Experiment 4: The Frequency Characteristics and Square Wave Response of Circuits & The testing of gates parameters and transmission characteristic

16231235 李谨杰　table number:23

Aim

1. To understand the principle of digital oscilloscopes.
2. To learn the operation of digital oscilloscopes
3. To test frequency characteristics and square wave response of circuits by digital oscilloscopes.
4. To learn testing methods of TTL NAND gates' key parameters and the transmission characteristics.

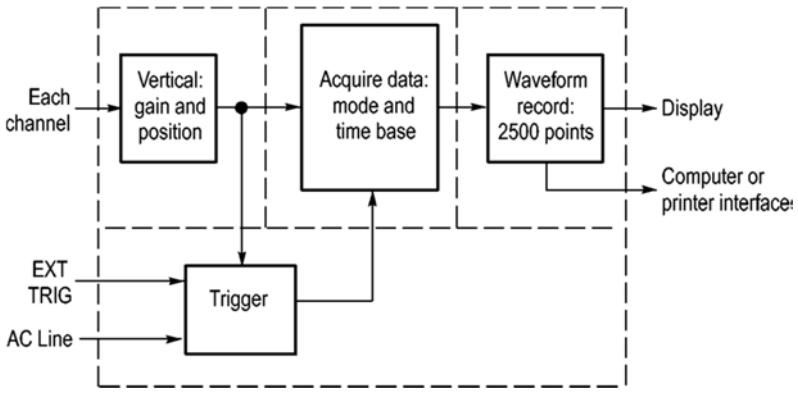
Principle and method

1. Principle and applications of oscilloscope:

1.1 Oscilloscope structure：

(a) An oscilloscope is composed of screen, vertical amplifier, horizontal amplifier, sweep voltage generator and power, etc.

(b) For a digital oscilloscope, data acquirement technology and LCD panel technology controlled by advanced microprocessor are adopted.

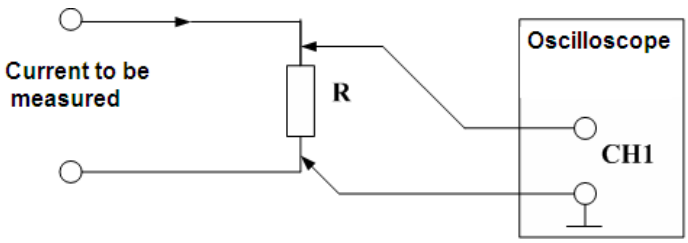


Block diagram of the digital oscilloscope structure

1.2 Applications of oscilloscope

(a) An oscilloscope gives a visual representation of how a voltage varies with time. It can monitor the voltage waves , measure amplitude, period, frequency , phase shift, etc.

(b) To make a measurement of current, the following method is usually adopted.



2. The frequency characteristics

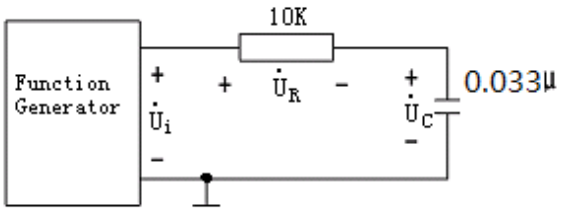
2.1 Amplitude-frequency characteristic

How the ratio of output over input varies with frequency.

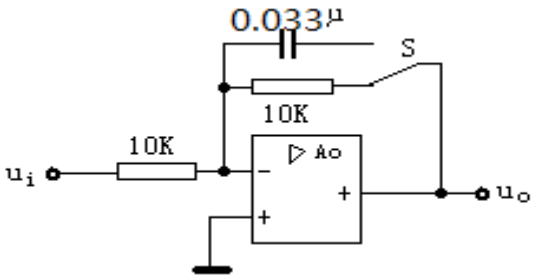
2.2 Phase difference-frequency characteristic

How the phase difference between input and output varies with frequency.

