Digital Lab 1:

Measurement of IC Electrical Characteristic

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Group: Group 8

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Digital Lab 1: Measurement of IC Electrical Characteristic

I. Objective

To understand the electrical characteristics of digital IC of logic gates.

II. Material List

1. IC: 74LS04
2. 2kΩ variable resistor (VR), resistors of 100 Ω, 330 Ω, 470 Ω and 1kΩ
3. Bread board
4. Single-core cable
5. LED
6. +5V power supply
7. Digital multi-meter
8. Oscilloscope
9. Function generator

III. Function of Experiment Circuits

According to the truth table of logic gates, observe the relationship between the logic levels of outputs and inputs.

Please note:

When you use the digital multi-meter to measure voltage, a parallel connection needs to be made with the circuit under test. As for the measurement of current, a series connection must be made.

IV. Implementation of Experiment Circuits

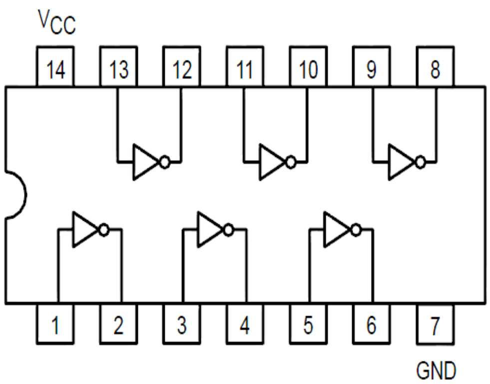


Fig. 1: 74LS04 IC pin diagram

A. Measurement of $V_{ih(min)}$ and $I_{ih\,(min)}$

1. $V_{ih(min)}$

Definition : The minimum voltage that the input is recognized as logic-1 (logic-high).

Method : Adjust the variable resister upward from 0Ω until the LED turns from dark to bright, then measure the voltage between Points A and B, as shown in Fig. 2.

2. $I_{ih\,(min)}$

Definition : The minimum current that the input is recognized as logic-1 (logic-high).

Method : Adjust the variable resister upward from 0Ω until the LED turns from dark to bright, then measure the current between Points A and D, as shown in Fig. 2.

Please note:

The second pin (*i.e.,* Point A) of the variable resistor is the output, which is connected to the input of the logic gate, and the other two pins (*i.e.,* Points C and B) are connected to the power supply and ground, respectively, as shown in Fig. 2.

B. Measurement of $V_{il(max)}$ and $I_{il\ (max)}$

1. $V_{il(max)}$

Definition : The maximum voltage that the input is recognized as logic-0 (logic-low).

Method : Adjust the variable resister downward from the maximum until the LED turns from bright to dark, then measure the voltage at **Points A and B**, as shown in Fig2.

2. $I_{il\ (max)}$

Definition : The maximum current that the input is recognized as logic-0 (logic-low).

Method : Adjust the variable resister downward from the maximum until the LED turns from bright to dark, then measure the current at **Points A and D**, as shown in Fig2.

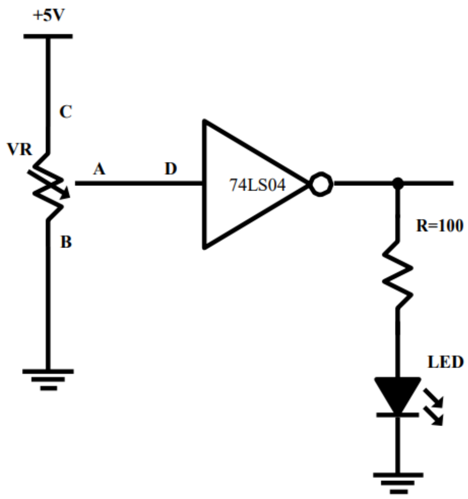


Fig. 2: Circuit diagram for measuring V_{ih} and I_{ih}, V_{il} and I_{il}

C. Measurement of V_{oh} and $I_{oh(max)}$

1. V_{oh}

Definition : The voltage level that the output is recognized as logic-1 (logic-high).

Method : Measure the voltage between **Points C and D** as V_{oh} when R=100 Ω, R=330 Ω, R=470 Ω, and R=1kΩ, as shown in Fig. 3.

2. $I_{oh(max)}$

Definition : The maximum current level that the output is recognized as logic-1 (logic-high).

Method :

(1) Replace the resistor R with a 10kΩ variable resistor, as shown in Fig. 4, adjust variable resistor and measure the voltage V_{oh} such that $V_{oh} = V_{ih}$.

(2) Measure the current between **Points C and D**.

