Experiment 7: Integrated Operational Amplifier(2)
---- Applications in Wave Generating and Negative Impedance Converting

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Aim

1. To consolidate the applications of integrated operational amplifier.
2. To learn the way to measure the output characteristic of power supply with negative impedance.
3. To test the transition characteristic of a circuit on oscilloscope.
4. To further understand a RLC second-stage circuit response to a square wave.

Principle

1. Sinusoidal oscillator

(1) Wien-bridge sinusoidal oscillator is made up of a RC series-parallel frequency-selective network (feedback) and an in-phase amplification circuit.

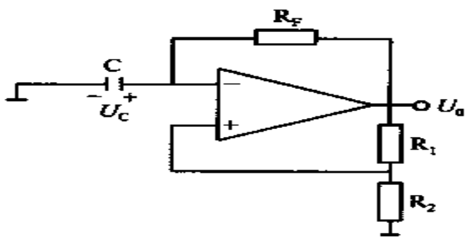
(2) Criterion of oscillation:

UO and Ui in-phase, and UO=3Ui (R2/R1=2)

(3) The characteristic of non-linear resistance of diodes is utilized to realize amplitude stabilization and distortion amendment.

2. Square wave generator

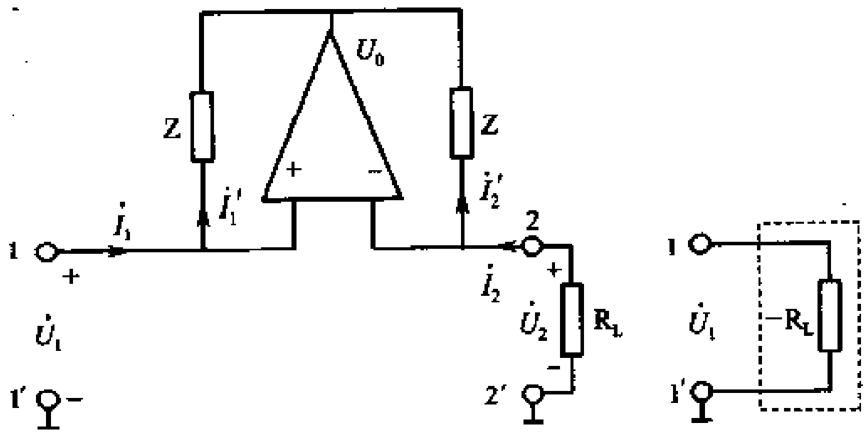
There are many ways to generate square wave. The following circuit is adopted here. R1 and R2 make up the positive feedback. The operational amplifier turns over alternatively, and the capacitor is recharged and discharged alternatively so that periodic square wave is generated.

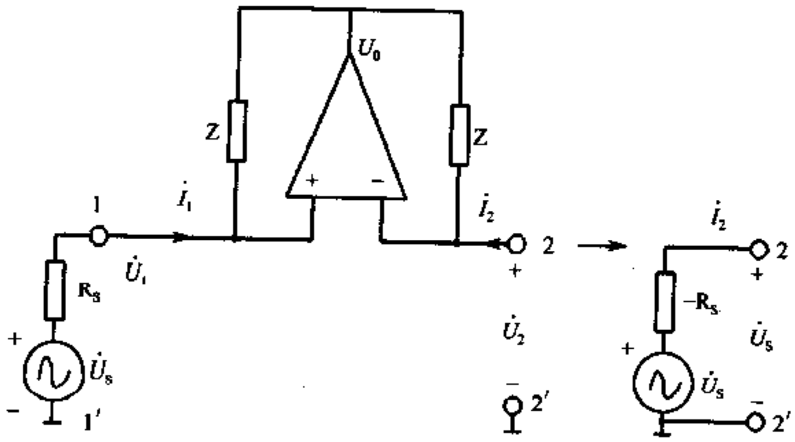


3. Negative impedance converter

The diagram is the circuit of negative impedance converter made up of integrated operational amplifier. On one hand , when load is connected, it is negative impedance (–RL) from 11’ point of view;

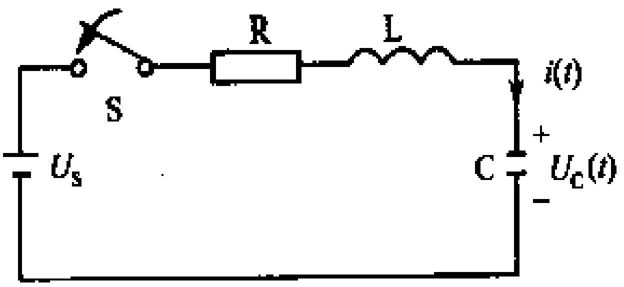
On the other hand, when a power supply Us with internal resistance Rs is added, from 22’ point of view, its equivalent circuit is an active leg with negative impedance –Rs.





