ECE2810 Digital Systems Design Laboratory

Laboratory 2

Logic Gates / Simulation Software

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

2025-2026 Term 1

1. Objectives

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

- Explore basic logic gates, including AND, NOT, OR, NAND, NOR, XOR, and XNOR.
- Learn to use digital logic simulation software, Multisim.
- Learn to combine logic gates to form a combined logic gate 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 GATE

There are different AND gates in terms of input numbers, such as those listed below. We are using CMOS in this lab, mainly in the 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 in Table 1.

Table 1. Truth table of a 2-input AND gate.

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

2.2. NOT GATE

NOT gate simply inverts the logic input, i.e., Y=$\overline{A}$. 74HC04 has 6 channels of NOT gates. The truth table is in Table 2.

Table 2. Truth table of a NOT gate.

A	Y
0	1
1	0

2.3. OR GATE

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 in the blanks below. It is not needed to include in the report. The truth table of a 2-input OR is in Table 3.

- 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

Table 3. Truth table of a 2-input OR gate.

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

2.4. NAND GATE

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 four 2-input NAND gates, with the truth table in Table 4. Y=$\overline{AB}$. There are also NAND gates with more inputs. You can try to search by yourself.

Table 4. Truth table of a 2-input NAND gate.

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

2.5. NOR GATE

NOR gate has logic function Y=$\overline{A + B}$. 74HC02 contains 4 2-input NOR gates, with the truth table in Table 5. There are also NOR gates with more inputs. You can try to search by yourself when needed.

Table 5. Truth table of a 2-input NOR gate.

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

2.6. XOR GATE

XOR gate has the logic function Y=$A\overline{B} + \overline{A}B$, with the truth table in Table 6. If A and B are identical, Y=0. Otherwise, Y=1. 74HC86 has 4 2-input XORs.

Table 6. Truth table of a 2-input XOR gate.

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

2.7. XNOR GATE

XNOR gate has the logic function Y=$AB + \overline{A}\overline{B}$, with the truth table in Table 7. It is the opposite of XOR. If A and B are identical, Y=1. Otherwise, Y=0. 74HC7266 has 4 2-input XNOR.

Table 7. Truth table of a 2-input XNOR gate.

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 an 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 14.0 in the startup menu. You will find an initial view of Multisim in Figure 1. There are 3 toolbars frequently used: the component toolbar, simulation toolbar, and instrument toolbar.

