Experiment 3: Two-port Networks and Applications

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Aim

1. Design a simple two-port circuit (attenuator) based on performance specifications.
2. Learn circuits construction and basic wiring technique proficiently(熟练地).
3. Formerly learn the specifications and operations of function generators, AC millivolt-meters, digital multimeters and DC regulated power supply.
4. Learn how to measure the parameters of two-port networks.
5. Learn the ways of testing input and output resistance of circuits.

Principle and method

Definition:

A two-port network is an electrical network with two separate ports for input (connecting to source) and output (to loads).

To characterize a two-port network requires that we relate the terminal quantities V1, V2, I1, I2 called parameters.

We are only interested in the terminal behavior of the circuits, which can contain independent sources, or not, linear or nonlinear, time-invariant or time-variant, very simple or extraordinarily complicated.

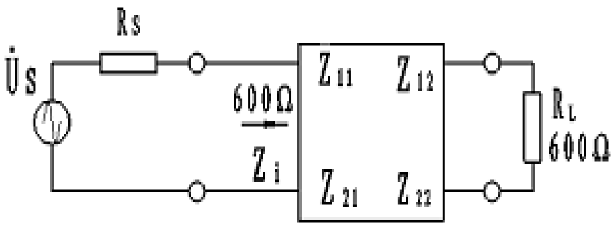
Applications:

In engineering, many circuits like amplifiers, filters, transformers, phase-shifters, are realized by connecting network terminals and exterior circuits.

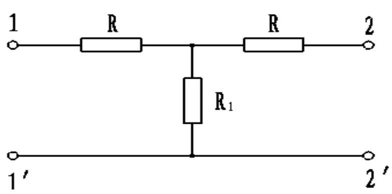
Two-port work can be featured by different sets of array, like Y, Z, T, H parameters.

Attenuator(衰减器):

It can reduce or enlarge a signal concerned. For example, testing instruments (oscilloscope, function generator).



Circuit with attenuator



T-type equivalent（等效）network

1. Load R_L=600Ω, and input impedance matches internal resistance of power source, that is Zi=600Ω, and Rs=600Ω.

2. The power attenuation is 20dB, which means $P_2=1\%P_1$.

P_1 -- Load power when the load is d

P_2 -- Load power when an attenuato oad.

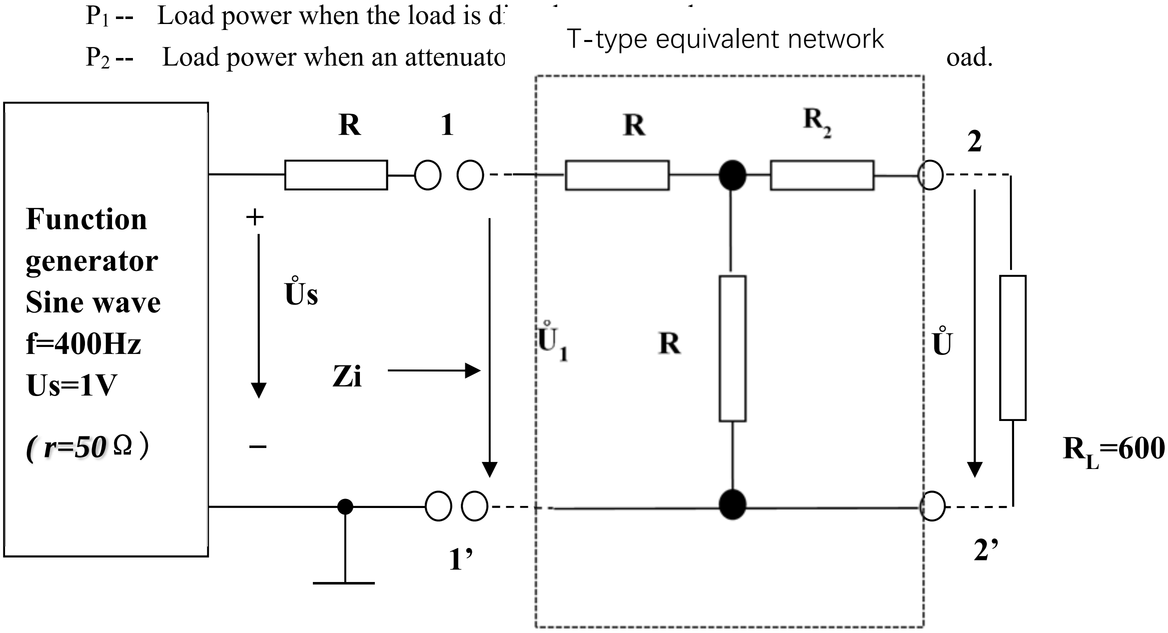


Diagram 1.