4. Zero state response of second stage circuit

This is a typical RLC series second stage circuit. The differential equation satisfies the following: $LC\frac{d^2u_C}{d^2t} + Rc\frac{du_C}{dt} + u_C = U_s$.



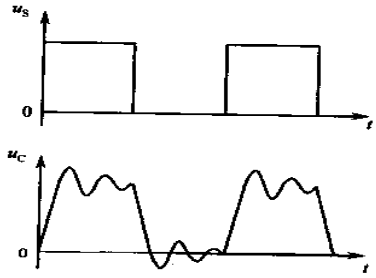
(1) When $R \geq 2\sqrt{L/C}$, the response is non-oscillation.

(2) When $R < 2\sqrt{L/C}$, the response is decreasing amplitude oscillation.

(3) When R=0, the response is persistent oscillation.

(4) When R<0, the response is increasing amplitude oscillation.

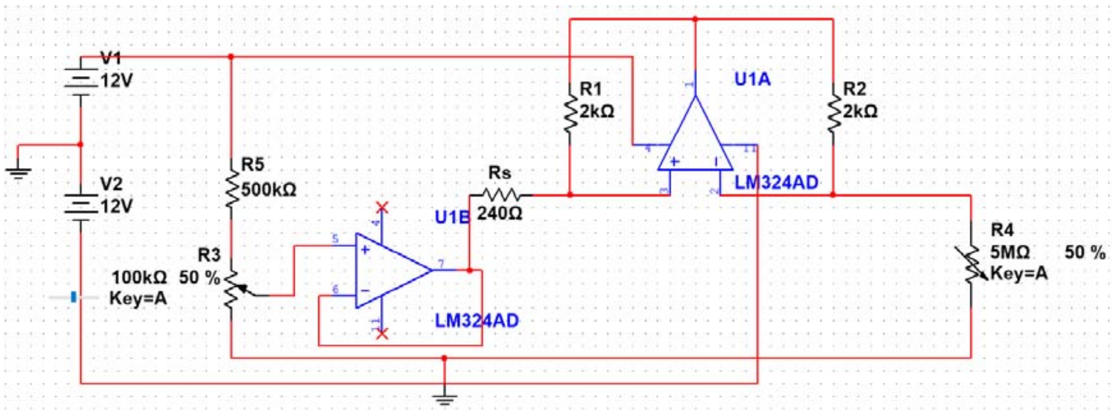
In order for us to see stable and periodic wave, periodic square wave is acted as input of RLC circuit, and the capacitor is recharged and discharged repeatedly so that to get periodic wave from output.



Tasks and circuits

1. Measure the output characteristic of power supply with negative impedance by voltmeter.

- Construct the circuit, $R_L = 240\Omega \sim \infty$, and get 10 points from this range to measure output voltage.
- Fill measurements in a table, and calculate open-circuit voltage and internal resistance.