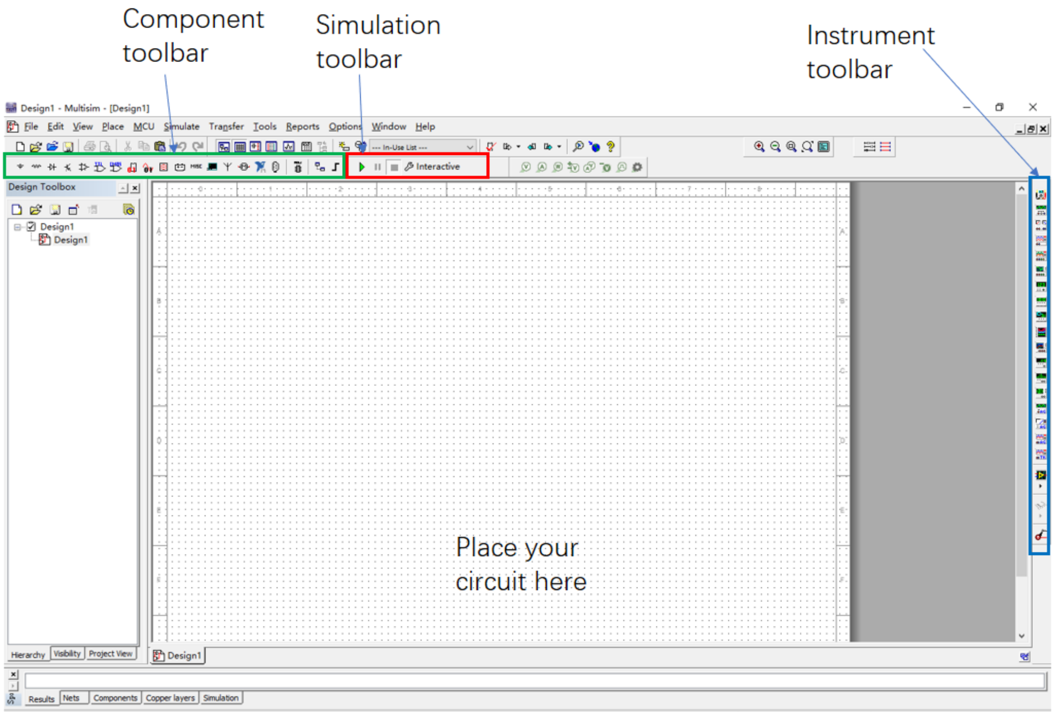

Figure 1. Multisim layout.

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

As shown in Figure 2, to place components, click on Place/Components. On the “Select a Component Window” in Figure 3, click Group to select the components needed for the circuit. Click OK to place the component on the schematic.

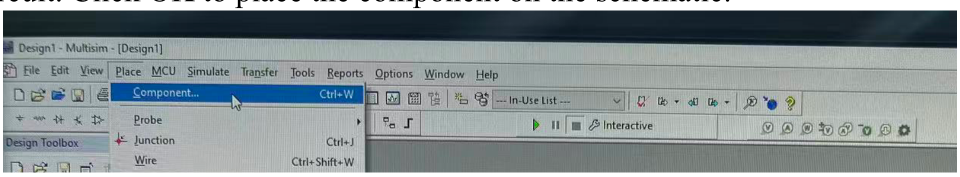

Figure 2. “Place -> Component” dialog box.

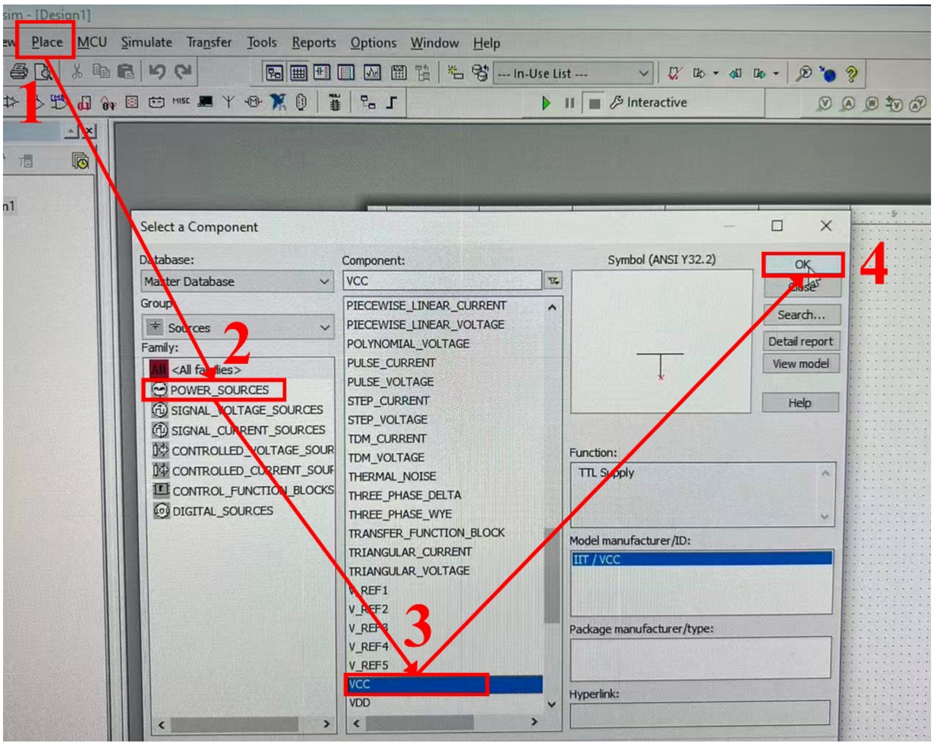

Figure 3. “Select a Component” dialog box.

