Lab 1 - Introduction to Electronic Instruments
Lab 2 - Fundamental switching circuit
Lab Report

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Experiment Purpose and Requirements

1.1 Introduction to Electronic Instruments

1.1.1 Learn about basic experiment instruments

1.1.2 Learn to use digital multimeter, oscillograph, signal generator, DC power supply.

1.1.3 Learn to use oscillograph to measure parameters such as amplitude and frequency of pulse forms.

1.1.4 Learn to use oscillograph to measure positive edge, negative edge and delay of pulse forms.

1.1.5 Learn to use digital multimeter to measure voltage, resistance and to test the states of diodes.

1.2 Fundamental switching circuit

1.2.1 Understand Basic Structure of logic switching circuit.

1.2.2 Understand Turn-on and Cut-off Concept of Diode and Triode.

1.2.3 Master the method of designing simple logic gate circuit with diode and triode.

2 Experiment Task and Theory

2.1 Introduction to Electronic Instruments

2.1.1 Use the oscillograph to measure the pulse waves generated by signal generator. Generate signal in frequency of 100Hz, 10KHz and 100KHz, and then measure the frequency and period with oscillograph.

2.1.2 Generate 1KHz signal with effective value of voltage in range of 1V-3V (you can measure the effective value with digital multimeter). Then measure the peak voltage of the signal and calculate its effective value for comparison.

2.2 Fundamental Switching Circuit

2.2.1 Design AND gate circuit with diodes, and calibrate the input and output voltage, and give the logic function table.

2.2.2 Design OR gate circuit with diodes, and calibrate the input and output voltage, and give the logic function table.

2.2.3 Design positive NOT gate circuit using inverted function of triode, and calibrate the input and output voltage, and give the logic function table.

2.2.4 Design NAND gate circuit with previous circuit, and calibrate the input and output voltage, and give the logic function table.

3 Experiment Instruments and Materials

3.1 Introduction to Electronic Instruments

Instruments	Digital Multimeter	1
	Oscillograph	1
	Signal Generator	1
	Experiment Box of Logic Circuit Design	1
Materials	Diode	
	Resistor	

3.2 Fundamental Switching Circuit

Instruments	Digital Multimeter		1
	Oscillograph		1
	Signal Generator		1
	Experiment Box of Logic Circuit Design		1
Materials	Diode IN4001		3
	Triode 9013		1
	LED		1
	Resistor	10KΩ	5
		5.1KΩ	3
		1KΩ	5

4 Experiment Procedure and Operations

4.1 Pre-learning #1

Before we actually come to the experiment, we learned how to use the oscillograph and the signal generator. Figure 1 shows the UI of these two instruments.

In this experiment, we mainly used Auto Adjust and the Vertical/Horizontal position/scale adjustments (to measure data as accurately as possible) on the oscillograph. As for the signal generator, there isn′t much to tell, switch the range buttons, then turn the knob to get signal with desirable frequency and voltage.

Additionally, we also learned about resistors′ 4-band-code color pattern and how to use digital multimeter to measure Voltage (DC and AC), resistance, diode and triode.