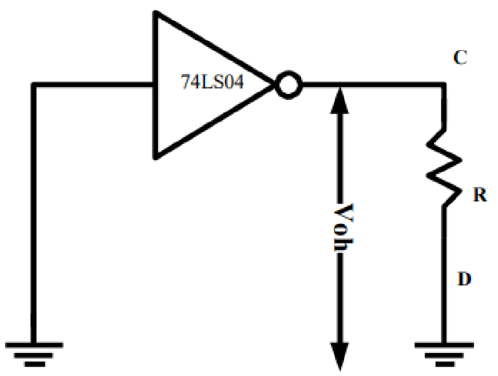


Fig. 3: Circuit Diagram for V_{oh} Measurement

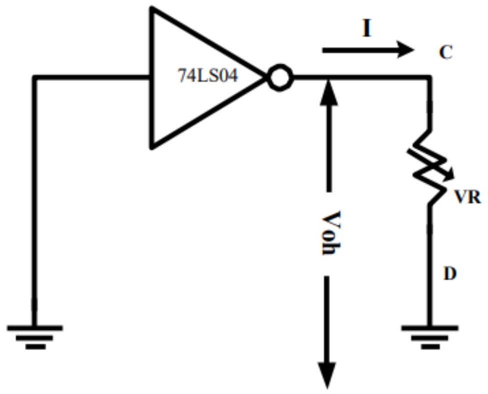


Fig. 4: Circuit Diagram for $I_{oh(max)}$ Measurement

D. Measurement of V_{ol} and $I_{ol(max)}$

1. V_{ol}

Definition : The voltage level that the output is recognized as logic-0 (logic-low).

Method : Measure the voltage between Point G and ground as V_{ol} when R=100 Ω, R=330 Ω, R=470 Ω, and R=1kΩ, as shown in Fig. 5.

2. $I_{ol\ (max)}$

Definition : The maximum current level that the output is recognized as logic-0 (logic-low).

Method :

(1) Replace the resistor R with a 10kΩ variable resistor, as shown in Fig. 6, adjust variable resistor and measure the voltage between **Points G and ground** such that $V_{oh} = V_{ih}$.

(2) Measure the current between **Points F and G**.

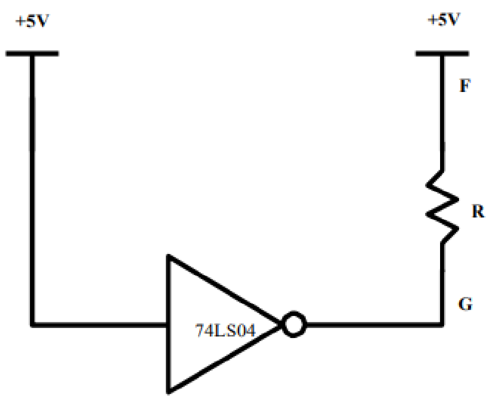


Fig. 5: Circuit diagram for V_{ol} measurement

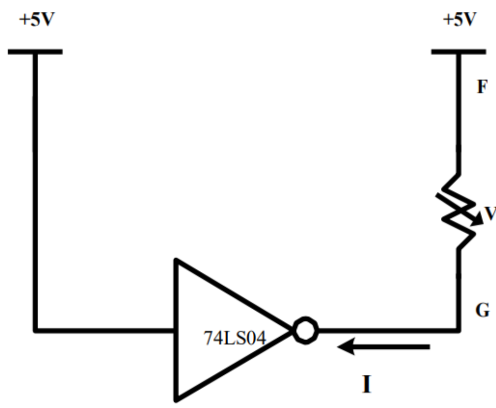


Fig. 6: Circuit diagram for I_{ol} measurement

E. Measurement of Fan-out

Definition: The maximum number of inputs of a logic gate that the output of a single logic gate can feed without disrupting the circuitry's operations.

$$Fan\_out = \frac{I_{oh(\max)}}{I_{ih}} \qquad Fan\_out = \frac{I_{ol(\max)}}{I_{il}}$$

We take the worst case among the above two ***Fan_out***. That is, the smallest value.

Remark:

I_{ih} and I_{il} are the actual values you measured at **Items A and B**.

$I_{oh(max)}$ and $I_{ol(max)}$ are the actual values of you measured at **Items C and D**.

F. Measurement of Propagation Delay

Definition: The timing difference between 50% of the input transition and 50% of the output transition.

Method :

(1) Use the functional generator to generate a square wave of 1kHz and $V_{p\text{-}p}$=5V.

(2) Observe the input and output waveforms of the circuit shown in Fig. 7 on the oscilloscope and calculate the propagation delay.

(3) Draw the waveform in your lab report.

Remark : **Calculate the time difference between input and output by observing the rising edge of input and output via adjusting the time scale of oscilloscope.**

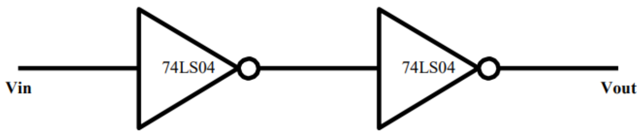


Fig. 7: Circuit diagram for measuring delay time

V. Checking Items:

A. Each team member must implement the circuits and make measurement. Those teams who have completed the experiment must ask a TA to check, and the TA will ask one of the team members to repeat the experiments and verify the results.

B. After completing the experiments, **all the components must be sorted** (placed in the material box), **the wires should be returned, and the instrument should be turned off. Clean up the seat and turn off the extension cord switch**. After completion, you must **ask a TA** to check if you can leave.

