Lab 1: Linear Harmonic Oscillator

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Contents

1 Introduction

This is the first Lab for ECE 395. We are supposed to build a linear harmonic oscillator, with a sinusoidal output of constant amplitude characterized by a single frequency. Here a some targets.

1 Write the equations that describe your system.

2 Find the conditions for oscillation.

3 Calculate the oscillation frequency.

4 Simulate your model.

5 Build your system. Measure its output with the oscilloscope.

2 System design

After reading through the paper about oscillator on "Electronics Tutorials", I choose RC Oscillator Circuit as my main research object. The basic oscillator system should be consist with amplifier and feedback network.(Figure 1)

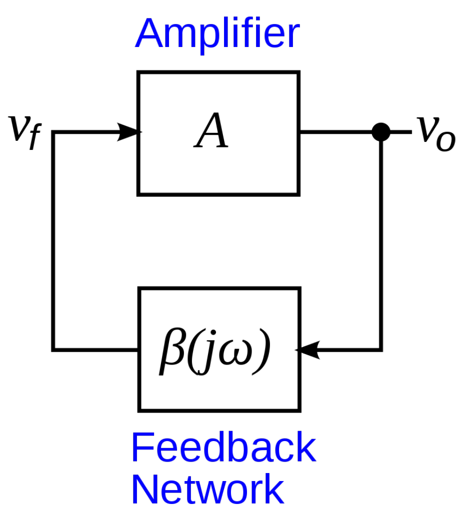

Figure 1: Oscillator system

As for RC Oscillator Circuit, the basic feedback network should look like the circuit below(Figure 2).

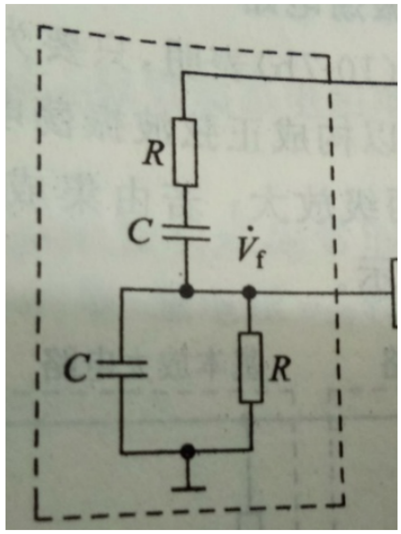

Figure 2: Feedback Network

Set V_f as the input to amplifier and V_o as the output of amplifier. The feedback coefficient F_v :

$$F_v = \frac{V_f}{V_o} = \frac{R//\frac{1}{j\omega C}}{R+\frac{1}{j\omega C}+R//\frac{1}{j\omega C}}$$

$$F_v = \frac{1}{3+j(\omega RC-\frac{1}{j\omega RC)}}$$

Let $\omega_0 = \frac{1}{RC}$, namely, $f_0 = \frac{1}{2\pi RC}$, then we could transfer F_v into:

$$F_v = \frac{V_f}{V_o} = \frac{1}{3+j(\frac{f}{f_0}-\frac{f_0}{f})}$$

Then we could write down amplitude and phase.

$$|F_v| = \frac{1}{\sqrt{9+(\frac{f}{f_0}-\frac{f_0}{f})^2}}$$

$$\varphi_F = \text{-arctan}\frac{(\frac{f}{f_0}-\frac{f_0}{f})}{3}$$

Now I choose LM324 as amplifier, here is my design circuit.(Figure 3)

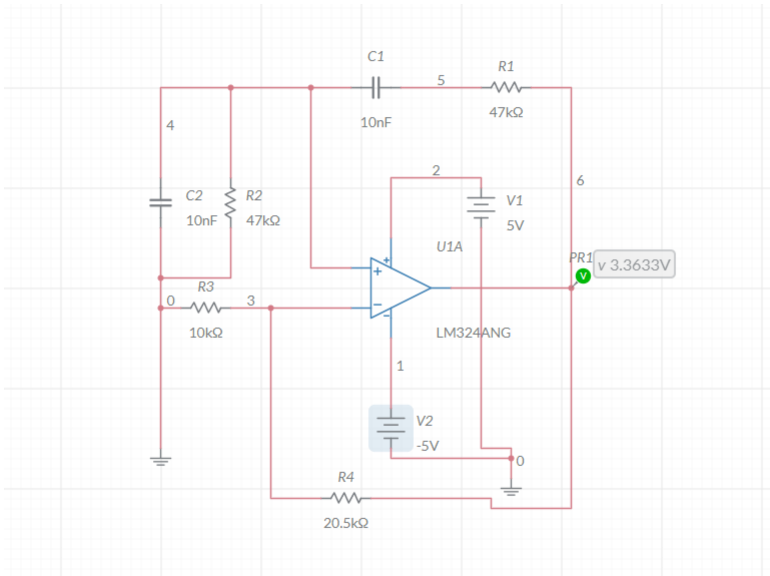

Figure 3: RC Oscillator Circuit

If we want produce oscillate. The amplifier coefficient A_v should a little bit bigger than three. Because When the amplifier coefficient is less than 3, the negative feedback branch is dominant and the circuit cannot vibrate; when the amplifier coefficient is greater than 3, the positive feedback branch is dominant, and the circuit starts to start and is not stable. The oscillation will continue to increase, eventually causing the op amp to saturate, and the output waveform is a clipped sine wave. Only when the amplifier coefficient is exactly 3, the positive and negative feedback are in balance, and the oscillation circuit will continue to work stably. At this time, the frequency is equal to f_0.