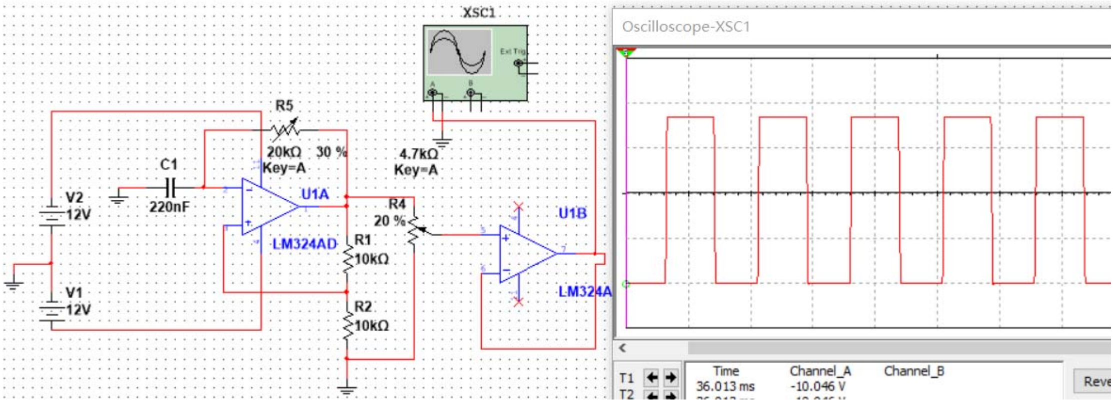


Circuit 1

2. Square wave generator

- Design a square wave generator with adjustable frequency and amplitude, and strong load-bearing capacity.
- Build the circuit and adjust to get the following result: f = 400Hz, Up-p = 1.5V.

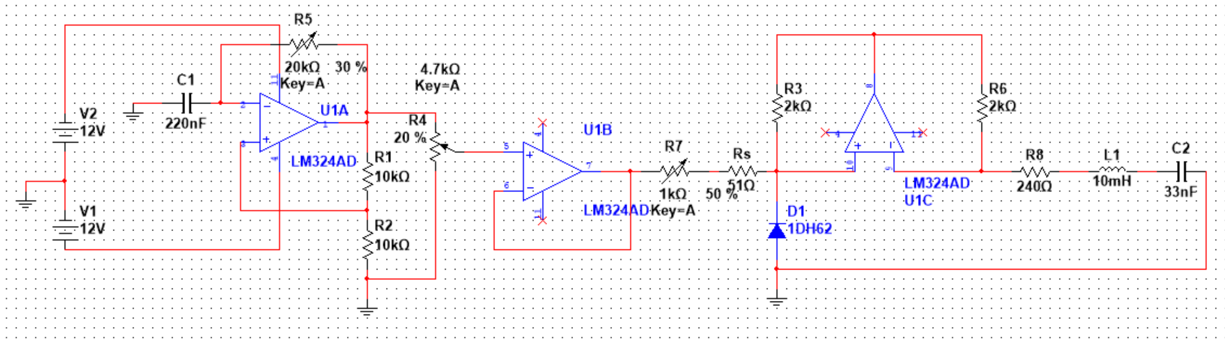
Plot it on square paper.



Circuit 2

3. Build the RLC circuit and observe Uc(t) wave.

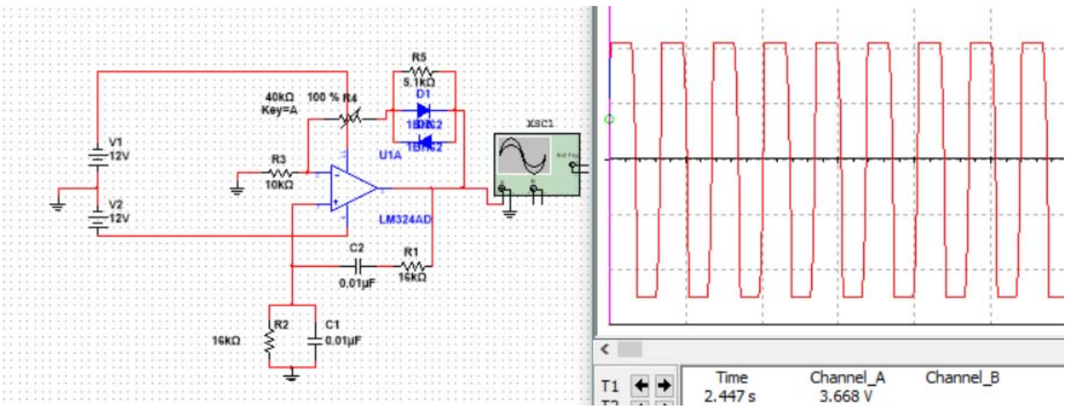
- Adjust the variable resistor, and observe the Uc(t) wave of positive half cycle of square wave.
- Draw 3 kinds of waves of persistent, increasing and decreasing amplitude, indicating corresponding resistance of variable resistor.