VI. Precautions:

A. The IC is placed with the notch facing left and then the IC pin diagram is referred. Each IC must be biased (VCC is connected to +5V, GND is connected to ground).

B. When measuring voltage or current, start from the large scale, and then turn it down gradually to avoid damage to the meter.

C. If you have any questions during the lab, or you can't hear clearly, you can raise your hand and ask the TA at any time.

D. Everyone needs to submit the lab report of this lab.

VII. Test Result

A.		B.		Resistor Value	C.		D.	
$V_{ih(min)}$	$I_{ih(min)}$	$V_{il(max)}$	$I_{il(max)}$		V_{oh}	$I_{oh(max)}$	V_{ol}	$I_{ol(max)}$
0.961V	0.09mA	0.92V	0.08mA	R=100Ω	2.02V	29.8mA	1.94V	21.3mA
				R=330Ω	3.08V		0.36V	
				R=470Ω	3.28V		0.28V	
				R=1kΩ	3.45V		0.18V	

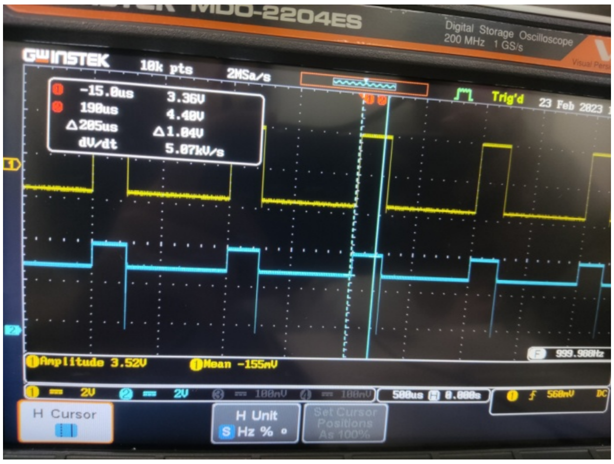
E. Fan-out:

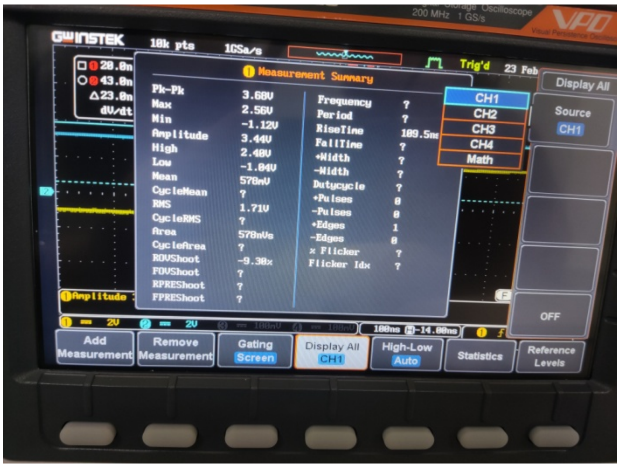
$$Fan\_out = \frac{I_{oh(max)}}{I_{ih}} = \frac{29.8\text{mA}}{0.09\text{mA}} = 331.11$$

$$Fan\_out = \frac{I_{ol(max)}}{I_{il}} = \frac{21.3\text{mA}}{0.08\text{mA}} = 266.25$$

We take the worse case of the above two *Fan_out*, that is, the smallest value: ‘266.25’= Fan-out.

F. Propagation Dalay:

	The yellow wave form (channel 1) is the input transition: a square wave of 1kHz and Vp-p=5V; and the blue wave form (channel 2) is the output transition.

	The maximum voltage of input is 2.56V; where the minimum voltage is -1.12V. Hence 50% of the input value is at 0.72V.
	The maximum voltage of output is 4.00V; where the minimum voltage is 3.12V. Hence 50% of the output value is at 3.56V.
	By using cursor, we know that the timing difference between 50% of the input transition and 50% of the output transition, which is also known as the propagation delay is 20.0ns.

VIII. Review of the experiment

The first experiment in this semester is measurement of IC electrical characteristics. We use IC (74LD04) to conduct the experiment and measure maximum and minimum input voltages and current by observing the LED. The problem that we encounter is that we don't know at what moment is the "LED turns from dark to bright" that we need to record, since light changing is a continuous process. After asking TA for help, we found that the LED we use is not working as well as other groups'. After changing to a new LED, the gap between bright and dark became more obvious for us to recognize.

However, there are still artificial errors when distinguishing the LED on-off turning point, what we can only do is to focus on the observation and turn the variable resistor carefully.

Another problem we encountered is in the experiment of measuring propagation delay. My teammate and I spent a lot of time remembering how to use the cursor in an oscilloscope. Finding 50% gain points required extra calculations, but it was still convenient to check data by using tools in an oscilloscope.

To conclude, the experiment this time reminds me of the course "digital design" when we were in the first grade of university, it is fun to conduct what we had learned in reality.