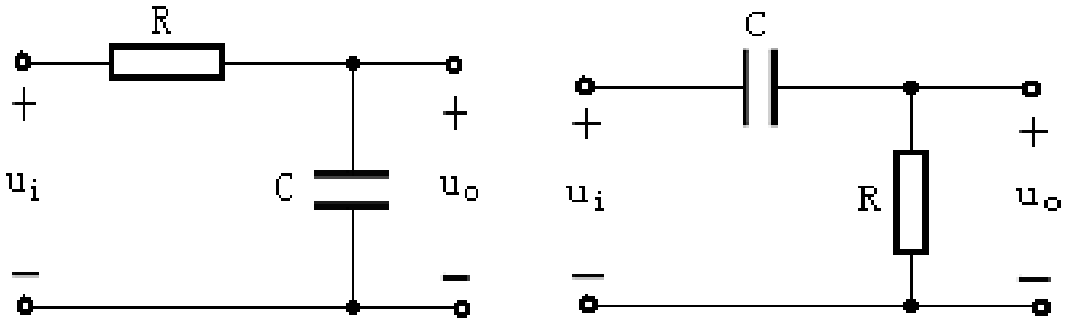
Experiment circuits



Circuit 1 Sine wave signal measurement and shift-phase observation of RC circuit



Circuit 2 Shift-phase circuit with operational amplifier



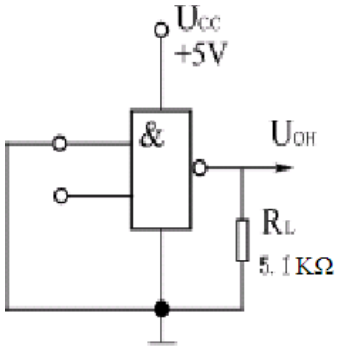
(1). Integral circuit (2). Differential circuit

Circuit 3 Square wave signal observation

4. Circuit diagram- TTL NAND Gate Key Parameters

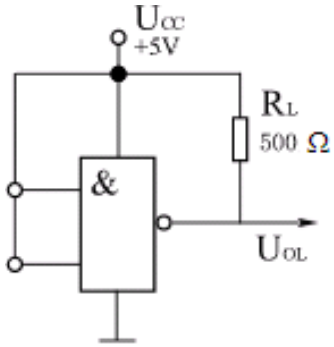
Output HIGH UOH

UOH must be higher than standard high voltage (2.4V) without load, and will decrease when a sinking current load is connected.



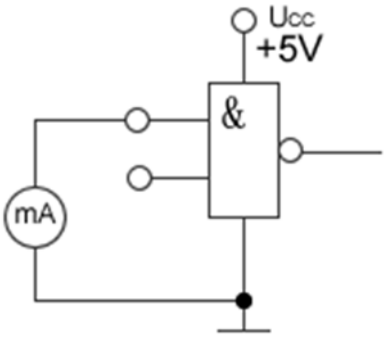
Output LOW UOL

UOL must be lower than standard low voltage (0.4V) without load, and will increase when a sourcing current load is connected.



Input short circuit current IIS

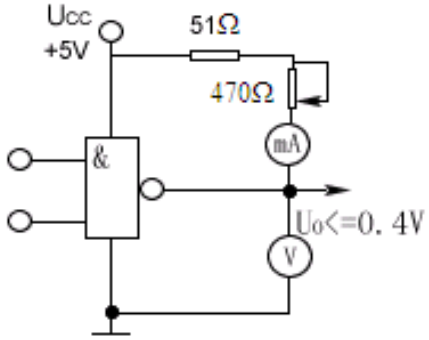
Normally IIS <1.6mA ,and IIS is last level's sourcing current when its output is LOW.



Fan-out N

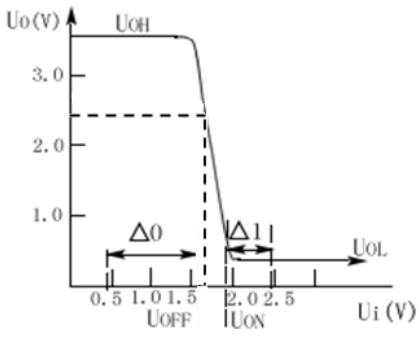
N is the number of load gate inputs that a given gate can drive. N = IOL / IIS

Normally, only those NAND gates with N >8 can be regarded as eligible.