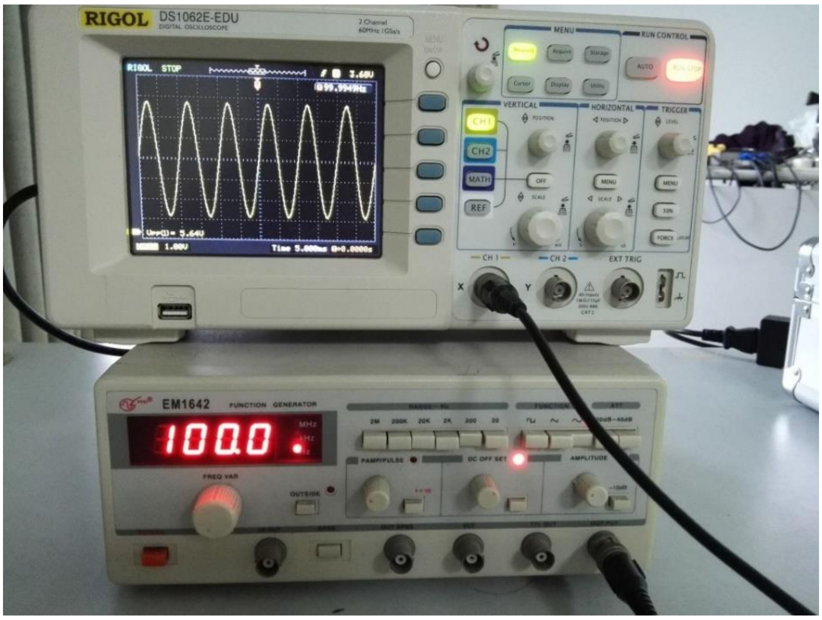


Figure 1 The oscillograph and the signal generator

4.2 Measure parameters of sinusoidal signal with oscillograph

In the first experiment, use the signal generator to generate sinusoidal signal of 100Hz, 10KHz and 100KHz, then measure signal′s Voltage, cycle, and calculate the frequency accordingly, then compare with the frequency shown on the signal generator. In the end, fill the table below.

	Sinusoidal signal	Div Count	Sensitivity	Measured value	
Voltage		Div	V/Div	V	
Frequency	100Hz	Div	ms/Div	ms	Hz
Voltage		Div	V/Div	V	
Frequency	10KHz	Div	μ s/Div	μ s	Hz
Voltage		Div	V/Div	V	
Frequency	100KHz	Div	μ s/Div	μ s	Hz

NOTICE: Input frequency doesn′t need to be exactly 100Hz, etc. It just need to match the following calculation. Because the input is not very stable (its frequency will shift slightly over time), measure data quickly and accurately is quite important. More importantly, to measure data more accurately, we should adjust the vertical and horizontal scale reasonably, not too small nor too big.

4.3 Measure the output voltage of YB1638 signal generator

Generate 1KHz signal with **effective value of voltage** in range of 1V-3V (V_{pp} in range of 4V-5V). Then measure the peak-peak voltage (V_{pp}) of the signal with oscillograph.

Measure the effective value with digital multimeter (AC Voltage 20V/2V).

Calculate the effective value from V_{pp} (Effective value=$\frac{V_{pp}}{2\sqrt{2}}$) and compare it with the reading of multimeter.

Output frequency	Oscillograph read		Effective value	Multimeter read
1KHz	div	V/div	V	V

4.4 Measure DC voltage of the experiment box with digital multimeter

Put the red probe of digital multimeter into VΩmA slot and black probe into COM slot.

Set the digital multimeter to **DC mode** with proper range and measure the voltage of DC power of experiment box.

Set the oscillograph to **DC mode** also, then connect the 5V output with the oscillograph, use vertical knob to adjust the range (or simply press “AUTO”), then measure the voltage of 5V output.

Measure the voltage of 5V output with multimeter and fill the table.

DC output	Oscillograph read		Effective value	Multimeter read
+5V	div	V/div	V	V

4.5 Test state of diode

Put the black probe into COM slot and red probe into VΩ slot.

Set the multimeter to model “”, connect the two probes with the two legs of diode. If the multimeter displayed number is between 0.6~1, then the red probe connected leg is positive; if the displayed number is “1.” then, the black probe connected leg is positive.

Use the same way to test LED on the experiment box, if light’s on, it means the red probe connected leg is positive. Otherwise, the black probe connected leg is positive.

4.6 Pre-learning #2

Before we design logic gate circuits with diodes/triode, we need to know about the I/O logic voltage table. Without the table, it’s impossible to determine whether the I/O is 1 or 0. Although the table is very big (for it consists of 7 voltage standard from TTL to RS232), but we only need TTL and COMS at this time.