Below, we will list how to find the components to build a simple AND gate circuit.

- Vcc: Sources => POWER_SOURCES => VCC (As shown in Figure 3)
- Resistor: Basic => RESISTOR => 1k (Add two 1k resistors into the circuit.)
- Ground: Sources => POWER_SOURCES => GROUND

As indicated in Figure 4, 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 use in SIM.

- DIP Switch: Basic => SWITCH> DIPSW8

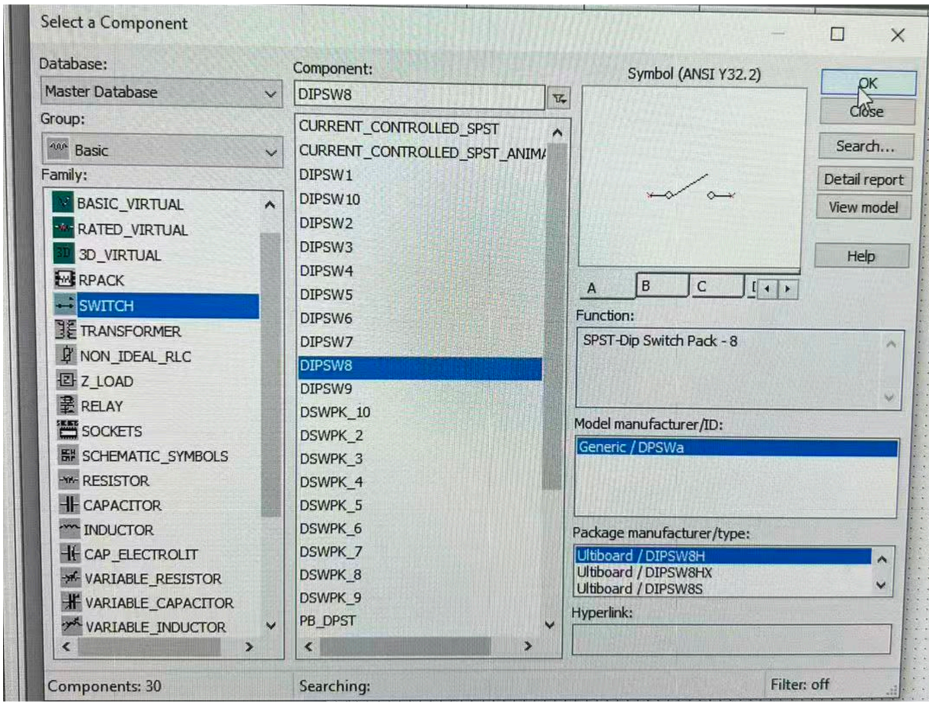

Figure 4. Select a switch dialog box.

For this switch, as DIPSW8 (Figure 5) 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.

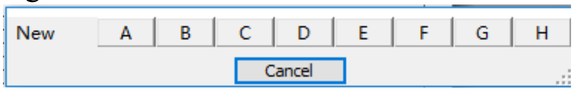

Figure 5. DIPSW8.

As 74HC08 (Figure 6) 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.

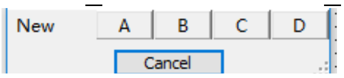

Figure 6. 74HC08N_6V.

For the measurement of output, there are a number of 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 to the circuit. Then, you will end up with the circuit shown in Figure 7.