Circuit 3

4. Sinusoidal oscillator

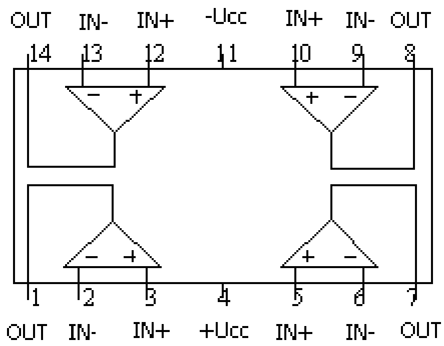
- Build the circuit by LM324.
- Connect close-loop and amplitude stabilization circuits to see whether oscillation is generated. Draw oscillation wave and record its frequency.
- Disconnect amplitude stabilization circuit and observe output wave to further understand its function.



Circuit 4

Instruments

Operational amplifier LM324, Oscilloscope, DC power supply, function generator, digital multimeter



LM324 Pin-out diagram

Data collation and analysis

Task 1 Measure the output characteristic of power supply with negative impedance by voltmeter.

R/Ω	251	370	452	525	593	687	781	977	3340	10000
Uo/V	0.876	1.534	1.791	2.085	2.462	2.341	2.180	1.992	1.610	1.542
I/mA	3.49	4.15	3.96	3.97	4.15	3.41	2.79	2.04	0.48	0.15

I plot Uo-R_L transfer curve as figure 1.

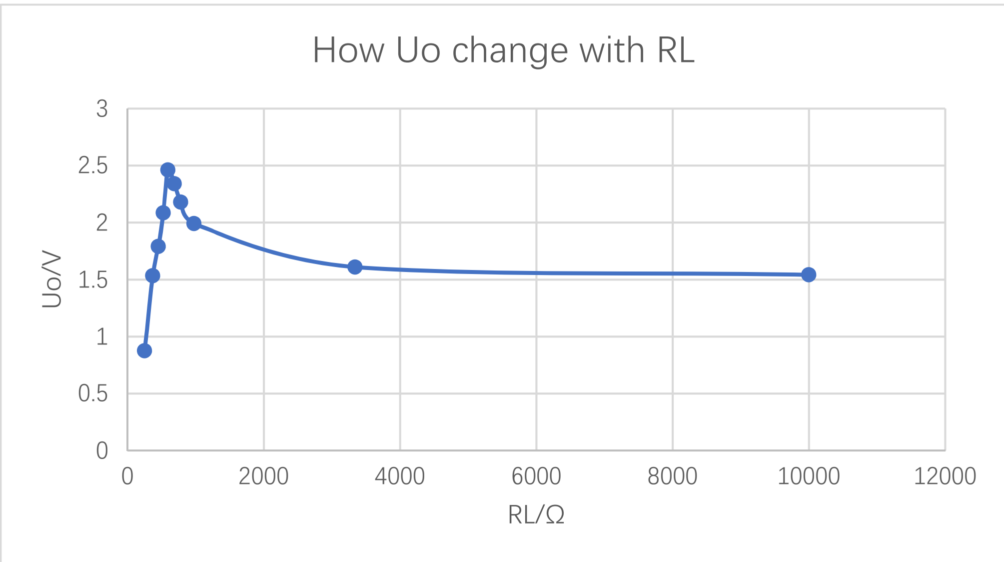


Figure 1 The Uo-R_L curve

Because I measure the voltage and resistance of RL, so according to the formula $\mathrm{Req} = \frac{\Delta U}{\Delta I}$, if ΔU is positive, then positive or negative of Req depends on ΔI. From the figure I find that, before peak(593Ω, 2.462V), when Uo go up, I fall down. So I choose data before peak and plot it at first. After that, I find my data is very bad. To explain it I plot all points on figure 2.