$$A_v = \frac{V_o}{V_f} = 1 + \frac{R_4}{R_3} >= 3$$

$$R_4 >= 2R_3$$

3 Simulation

Then I use the circuit in Figure 3 to simulate on Multisim Live (an online circuit simulator). I got the output signal below. (Figure 4)

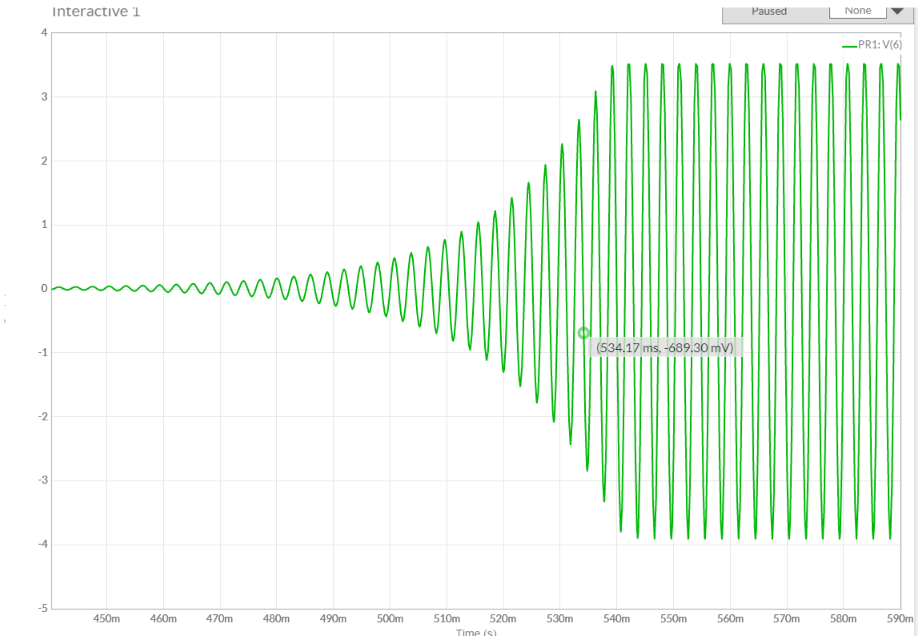

Figure 4: Output Signal

The period of this signal T = 1.2034s-1.2004s = 0.0030s, so the frequency is 333.3Hz. Theoretically, frequency $= \frac{1}{2\pi RC} = \frac{1}{2\pi 47k*10n} =$ 338.8Hz. Above all, the result from simulation is similar to result from calculations.

4 Real system

Then I build this system on breadboard.(Figure 5, Figure 6)