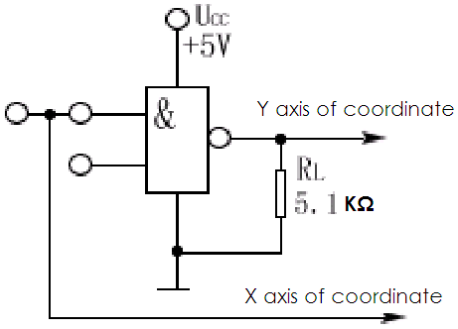


5. Circuit diagram-TTL NAND gates' transmission characteristics

Based on the transmission characteristics, examination on TTL NAND gates can be carried on. In the meantime, its key static parameters like UOH ,UOL ,UON ,UOFF and △1、△0 can be read out.



TTL NAND Gate Transmission Characteristic



Circuit for TTL NAND Gate Transmission Characteristic Testing

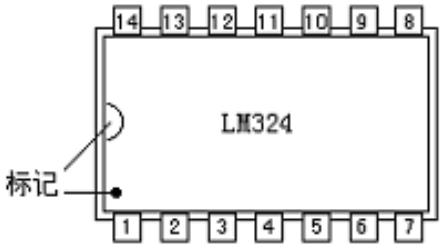
Instruments

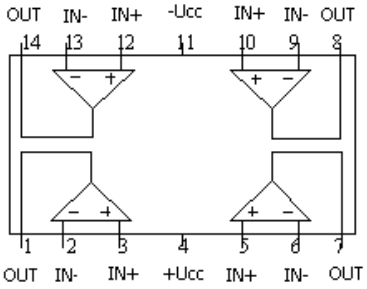
1. **Digital oscilloscope model DPO2014**

   To use your oscilloscope effectively, you need to learn about the following functions:
   (a) Setting up the oscilloscope
   (b) Triggering
   (c) Acquiring signals (waveforms)
   (d) Scaling and positioning waveforms
   (e) Measuring waveforms

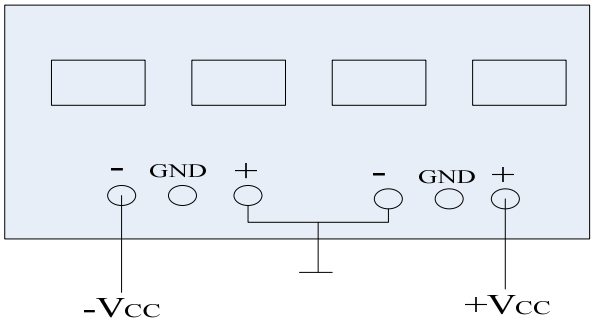
2. **Two-path DC regulated power supply**

3. **Integrated operational amplifier LM324**





LM324 DIP (Double in-line Package) LM324 Pin-out diagram



Dual power ±12V for LM324 （pin4 +12V, pin11 -12V)

Tasks

1. **Familiarize yourself with locations and functions of those buttons and knobs on digital oscilloscope.**

2. **Sine wave signal measurement.**

   Measure the frequency characteristic of circuit

   2.1 Construct the circuit from the diagram.

   Put the function generator settings as follows:

a. Signal form: sinusoidal wave

b. Frequency: **f = 400Hz**

c. Amplitude: **Ui = 1V**

2.2 Measure Uc with voltmeter . Simulation:1.083V

2.3 Power on oscilloscope, and connect Ui to CH1 and Uc to CH2, then measure the following values with oscilloscope after steady waves displaying on screen:

a. Input peak voltage Uim and output peak voltage Ucm Simulation: 1.99V 1.53V

b. Frequency of Ui and Uc 400hz 400hz

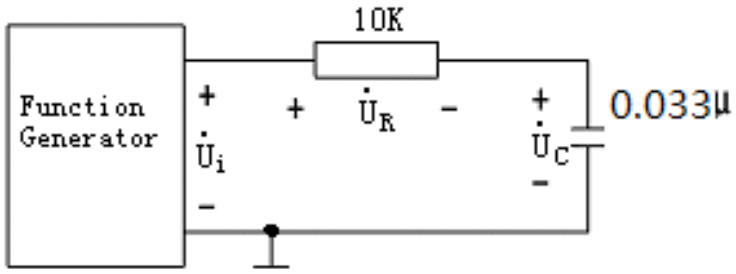
c. Phase shift between Ui and Uc

d. Phase shift between Ui and Uc by Lissajous figures.

e. URm (COM measurement)

f. Phase shift between UR and Uc. Draw vector plot of Ui ,Uc and UR.

2.4 Adjust the frequency of the function generator to 200Hz and 1KHz, then repeat step 2.3 a ~ c.



Sine wave signal measurement and shift-phase observation of RC circuit

3. Phase-shifting observation.

3.1 RC circuit

Replace fixed resistor with 22kΩ variable resistor, and observe phase difference between input and output while adjusting variable resistor, then read out phase difference values when potentiometer(电位器) is on both sides and middle position. Uc get smaller and phase difference is bigger

Selective: Change the position of potentiometer and capacitor, repeat above operation.

3.2 Circuit with operational amplifier

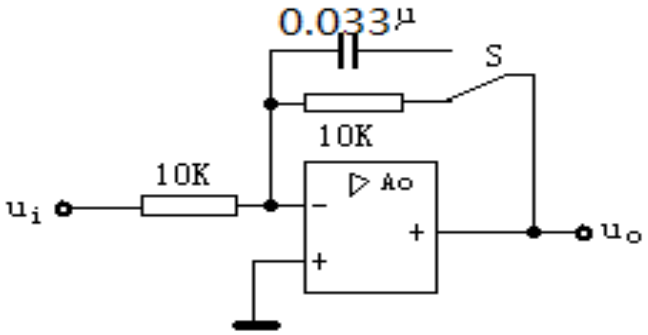
In the circuit, switch S is used to choose the resistor or capacitor to be connected. Put input signal: **1.0v** and **400Hz sine wave**, and Test phase difference of output and input by oscilloscope when S is as following :

a. S is connected to the resistor.

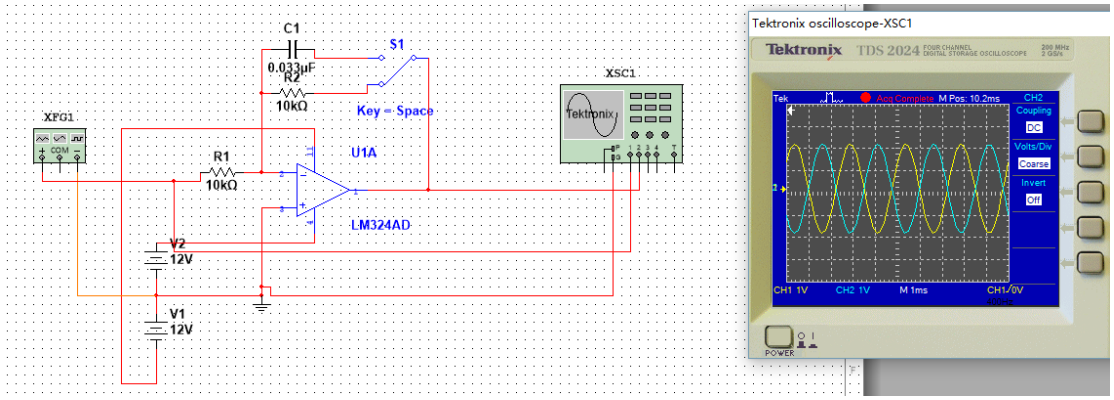
b. S is connected to the capacitor.

Cautions:

If a distortion wave appeared, a resistor less than 1MΩcan be parallel with the capacitor till distortion is eliminated.



