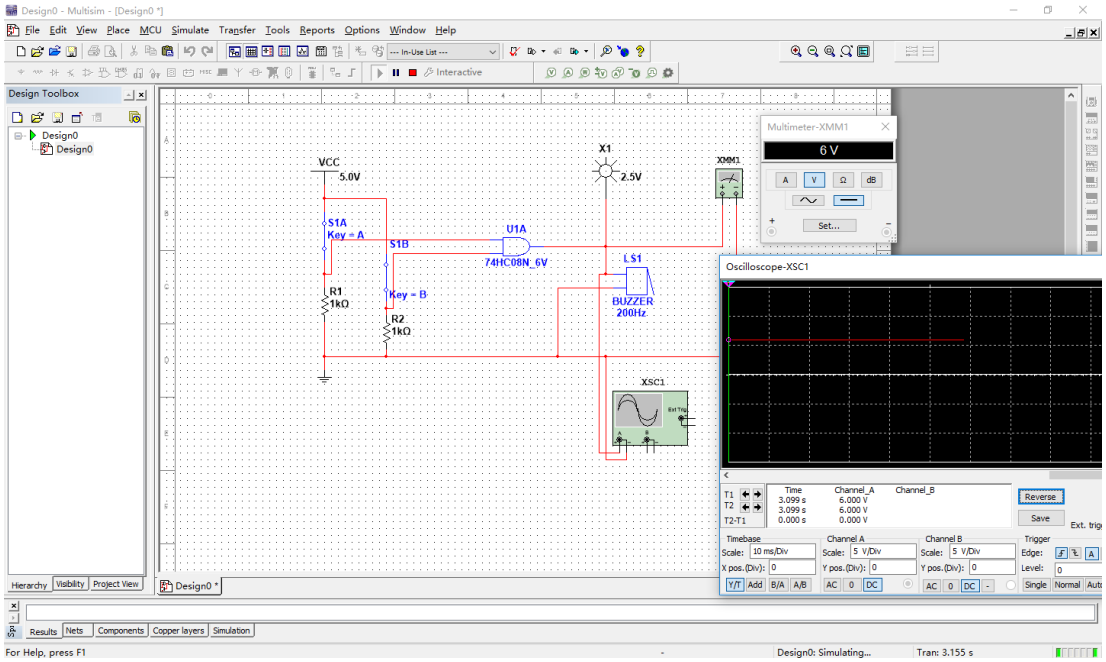

Fig. 7 Circuit with the illustrated output

3.8 Save

When your circuit works, do not forget to save the file. In the future, when you are working on a big project, you should keep the habit of file saving after achieving some stage, to prevent data loss.

4. Experiments

4.1 Guided Multisim Simulation

Follow the instructor's demonstration in Section 3, build up the circuit in Fig. 6, and test it.

[DEMONSTRATION 4.1] When it is successfully tested , demonstrate to instructor or TA.

[IN REPORT] Include the image of a circuit designed and the test result.

4.2 Individual Gate Test (Hardware Experiment)

In this experiment, we will test several digital logic ICs, including 74HC00, 74HC02, 74HC32, 74HC86, 74HC7266. As you have examined AND and NOT gate in Lab 1, you are not required to test them again.

Try to search for datasheets of the ICs by search engines, e.g. Google, Bing, Baidu, etc. An example of keywords is "74HC32 datasheet". Download it, and get to know the appropriate Vcc to set, and how the pins are arranged.

Thereafter, wire one gate in each IC onto the breadboard with SIM and LOM. You can give different combination of inputs by SIM, and observe outputs by LOM. Meanwhile,

use a logic analyzer (pins 0, 1, and 2) to measure the input and output of each gate. Verify if the wave is consistent with the output of LOM. Finally, verify the function of each gate.

[IN REPORT] Include the images of waves on the logic analyzer for each gate. Analyze the image to verify the truth table.

4.3 Functional Completeness of NAND (Hardware Experiment)

Based on NAND gates, we can build up the other 6 types of gates. Design the circuit and use 74HC00 ONLY to build AND, OR, NOT, NOR, XOR, XNOR. Verify the design with SIM and LOM.

[DEMONSTRATION 4.3] When you have realized OR, XOR and XNOR, demonstrate to instructor or TA. No need to demonstrate AND, NOT, and NOR.

[IN REPORT] Draw all the circuit diagrams with gate logic symbols by hand. Based on Boolean logic, theoretically derive that the final outputs of each circuit can realize the purpose of design. E.g., for AND, $AB = \overline{\overline{AB}} = \overline{\overline{AB}}\,\overline{\overline{AB}}$, so by using 2 NAND gates, we can realize AND.