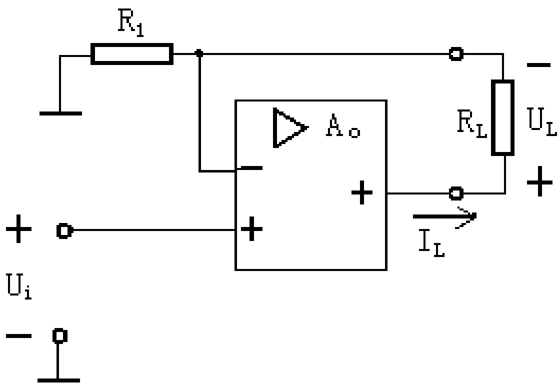


Diagram 2.

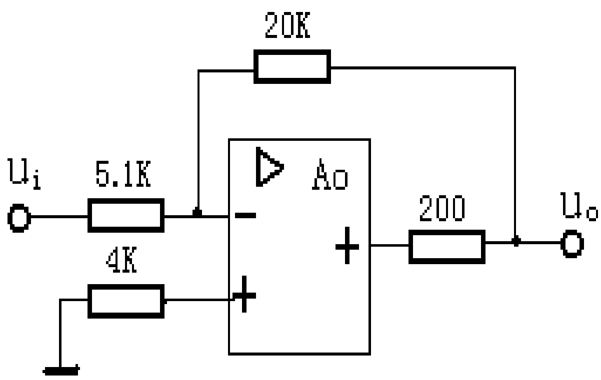
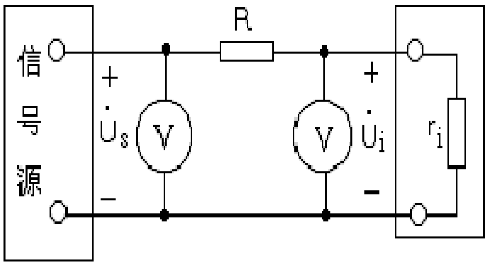


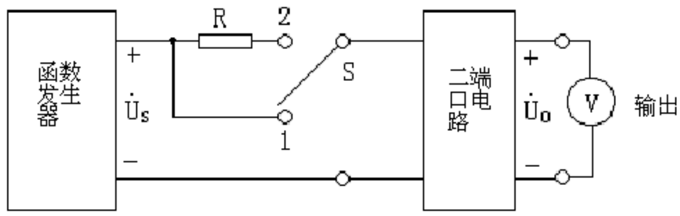
Diagram 3.

Measurement of input and output resistance of circuits



Input resistance testing

$$r_i = \frac{U_i}{I_i} = \frac{U_i}{U_s - U_i} R$$

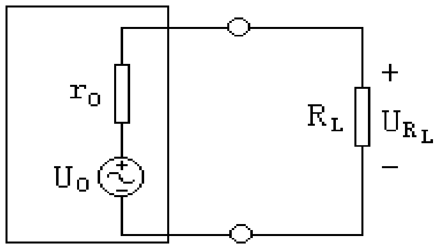


Large input resistance testing

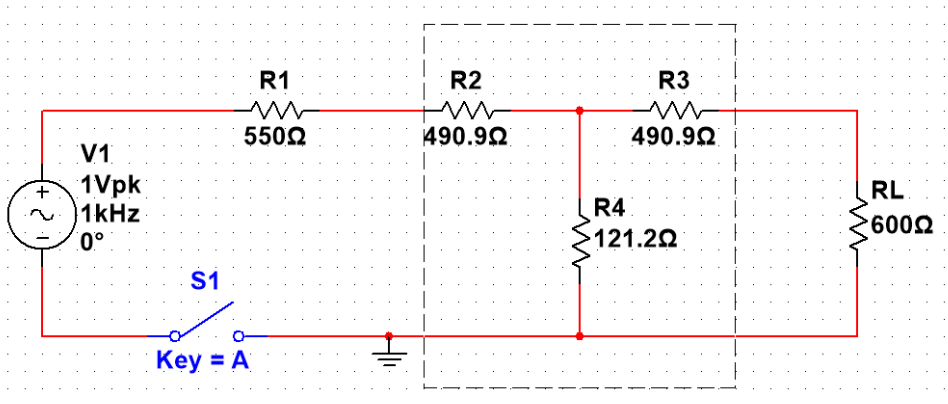
$$r_i = \frac{U_{o1}}{U_{o1} - U_{o2}} R$$