Shift-phase circuit with operational amplifier



Simulation circuit and result

4. Square wave response observation.

For the two circuits, add input signal **2.0v P-P value**, **1KHz square wave**, plot input and output waves under following parameters:

(1) Integral circuit

a. R=5.1KΩ, C=0.01μF;

b. R=10 KΩ, C=0.22μF.

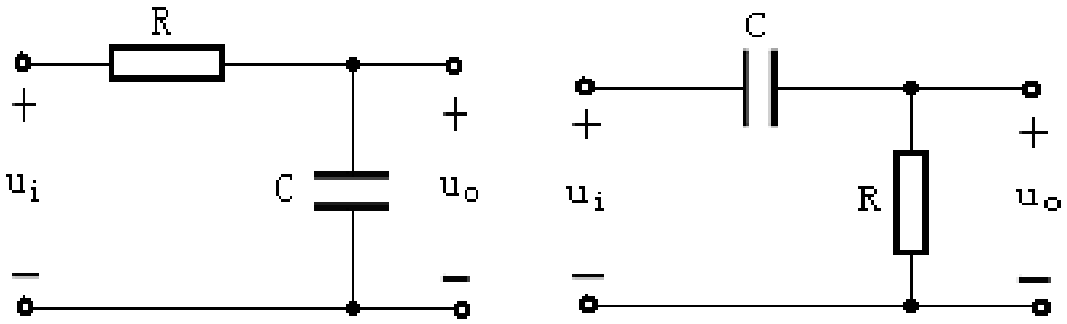
(2) Differential circuit

a. R=1KΩ, C=0.01μF;

b. R=10 KΩ, C=0.22μF.

Caution:

Time corresponding in vertical direction when plotting waves.



(1). Integral circuit (2). Differential circuit

Square wave signal observation

5. Measure the key parameters of TTL NAND gate(74LS00).

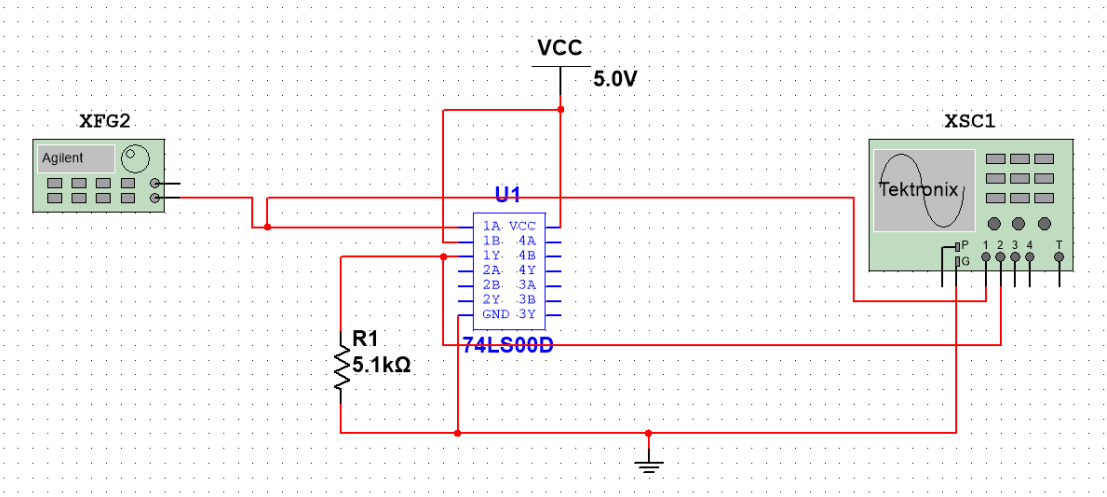
5.1 Output HIGH UOH with and without load.
5.2 Output LOW UOL with and without load.
5.3 Input short circuit current IIS.
5.4 Fan-out N.(扇出系数)

6. Test and draw the voltage transmission characteristic of TTL NAND gate(74LS00).

Input **400Hz sawtooth wave**.
Observe output on CRO and draw transmission wave on square paper indicating UOH UOL 、UON 、UOFF , calculating △1 and △0.