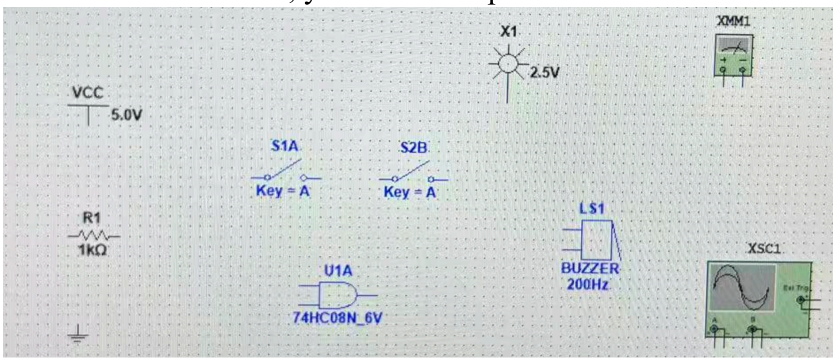

Figure 7. All components.

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

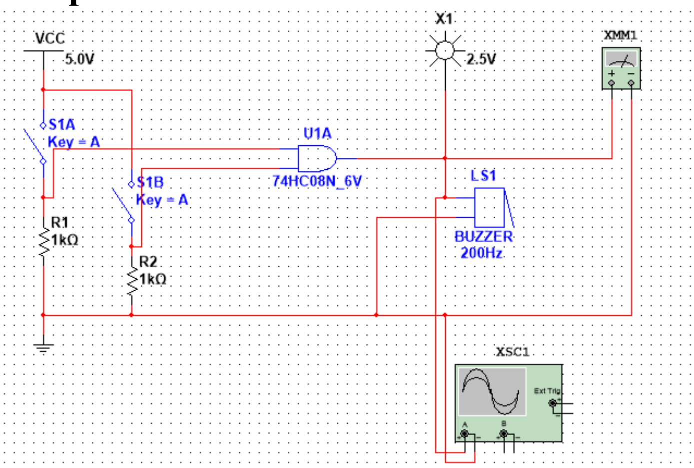

Figure 8. Completed circuit.

Each component has some ends, you can left-click the ends to connect them together. If any component or linkage does not look in the right place, you can drag it and place it appropriately. A completed circuit is shown in Figure 8.

3.6. Adjust Some Components' Parameters

- Hot key of S1B: Now the two switches have the same hotkey "A" to turn them on or off. Double click S1B => Value => Key for toggle => B.
- Buzzer threshold voltage: The 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 a simulation. Double-click the multimeter and oscilloscope, and you will view the curve as shown in Figure 9. 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.

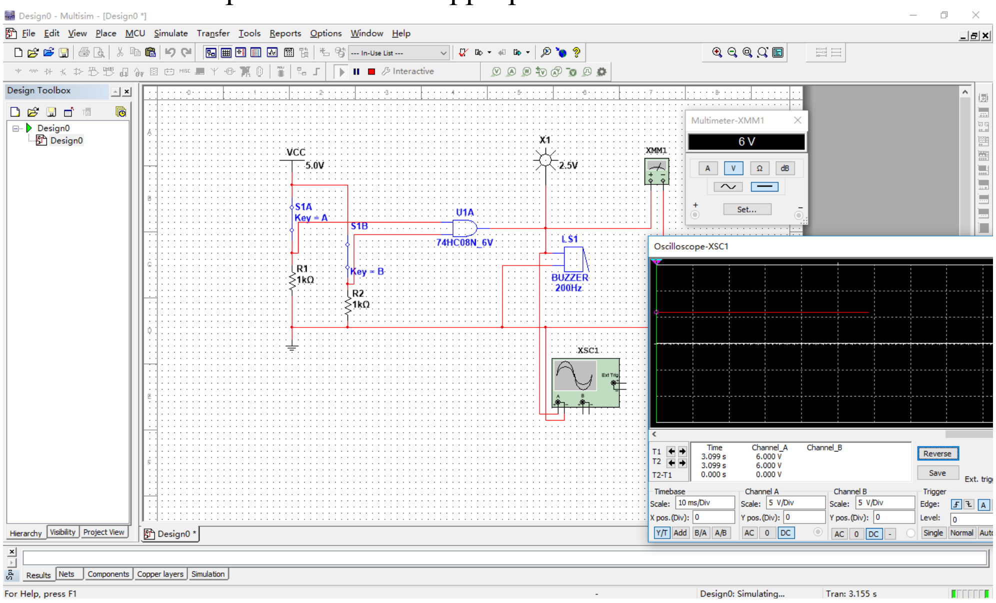

Figure 9. Circuit with illustrated output.