Output resistance testing

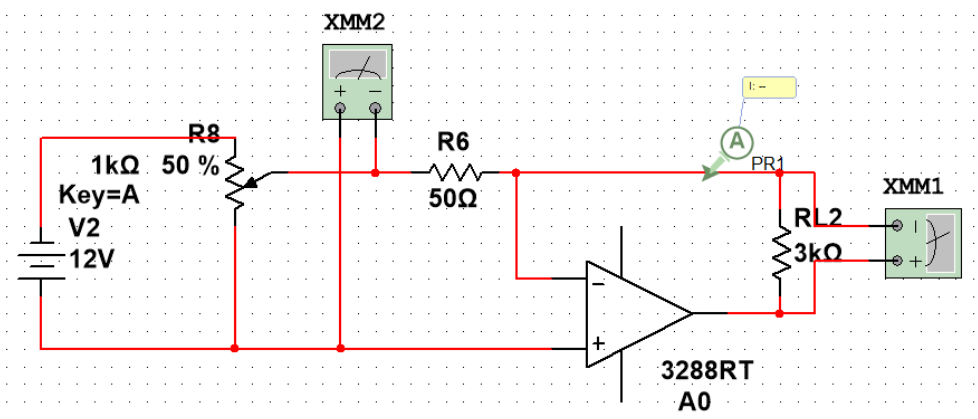
$$r_0 = \left(\frac{U_0}{U_{R_L}} - 1\right) R_L$$



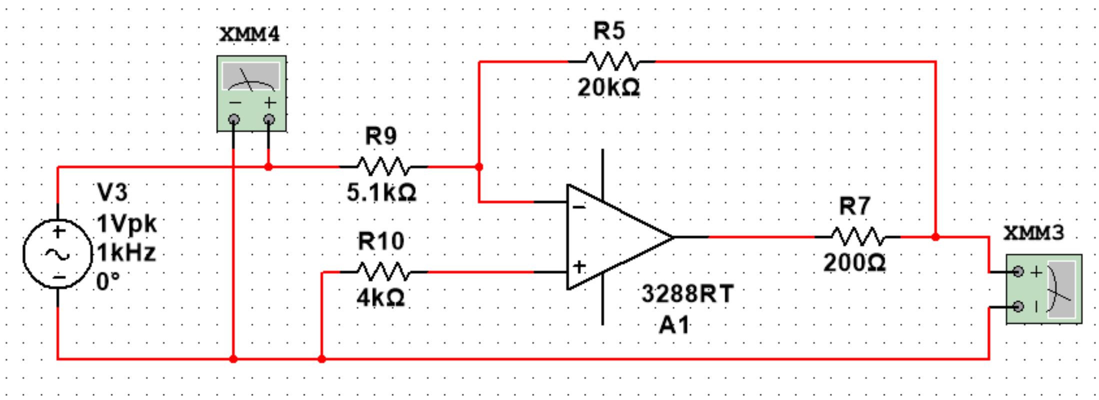
Experiment circuits



Circuit 1



Circuit 2



Circuit 3

Instruments

1. Alternating current millivolt-meter

Function: measure AC voltage

u_i<500V (DC + ACp-p)。

Range: 300μV ~ 300V -70dB ~ +50dB 1V=0dB

Frequency range: 10Hz ~ 2MHz。

Red of probe: signal anode

Black of probe: signal cathode

2. Function generator

Wave forms: sine, square, ramp, pulse, noise.

Frequency range: sine: 1μHz ~ 80MHz ramp: 1μHz ~ 1MHz,

square (pulse): 1μHz ~ 25MHz,

Amplitude: >20V $_{P\text{-}P}$

Output resistance: 50Ω

3. Input and output resistance of circuits measurements.

4. Digital multimeter UT804

Function:

AC/DC voltage, AC/DC current, resistance, frequency (period),

Diode testing, conducting test

Tasks

1. Attenuator

1.1 Measure the resistance of R1, R2 and R3 of T-type network, and record them in a table.

1.2 Build T-type network, and measure Z-parameters of the T-type network: Z_{11}、Z_{22} 、Z_{is22} , and calculate:

$$Z_{12} X Z_{21} = (Z_{11} - Z_{is22}) Z_{22}$$

Connect load, and measure Z_i When R_L=600Ω.

1.3 Construct the whole circuit, and make measurements of U_s, U_1 and U_2, verifying $U_s/U_1=2$, $U_1/U_2=10$ while R_s = 600Ω.

Thinking:

How to make the function generator internal impedance to 600Ω?

2. Two-port network with operational amplifier circuit

Diagram2. Test the transmission characteristic $I_L=f(U_i)$ and load characteristic $I_L=f(U_L)$ of the two-port circuit. Therein, the op Amp is supplied with bipolar power ±12V, and R_1=1KΩ.