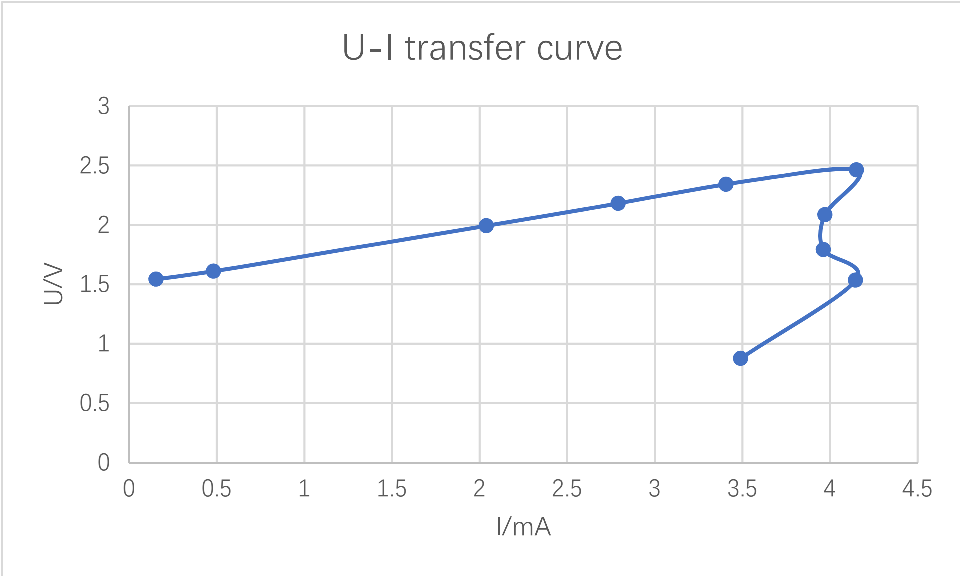


Figure 2 Uo-I transfer curve

My data is so bad that it's impossible to calculate minus resistance. Combined with my real experience when doing experiments, I think the reason is potentiometer. This experiment requires adjust resistance precisely, but my 1KΩ resistance is extremely unstable. When I made a measurement, first I measured the voltage, then I separated potentiometer from circuit to measure its resistance. In this process, resistance of potentiometer would change. In addition, the number of voltage meter jumped up and down every time, also gave error to result.

When resistance get big enough, the influence of instability of potentiometer is getting smaller and smaller, so my U-I curve from zero to peak is good, and when I is zero, U is like 1.5V, just like theory. From figure3, open circuit voltage is 1.5059V. When RL equals to 593Ω, U turn to peak number 2.462V.

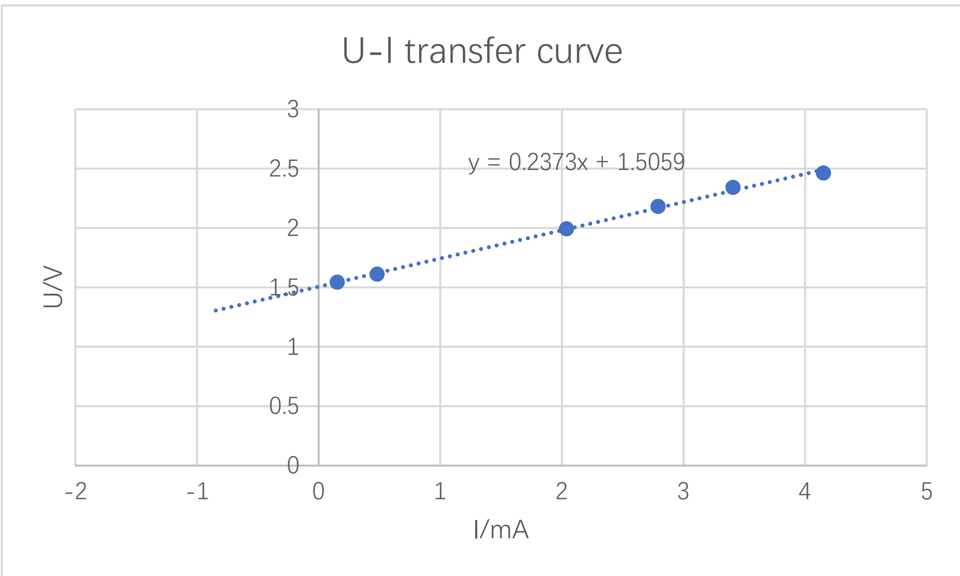


Figure 3 calculate Uo based on U-I curve

Question: Why RL must be bigger than Rs(240Ω)?