3.8 Save

When you're done working on your circuit, don't forget to save your file. When you work on large projects in the future, it is best to develop the habit of saving files after completing a certain stage to avoid data loss.

4. Logic Analyzer

The oscilloscope Tektronix MSO2022B has the functionality of a logic analyzer.

- To enable this, press the button D15-D0. You will find 8 lines of signals indicating 8 digital channels.
- The timeline may be too fast to observe. To slow down, use the 'Horizontal-scale'.

Experiment 0: Using Logic Analyzer

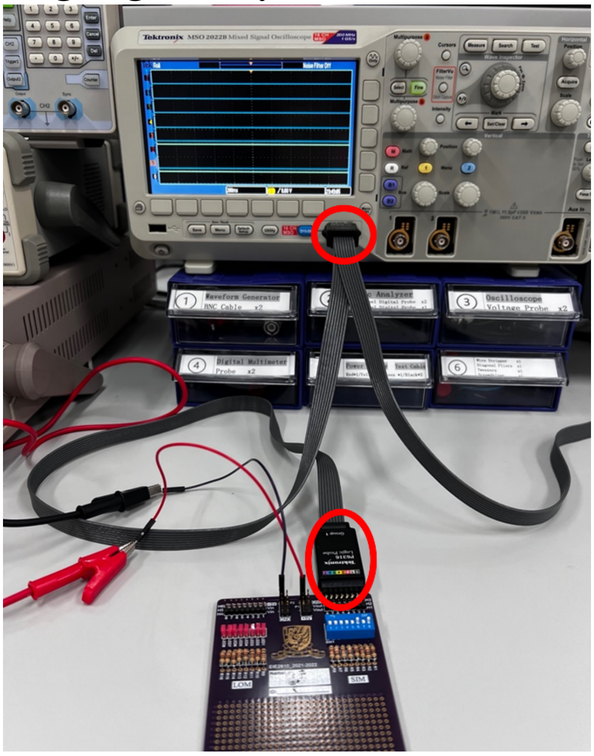

Figure 10. Probes in a logic analyzer.

- Generate approximately 0V as "0" and 5V as "1", to output by your SIM. Think about how to do this.
- Connect the SIM output pins with the logic analyzer through the socket (ref. Figure 10). Before the connection, make sure that the SIM is powered off. The ground signal of the SIM should be connected to the GND of the logic probe. As you can see from the requirement on the socket, NEVER exceed the voltage range of ±40V.

Figure 11. Buttons for the logic analyzer.

- Now you will be able to test the logic analyzer with your SIM. Press the "D15-D0" button to display 8 channels, corresponding to the eight-channel switch. Manually turn on/off each switch and check the images on the logic analyzer screen.

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

5. Experiments

5.1 Experiment 1: Guided Multisim Simulation

Build up the circuit in Figure 8, and test it.

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

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

5.2 Experiment 2: Individual Gate Test (Hardware Experiment)

In this experiment, we will test a number of digital logic ICs, including **74HC00** (NAND), **74HC02** (NOR), **74HC32** (OR), **74HC86** (XOR), **and 74HC7266** (XNOR). As you have examined the AND and NOT gates in Lab 1, you are not required to test them again. During future experiments, datasheets will not be provided by the teacher. Instead, you will need to develop the ability to search for the necessary information. Try to find the datasheets of the ICs using search engines, e.g., Google, Bing, Baidu, etc. An example of a keyword is “74HC32 datasheet”. Download it, and familiarize yourself with the appropriate Vcc to set and how the pins are arranged.