7. Observe two signal waves with different frequency. (selective)

CH1 to calibration signal, CH2 to function generation and change its frequency. Observe the two waves on screen, and explain the reason based on the principle of oscilloscope synchronization.



Data collation and analysis

Task 2:

Data collation

Frequency(Hz)	Ui (V)	Uc (V)	Uim (V)	Ucm (V)	URm (v)	T (ms)	Fuc=1/T (Hz)	$\Delta\Psi = \Delta t/T * 360^0$
400	0.983	0.765	1.480	1.440	0.920	2.494	400.9	36.80°
200	0.979	0.904	1.440	1.320	0.600	5.002	199.9	20.18°
1000	0.977	0.442	1.440	0.660	1.300	1.000	999.6	62.88°

Table 1

Frequency(Hz)	B(v)	A(v)	$\Delta\Psi_L = \arcsin B/A$
400	1.34	2.18	37.92°
200	0.90	2.56	20.57°
1000	1.08	1.24	60.57°

Table 2

$\Delta\Psi$ is similar in measurement 1 and 2.

When measure meters of circuit, the digital oscilloscope has a function named ‘quick photo’, which can measure all parameters at one time. Using this function, I finished most measurement of this task. But when I choose X-Y mode, ‘quick photo’ function failed, so I move cursor to measure the highest and lowest point of Lissajous figures.

Task 3

Frequency=400Hz

3.1

Pin	A	Middle	B
Resistance / kΩ	0	11.04	22.04
Phase	0.501°	62.85°	69.14°

3.2

Mode	Phase

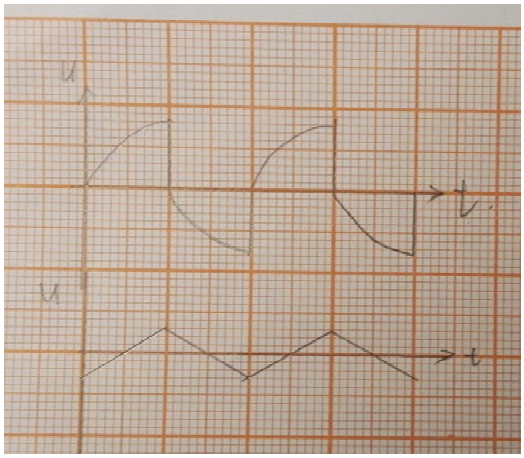
S→ Resistor	179.60°
S→ Capacitor	-92.75°

In task 3.1, According to the series partial pressure law $\frac{\dot{U}_C}{\dot{U}_i} = \frac{\frac{1}{jwC}}{\frac{1}{jwC}+R}$, $\Delta\varphi = \arctan(wcR)$. So change R and C will change phase between $\dot{U}_C$ and $\dot{U}_i$, and the more resistance is, the more $\Delta\varphi$ will turn to, just as measured.

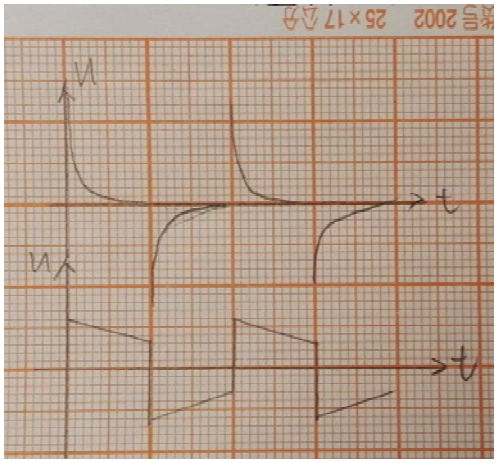
In task 3.2, when S→ Resistor, $\frac{\dot{U}_c}{R_2} = -\frac{\dot{U}_i}{R_1}$, so $\Delta\varphi$ equals to 180°; when S→ Capacitor, $\frac{\dot{U}_0}{\frac{1}{jwc}} = -\frac{\dot{U}_i}{R}$ $\Delta\varphi$ equals to -90°.