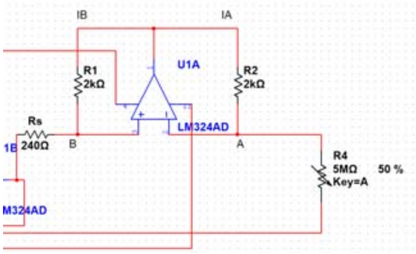


Figure 4

According to figure 4, if RL is too small, because of the character of operational amplifier, IB=IA, so voltage of R4 is very small, UA can’t equal to UB, so virtual short is no longer applicable. As the result, power supply with negative impedance can’t work well.

In this experiment I use voltage follower to make power stable.

Task 2 Square wave generator

I plot square wave on figure 5.

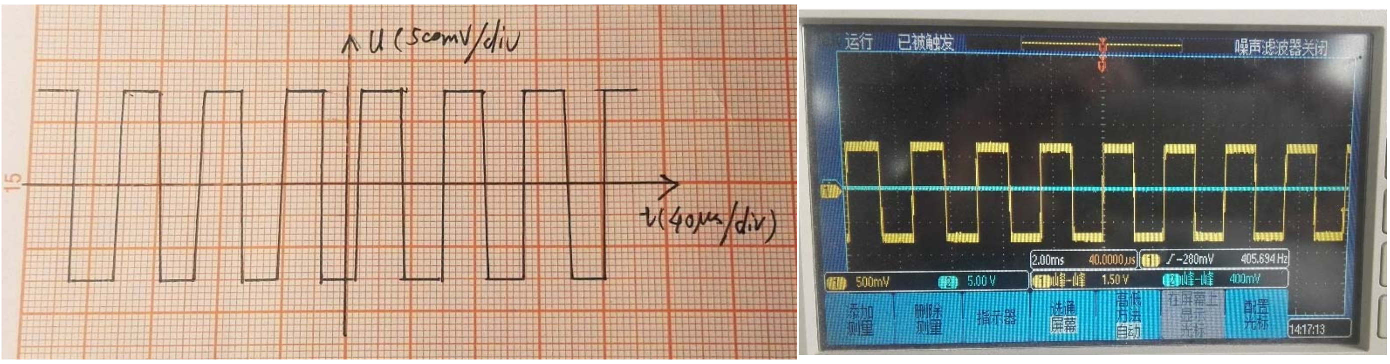


Figure 5 Square wave I generated

Vp-p=1.5V, f=405Hz. Then I lap the triangle circuit based on figure 6.

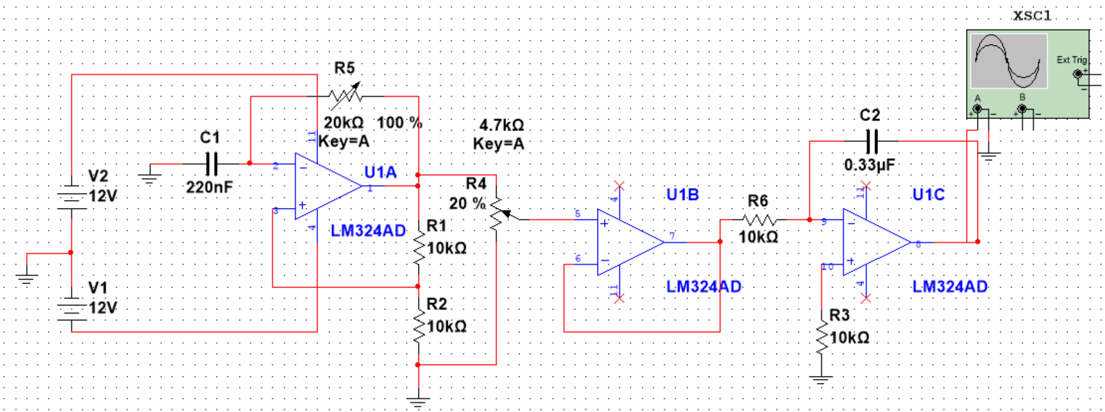


Figure 6 The circuit I transfer square wave to triangle wave

Figure 7 Triangle wave with distortion

Figure 8 Triangle wave after changing Vp-p

In this experiment, at first triangle waveform is like figure 7. I think the reason of distortion is the peak of triangle wave is bigger than maximum output voltage of LM324. So after I turn down the Vp-p of input, I get the normal triangle waveform like figure 8.