Logic voltage	V_{CC} / V	V_{OH} / V	V_{OL} / V	V_{IH} / V	V_{IL} / V	Description
TTL	5	⩾ 2.4	⩽ 0.4	⩾ 2.0	⩽ 0.8	Floating Input is High level
LVTTL	3.3	⩾ 2.4	⩽ 0.4	⩾ 2.0	⩽ 0.8	
LVTTL	2.5	⩾ 2.0	⩽ 0.2	⩾ 1.7	⩽ 0.7	
COMS	5	⩾ 4.45	⩽ 0.5	⩾ 3.5	⩽ 1.5	Input resistor is big
LVCOMS	3.3	⩾ 3.2	⩽ 0.1	⩾ 2.0V	⩽ 0.7	
LVCOMS	2.5	⩾ 2.0	⩽ 0.1	⩾ 1.7	⩽ 0.7	
RS232	±12~15	-3 ~ -5	3 ~ 15	-3 ~ -15	3 ~ 15	Negative logic

4.7 Design AND gate circuit with diodes

Connect the circuit according to Figure 2 (circuit inside the red rectangle has been simplified into switches in the experiment box).

Input high voltage (1) and low voltage (0) into A and B with the switches of S1/S2.

Measure the voltage of point A, B and F of all 4 states with Digital Multimeter, translate V_F into logic value, fill in Table 1 and check if the relationship is **F = AB**.

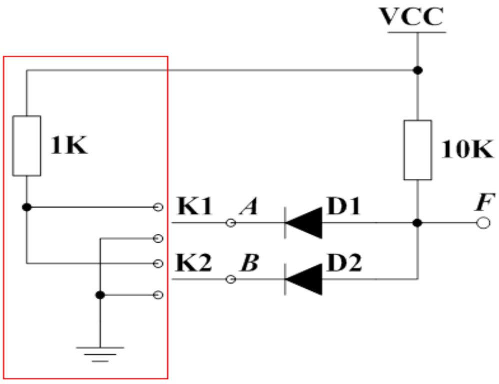


Figure 2 AND gate circuit using diodes

V_A/V	V_B/V	V_F/V	F 0/1

Table 1 Logic voltage table of AND, OR and NAND gate

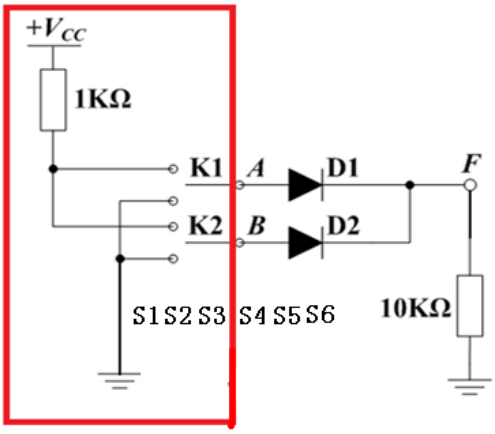


Figure 3 OR gate circuit using diodes

4.8 Design OR gate circuit with diodes

Connect the circuit according to Figure 3 (circuit inside the red rectangle simplified).

Repeat "input signals->measure voltages->fill in the table" procedure described above. Then check if the relationship is **F = A+B**.

4.9 Test the type and pin position of the triode with digital multimeter

Plug the red pen into V Ω mA slot, plug the black pen into COM slot. Determine whether the triode is PNP or NPN type.

Switch multimeter in hFE position, place B pin in b slot. Place the other two pin in c and e, read the value. Then switch the two pins and repeat the reading.

Record the C and E pin of the higher value (>200).

4.10 Design NOT gate circuit with triode

Insert the triode into its place in order of "C-B-E".

Connect the circuit according to Figure 4.

Input high voltage (1) and low voltage (0) into A with S1.

Measure the voltage of point A and F, fill in Table 2, and check if their logic relationship is **F** = $\overline{\mathbf{A}}$.

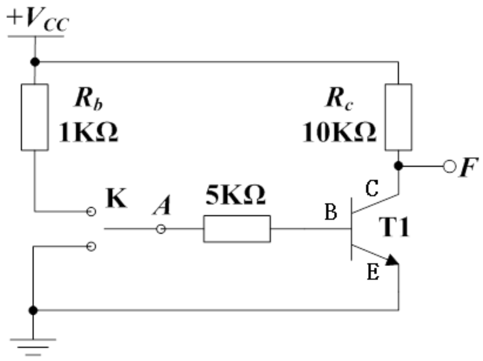


Figure 4 NOT gate circuit with triode

V_A/V	V_F/V	F 0/1

Table 2 Logic voltage table of NOT gate

4.11 Design NAND gate circuit with diodes and triode

Connect the circuit according to Figure 5.