Thereafter, wire one gate from each individual IC onto the breadboard with SIM and LOM. You can use different combinations of inputs via SIM, and observe the outputs using 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.

5.3 Experiment 3: Combination of Gates (Simulation and Hardware Experiment)

I. Observe the circuit diagram below (Figure 12). Based on your theoretical knowledge, write the function of output Y in terms of 3 inputs A, B, and C.

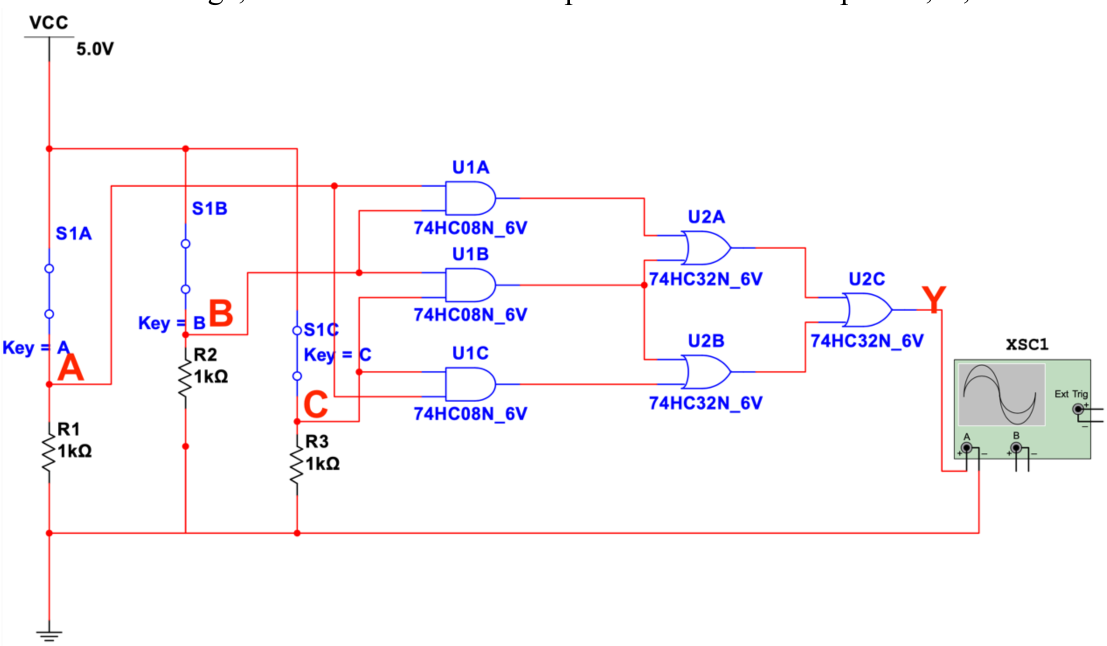

Figure 12. A combination of gate circuits is to be built.

II. Use Multisim to build the circuit. When completed, test it and demonstrate it to the instructor or TA.

III. 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.

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

[DEMONSTRATION] When you have completed step II and step IV, show it to the 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 III. Include all the results, e.g., the output of Y in terms of A, B, and C, the truth table, the diagram that you built by Multisim, logic analyzer wave, etc.
[QUESTION IN THE REPORT] Can you think of any application for this circuit?

6. Lab Report

Write the lab report comprehensively. A template has been provided on Blackboard.

Submit the report of Lab 2 in ***PDF*** to the folder ***Digital Systems Design Lab/Report Submission/Lab 1*** on Blackboard by the deadline below:

- ***LAB01 (Thursday session): 23:59, Saturday, October 18, 2025***
- ***LAB02 (Friday session): 23:59, Sunday, October 19, 2025***

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

7. 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 1-6 back to the storeroom after lab.

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