Task 3 Build the RLC circuit and observe Uc(t) wave.

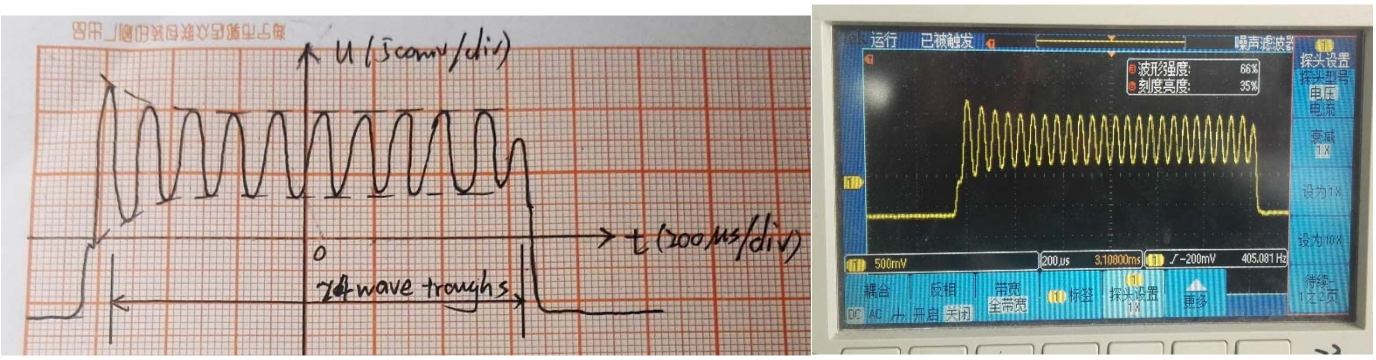


Figure 9 decreasing amplitude oscillation

Decreasing amplitude oscillation is plotted on figure 9. RF is 199.3Ω. R=240Ω-(51Ω+RF)=-10.3Ω. In theory, 0<R< 2√L/C. Measurement error of potentiometer may cause this result.

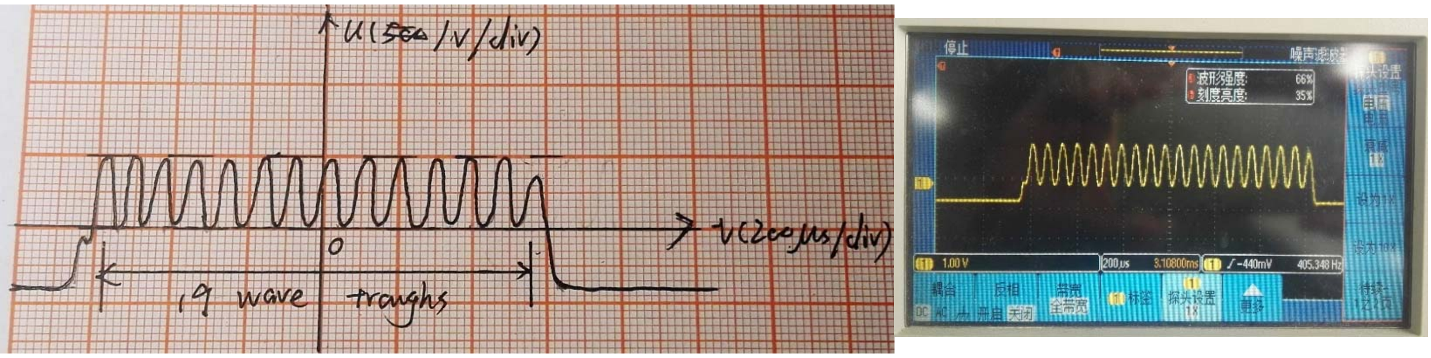


Figure 10 Persistent oscillation

Persistent oscillation is plotted on figure 10. RF is 187.0Ω. R=240Ω-(51Ω+RF)=2Ω. In theory, R should be zero. The measurement is very close to ideal value.