Input high voltage (1) and low voltage (0) into A and B with the switches of S1/S2.

Measure the voltage of point A, B and F of all 4 states with multimeter, translate V_F into logic value, fill in Table 1 and check if the relationship is **F** = $\overline{\mathbf{AB}}$.

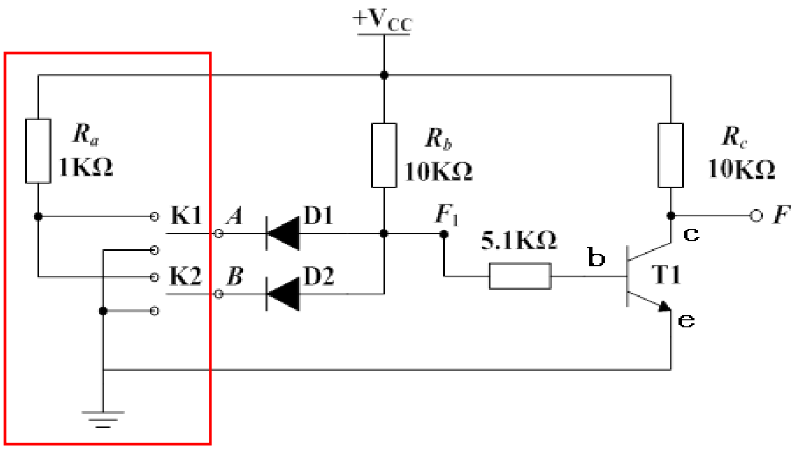


Figure 5 NAND gate circuit with diodes and triode

5 Experiment Result and Analysis

5.1 Measure parameters of sinusoidal signal with oscillograph

Result:

	Sinusoidal signal	Div Count	Sensitivity	Measured value	
Voltage		5.6 Div	1.00 V/Div	5.60 V	
Frequency	99.99Hz	5.0 Div	2.000 ms/Div	10.000ms	100 Hz
Voltage		5.5 Div	1.00 V/Div	5.60 V	
Frequency	10.01KHz	5.0 Div	20.00 μs/Div	100.00 μs	10KHz
Voltage		5.6 Div	1.00 V/Div	5.60 V	
Frequency	100.0KHz	5.0 Div	2.000 μs/Div	10.000 μs	100KHz

Analysis: The procedure of this experiment is relatively simple, the frequency calculated from the measurement of the oscillograph ($f = \frac{1}{X\ div\ \times\ Y\ time/div}$) roughly match the output frequency of the signal generator, meaning that oscillograph can be used to test sinusoidal signal. Deviations might come from inaccurate measuring or the stability of the output signal from the signal generator.

5.2 Measure the output voltage of YB1638 signal generator

Result:

Output frequency	Oscillograph read		Effective value	Multimeter read
1KHz	4.5 div	1.00 V/div	1.591 V	1.504 V

Analysis: Read V_{pp} from the oscillograph and calculate the effective voltage value ($Effective\ value = \frac{X(div)\times V/div}{2\sqrt{2}}$), which near the reading of the multimeter. Deviations might come from inaccurate measuring or the stability of the output signal from the signal generator.

5.3 Measure DC voltage of the experiment box with digital multimeter

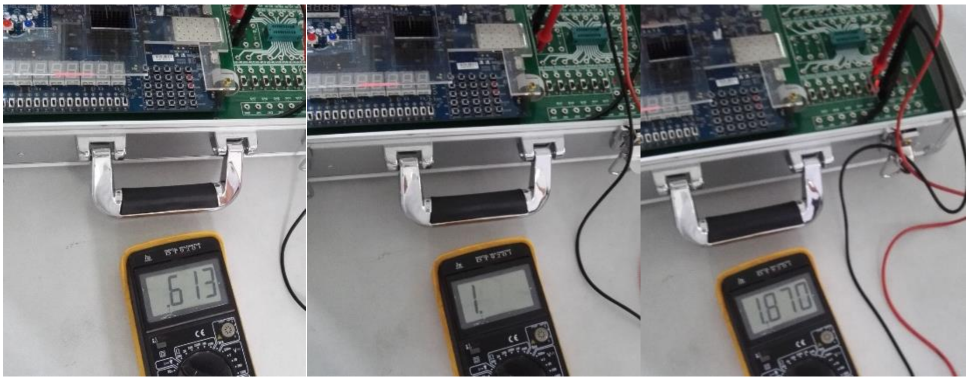
Result:

DC output	Oscillograph read		Effective value	Multimeter read
+5V	5.0 div	1.00 V/div	5.00 V	4.90 V

Analysis: The reading of the oscillograph and multimeter is roughly the same, which means that the multimeter can measure the DC voltage in the experiment box accurately. Deviations might come from inaccurate measuring.

5.4 Test state of diode

Result:



diode(+ to -) diode(- to +) LED(+ to -)

Analysis: The reading of Picture 1 and 3 might diverse depending on the multimeter, but the reading still follows the rule of not “1.”, which stands for open circuits always.

5.5 Design AND gate circuit with diodes

Result:

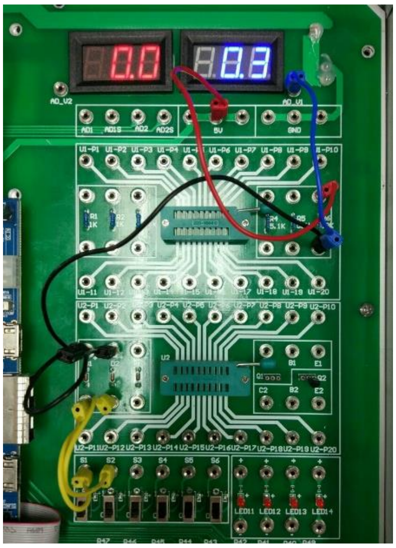


Figure 6 AND gate circuit snapshot (A=0.0V, B=0.0V, F=0.3V)

V_A/V	V_B/V	V_F/V	F 0/1
0.0	0.0	0.3	0
0.0	4.8	0.3	0
4.8	0.0	0.3	0
4.8	4.8	4.6	1

Analysis: The logic result translated according to the logic voltage table of TTL match the AND operation. No deviation is allowed.

5.6 Design OR gate circuit with diodes

Result:

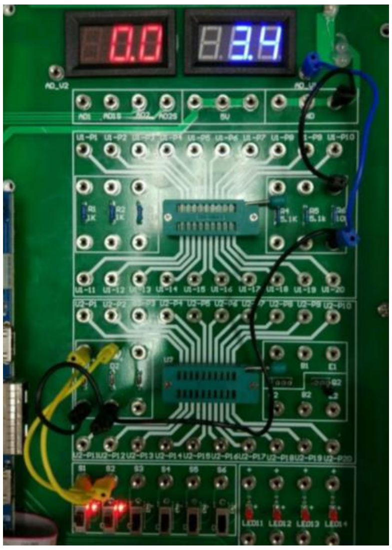


Figure 7 OR gate circuit snapshot (A=3.8V, B=3.8V, F=3.4V)

V_A/V	V_B/V	V_F/V	F 0/1
0.0	0.0	0.0	0
0.0	3.2	2.8	1
3.2	0.0	2.8	1
3.8	3.8	3.4	1

Analysis: The logic result translated according to the logic voltage table of TTL match the OR operation. No deviation is allowed.

5.7 Test the type and pin position of the triode with digital multimeter

Result:

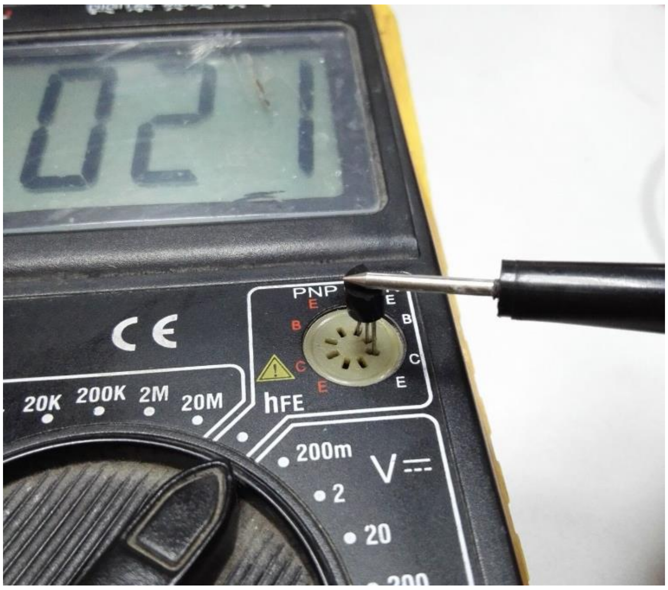


Figure 8 NPN-low reading (reversed C and E pin)

Analysis: In the testing, the triode must be pressed hard enough to get stable reading. Deviation might come from not pressing hard enough and not choosing the right B pin.

5.8 Design NOT gate circuit with triode

Result:

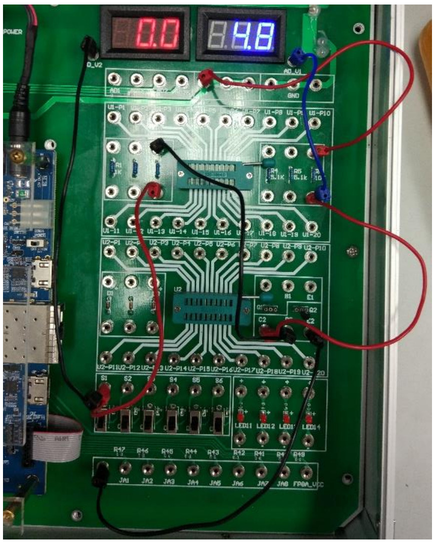


Figure 9 NOT gate circuit snapshot (A=0.0V, F=4.8V)

V_A/V	V_F/V	F 0/1
0.0	4.8	1
2.6	0.0	0

Analysis: The logic result translated according to the logic voltage table of TTL match the NOT operation. No deviation is allowed.

5.9 Design NAND gate circuit with diodes and triode

Result:

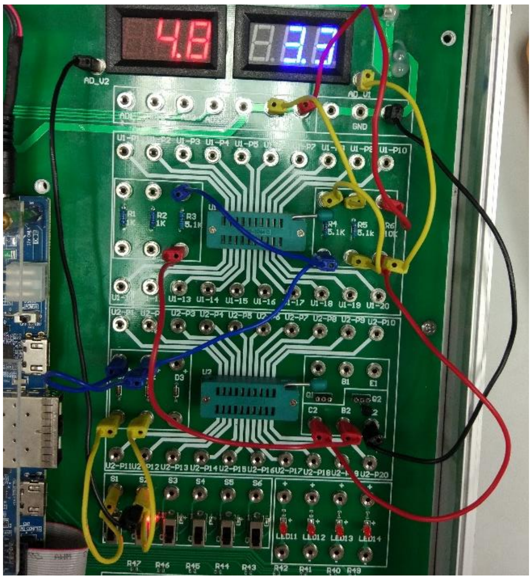


Figure 10 NAND gate circuit snapshot (A=0.0V, B=4.8V, F=4.3V)

V_A/V	V_B/V	V_F/V	F 0/1
0.0	0.0	4.3	1
0.0	4.8	3.3	1
4.8	0.0	3.4	1
4.8	4.8	0.0	0

Analysis: The logic result translated according to the logic voltage table of TTL match the NAND operation. No deviation is allowed.

6 Discussion and Revision

During the two experiments, I gradually connect abstract concept of logic 1s and 0s with actual circuits consists of electronic components. And this deepened my understanding of computing, logic operations and digital logic itself.

In my summer vacation, we learned a course named “Introduction to Computer System” lectured by Professor Patt N. Yale. In that course, although we are taught that logic gates are made of transistors, but we never got the chance to test the theory. And in this course, I got the chance. And this triggered my curiosity: can we optimize logic operations in level of circuits? If so, how can we do that? I believe during this course along with the remaining 10 experiments, I will receive more knowledge than I expect!

Also, during the experiments, I and my partner grows attention to the validity of the data, which is important for all experiments. I believe this carefulness on data is also a valuable assets for my further study.