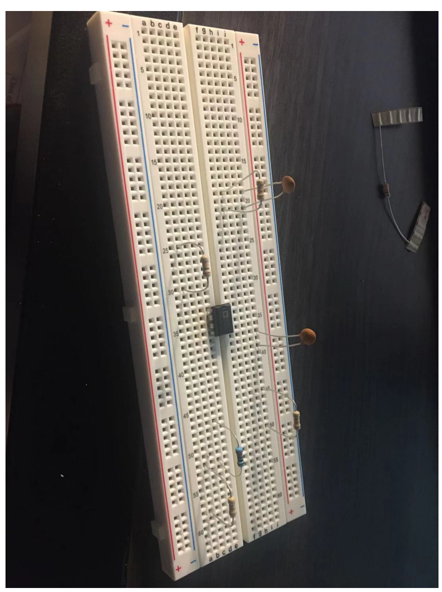

Figure 5: Half Build

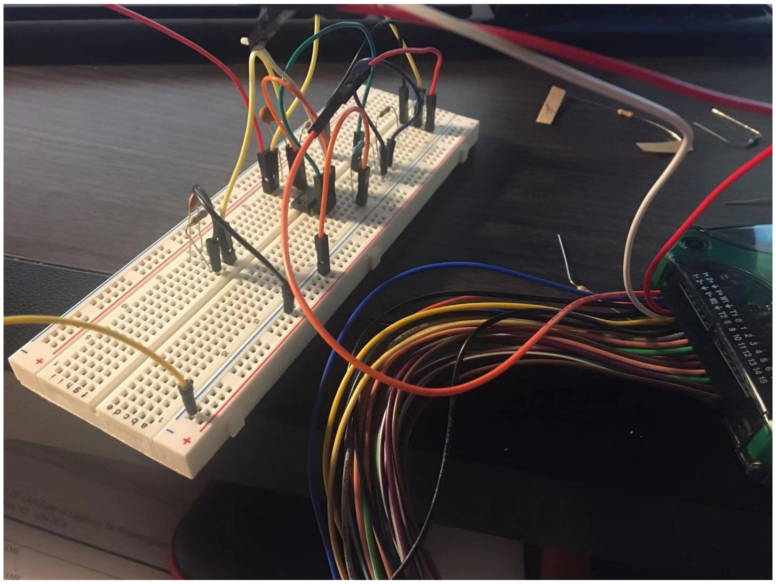

Figure 6: Full Build

After building, I connected voltage source into circuit, and read the voltage signal by oscilloscope. However, because capacitors, wires, and op amps are not ideal, when I set R_4 value to 20.470kΩ (20kΩ + 470Ω), the output is zero. That's means the amplifier coefficient is less than 3, so I rise the value of R_4 to 21KΩ. Now the output signal looks good.(Figure 7)

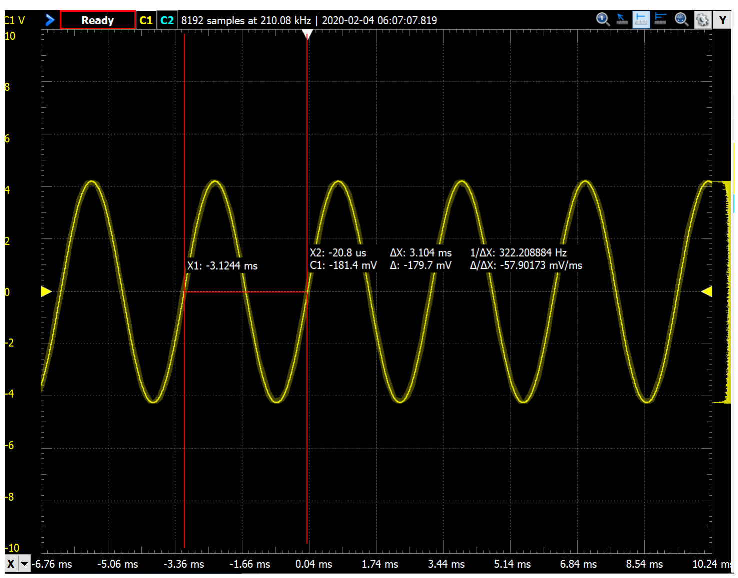

Figure 7: Output Signal

We can find it is similar to sine wave, and the period of it is 3.104ms, so the frequency is 322.16Hz, which is similar to calculate frequency (333.3Hz) and simulate frequency (338.8Hz).

Finally, I change R_4 to 30KΩ (A_F>3) and 20KΩ (A_F<3) to observe the condition of oscillation. Theoretically, when R_4 = 20KΩ, the output should equal to zero, when R_4 = 30KΩ the output waveform should be a clipped sine wave. Here are my output signal diagram(Figure 8, Figure 9), in line with expectations.

Figure 8: 20K (A_F<3) Output Signal

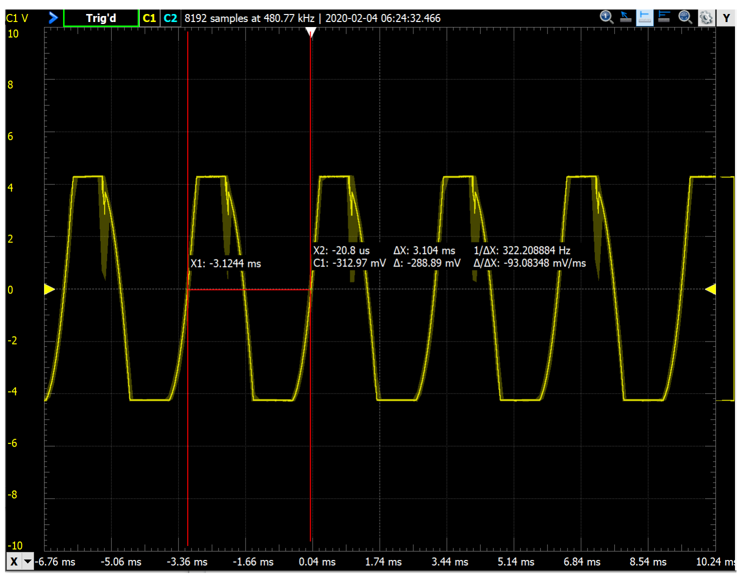

Figure 9: 30K (A_F>3) Output Signal

5 Conclusion

Now we can make a conclusion, as for RC oscillator, the output frequency is depend on feedback network, while the output amplitude is depend on amplifier. What's more, the amplifier coefficient should a little bit bigger than three to get an perfect sine output signal.

6 Recommendation

Next time, I may add some amplitude stabilization measures, maybe we could add two antiparallel diode in parallel with R_4

7 Reference

"RC Oscillator Circuit - The RC Oscillator Tutorial." *Basic Electronics Tutorials,* 11 June 2019, `www.electronics-tutorials.ws/oscillator/rc_oscillator.html`