Task 4

(1) Integral circuit



(2) Differential circuit



Task 5

5.1 5.2

U_{OH}	With load	Without load

	3.592v	4.509v
U_{OL}	With load	Without load
	0.380v	0.167v

From datasheet of 74LS00N, U_{OH} is higher than 2.4V, and U_{OL} is lower than 0.4V, according to measurement, this element is qualified.

5.3

I_{IS}=0.2410mA, which is similar to ideal value 0.2mA.

5.4

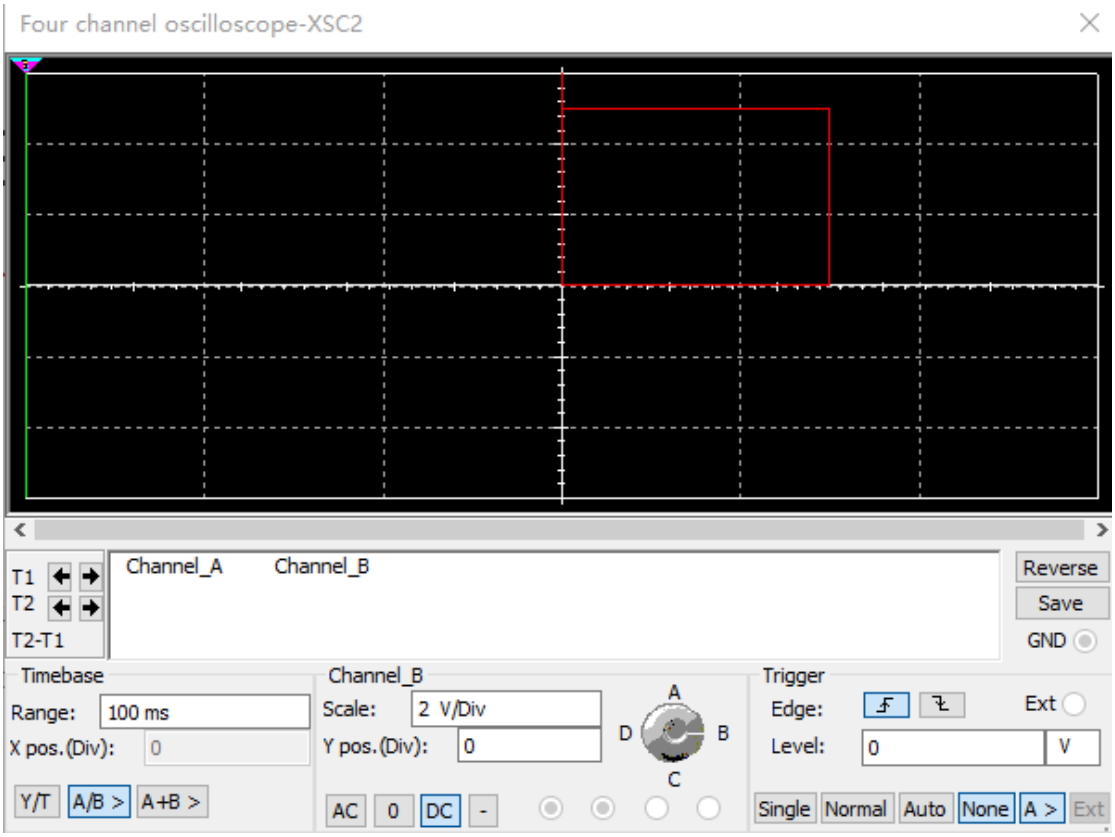
U_0=0.395V I_{OL}=10.510mA

$N=\frac{IOL}{IIS} \approx \mathbf{43}$

N is bigger than 8, so this element is qualified.

5.5

I didn't finish this experiment, so I make a simulation. The result is as follows:



Summary and problem discussion

I have made a great progress in this experiment. This time, I did some simulation before, so I had an estimate of results. Before experiment, I check every wire on my table, and in this time, I never met the mistake of broken wires, which accelerates speed. These are valuable lessons for experimentation, after these two experiments, I realise that Failure is the mother of success.