4.4 Combination of Gates (Simulation and Hardware Experiment)

4.4.1. Observe the circuit diagram below, based on your theoretical knowledge, write the function of output Y in terms of 3 inputs A, B, and C.

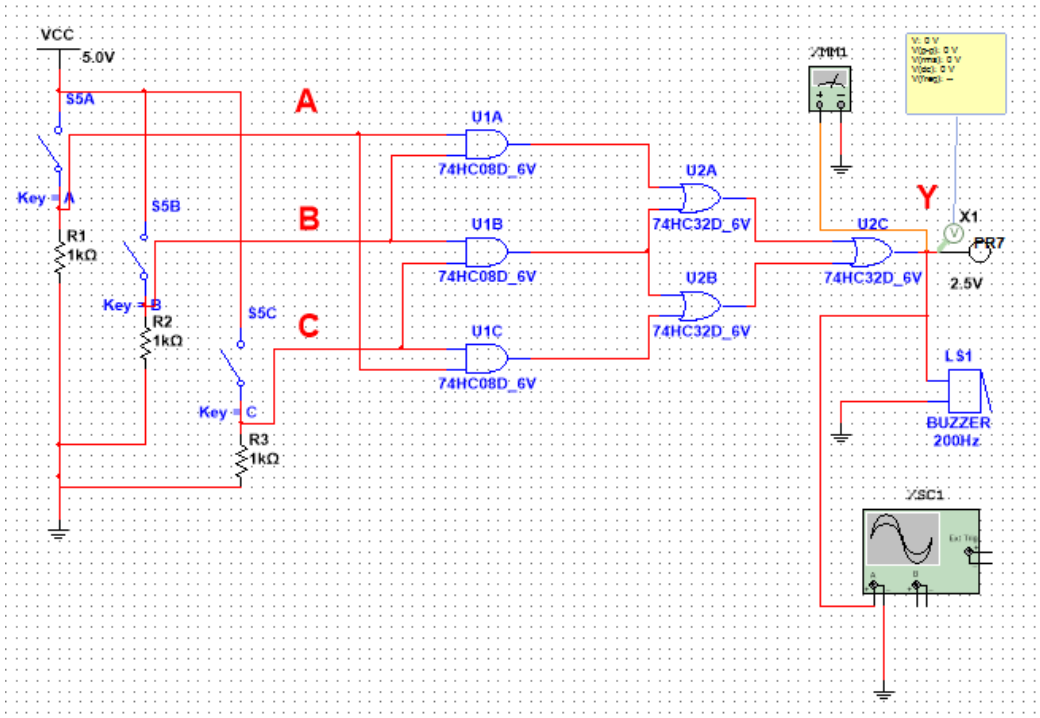

Fig. 8 Combination of gates circuit to be built

4.4.2. Use Multisim to build up the circuit. When completed, test it, and demonstrate to instructor or TA. In this circuit, to reduce the number of ground wires and improve the clearness, you can add 4 GROUNDs which are interconnected in Multisim.

4.4.3. Use appropriate ICs to realize the circuit in the breadboard. Connect 3 channels of SIM and 1 channel of LOM into the circuit, and measure the truth table with ON/OFF in SIM and LED states in LOM. You DO NOT need to use a multimeter, oscilloscope, buzzer as included in the Multisim diagram.

4.4.4 Connect Pin 0-4 of logic analyzer into the circuit constructed in step 4.4.3, turn the 3 switches in SIM to realize all 8 states of inputs, record and analyze the waveform in a logic analyzer.

[DEMONSTRATION 4.4] When you have completed step 4.4.2 and step 4.4.4, show them to instructor or TA.

[IN REPORT] Draw a circuit diagram with IC pins by hand, demonstrating how you wire the pins of each IC in step 4.4.3. Include all the results, e.g. the output of Y in terms of A, B, and C, truth table, diagram which you build by Multisim, logic analyzer wave, etc.

[QUESTION IN THE REPORT] Can you think of any application for this circuit?

5. Lab Report

Write the lab report comprehensively. A template has been provided on Blackboard. You can find it in the folder named ***Digital Systems Design Lab/Report Template***.

Submit the report of Lab 2 in ***PDF*** to the folder ***Digital Systems Design Lab/Report Submission/Lab 2*** on Blackboard by the deadline below:

- ***23:59, Friday, March 8th, 2024***

Each day of late submission will result in 10% deduction in the report raw marks.

Appendix:

IC needed for this lab:

1. 74HC00 x2
2. 74HC02 x1
3. 74HC08 x1
4. 74HC32 x1
5. 74HC86 x1
6. 74HC7266 x1

Remember to sort and return items 2-8 back to the storeroom after lab. You can keep item 1 in your box for usage in the future.

For any malfunctioning component, report to instructor or TA, and DO NOT put it back.