2.1 R_L=3KΩ, select suitable components to make adjustable signal source with 0 ~ 2.5V as input U_i. Test the output current I_L by digital multimeter under U_i is 0.0V, 0.5V, 1.0V, 1.5V, 2.0V and 2.5V separately.

2.2 U_i=2V, get the load R_L is 20KΩ, 10KΩ, 5.1KΩ, 3KΩ, 1KΩ and 100Ω separately, test load voltage U_L by multimeter, and compute corresponding I_L.

3. Input and output resistance measurements.

Diagram 3. Input sine wave with *f*=1KHz, U_i=1v, test the input resistance and output resistance of the circuit under the condition of no output distortion.

4. Test the input resistance of the circuit in diagram2.

Data collation and analysis

Task 1

Data collation:

R_1/Ω	R_2/Ω	R_4/Ω	Z_{11}/Ω	Z_{22}/Ω	Zis_{22}/Ω
489.42	**494.01**	**118.57**	**608.00**	**612.54**	**585.07**
$Z_{12}*Z_{21}=(Z_{11}-Z_{is22})Z_{22}$/Ω			**$Z_{12}=Z_{21}$**	**R_L/Ω**	**Z_i/Ω**
14045.5422			**118.51**	**595.22**	**608.02**

Compared with the theoretical value:

$$\eta_{R_1}=\frac{|490-489.42|}{490}*100\%=0.12\%$$

$$\eta_{R_2}=\frac{|490-494.01|}{490}*100\%=0.82\%$$

$$\eta_{R_4}=\frac{|120-118.57|}{120}*100\%=1.19\%$$

The resistance value is suitable for T-type network.

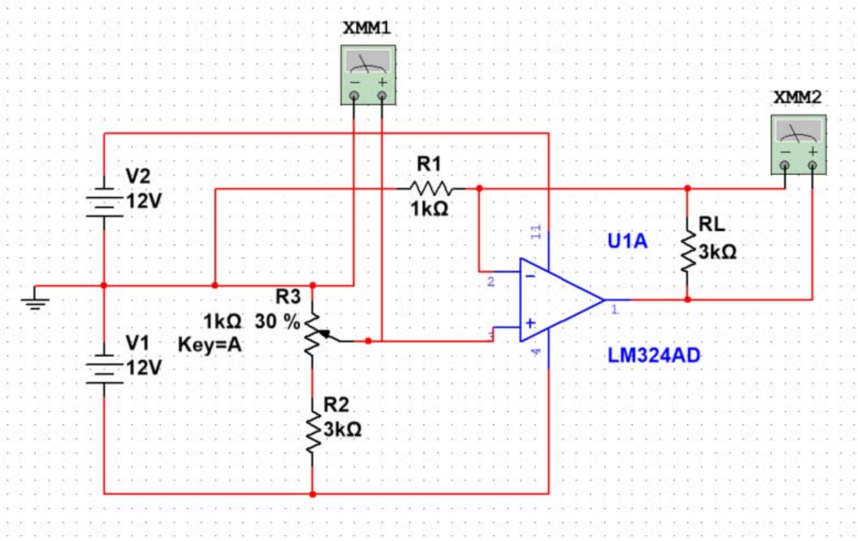
$$\eta_{R_L} = \frac{|595.22 - 600|}{600} * 100\% = 0.80\%$$

$$\eta_{Zi} = \frac{|608.02 - 600|}{600} * 100\% = 1.34\%$$

Based on the parameter upon, we can find that the attenuator has been successfully designed, as measurement is similar to theoretical value. The attenuator is satisfied with the requirements.

Task 2

Because of time wasted by a broken wire in task 1, I do not have enough time for other tasks. I am not clear about how to use the amplifier either, as the result I designed a wrong circuit in my preview report. After class, I get to know the right circuit, and perform simulation experiments. Task 2 and 3 are based on simulation results.