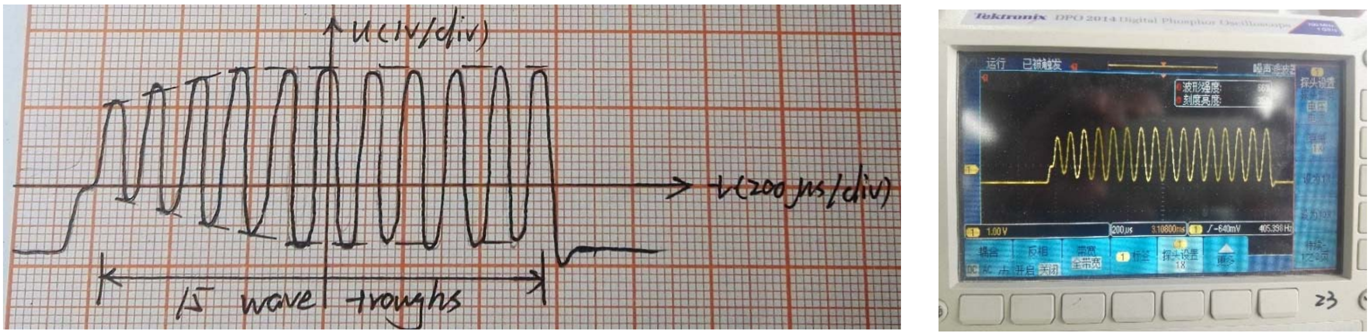


Figure 11 Increasing amplitude oscillation

Increasing amplitude oscillation is plotted on figure 11. RF is 270.1Ω. R=240Ω-(51Ω+RF)=-81.1Ω. In theory, R should be minus resistance. The measured value agrees well with the theoretical value.

Task 4 Sinusoidal oscillator

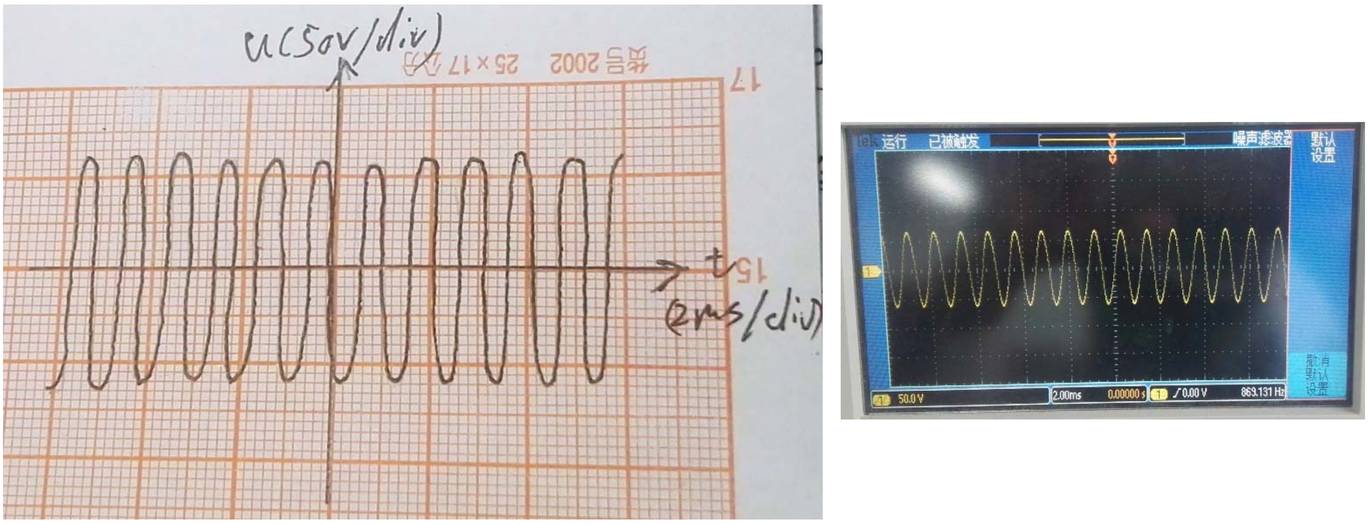


Figure 12 Sin wave form

I plot my sin waveform on figure 12.

Frequency is 869.131Hz, I choose R in selective network is 20kΩ.

According to formula $f = \frac{1}{2\pi Rc}$, if frequency is 1000Hz, C=0.01uF, R should be 16kΩ.

Summary

1. Full preparation is the key factor of successful experiment.
2. The stability of potentiometer is extremely important.