Simulation circuit

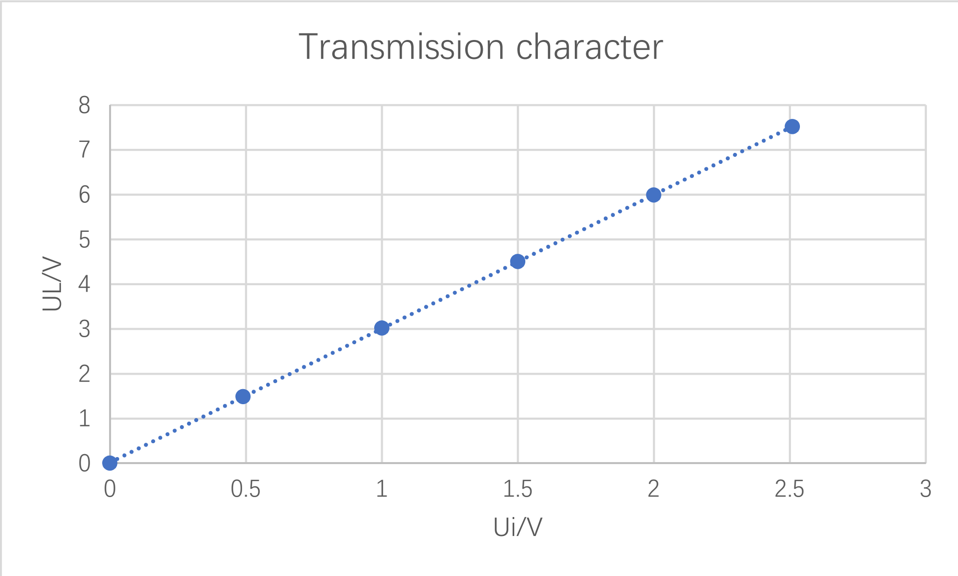
Data collation:

2.1

U_i/V	**0.00**	**0.49**	**1.00**	**1.50**	**2.00**	**2.51**
U_L/V	**0.006**	**1.491**	**3.021**	**4.506**	**5.991**	**7.521**

R_L=3000Ω

I draw the curve as follows:



Then I change value of resistance of load, after simulation, get the data bellow:

R_L/kΩ	**20**	**10**	**5.1**	**3**	**1**	**0.1**
U_L/V	**40.051**	**20.028**	**10.215**	**6.009**	**2.003**	**0.200**
I_L/A	**0.002**	**0.002**	**0.002**	**0.002**	**0.002**	**0.002**

Ui=2V

I_L is always 0.002A.

This circuit is a proportional amplification circuit. It can amplify Ui, and Uo is equal to Ui*RL/R1.

When I try to finish this experiment , I made 3 mistakes as follows:

(1) When I used the amplifier, I supplied just 12V to support it. The correct supply voltage is -12V to +12V.

(2) When I do the real experiment, I misunderstood the meaning of ‘one circuit has just only one grand’. In this circuit, the grand is only the medium point of two series 12V AC power, because the amplifier also need grand as reference.

(3) When I do the simulation, I don’t connect grand to the medium point of two AC power at first. Simulation is different with real circumstance that, only if I tell the software where is the grand, software can measure V of every point. But in real circuit, grand is relatively, not a fixed point.

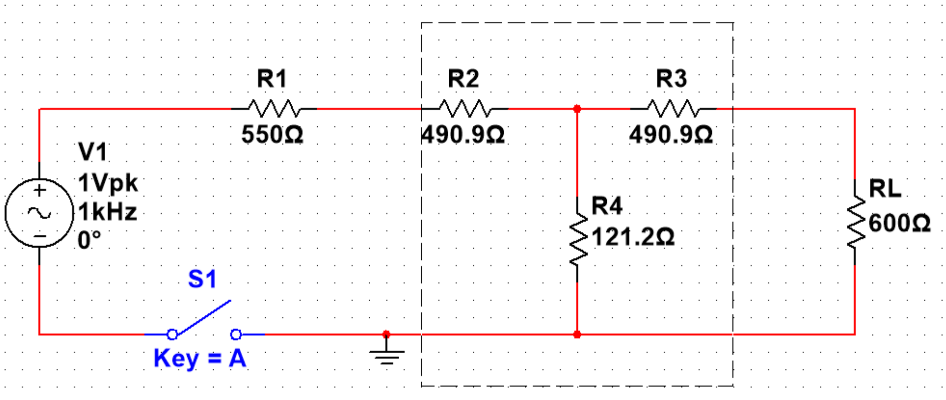
Task 3

I can’t simulate task 3, because I can’t know the inner resistance of power source.

Summary and problem discussion

This experiment give me a lesson.

I used many time on task 1, all because a broken wire. Coincidentally, the broken wire is



between R2 and RL. So, when I measure the Zi, Zi=R2+R4=around 610Ω, just equal to Zi of normal data. As the result, I didn’t think that some wire is broken. After this, one thing is deeply in my mind forever that, no matter when, no matter what, I need to check every wire firstly. The capacity of finding errors is extremely important.

The second thing I have learned is the meaning of grand. One circuit only have one grand, and this grand is a virtual concept. Next time I will remember this rule,