EE233 Circuit Theory Lab2

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EE233 Circuit Theory

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Abstract—Lab2 verifies the characteristics of the voltage follower and the summer. The speed to response to large signals causes finite slope of the output wave., thus causes the distortion. The voltage follower blocks noises and keeps the output voltage equal to the input. The summing amplifier combines several inputs and output in a single output. Each potentiometer serves as volume controller. The audio sounds are not purely sinusoidal wave and the sound of high-frequency sine wave sounds terrible and sharp.

Keywords: operational ampliier(op-amp), voltage follower, summing amplifier, audio mixer

I. INTRODUCTION

The main purpose of lab2 is to build, analyze and measure characteristics of circuits with op-amps (operational amplifiers). There are two parts in this lab, with the first one requiring to build a voltage follower circuit and analyze its characteristics and the second one aiming to build a summing amplifier as well as analyze characteristics of it. We use a square wave as input in the first part and sinusoidal wave as input in the second one. Especially, our phones or laptops are utilized to send signals to the circuit when building an audio mixer in the second part. We may finally gain knowledge of the basic ways to analyze a circuit with op-amps in this lab.

II. LAB PROCEDURE

A. Voltage follower

In part 1, we mainly focus on an electronic chip named LM348N. We use it to build a voltage follower circuit. And we use a function generator which provides square wave as input voltage. As for measurement, we use the oscilloscope. Channel 1 is used to measure the input voltage while Channel 2 is used to measure the output voltage. For the generator and the oscilloscope, we should connect the negative port to the ground.

B. Summing amplifier

We use the same electronic chip in part 1. To build a summing amplifier circuit, we add four variable resistances and set them in 100 Ohm. We also use a capacitor whose value is 22pF. In the first task of this experiment, we use a function generator which provides sine wave as input voltage. In the second task, we use our cellphone and computer playing music as input, and a speaker to play the audio sound. Every time for measurement, we use the oscilloscope. Channel 1 is used to measure the input voltage while Channel 2 is used to measure the output voltage.

III. EXPERIMENTAL PROCEDURE

A. voltage follower

1) Testing procedure: Firstly, we use an amplifier, a function generator and two power supplies to build the circuit in Figure 1.

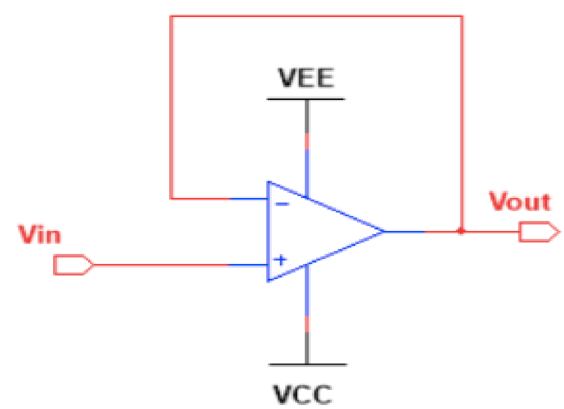

Fig. 1: The diagram of voltage follower circuit

We connect the anode of a power supply to the cathode of another one and connect these two electrodes to ground. Then we generate the voltage of 12V on the anode of the second supply and -12V on the cathode of the first supply. Then we set the frequency and the amplitude of the input to 3kHz and Vpk-pk=20V. We use the oscilloscope to display the input and the output voltage.

Next, we clear all measurements and change the signal to a sinusoidal wave. The frequency is changed to 1kHz and Vpk-pk equals to 6V after setting the generator. To make the output wave distorted, we increase the frequency of the input signal gradually, which aims to find the approximate upper bond of frequency due to the slew rate limitation.

Finally, we clear the measurements again and set another required sinusoidal wave with an amplitude of 100mV and a frequency of 10Hz. After checking the output signal to ensure the reliability of the circuit, we record the peak to peak of the input and output voltage and calculate the gain of the voltage follower. In the final step, we modify the frequency of the input signal and keep the amplitude constant. In the meantime, we record the amplitude of the output voltage and calculate the gain and compare it to the half of the low-frequency gain. In the end, we find the approximate value of the target frequency.

2) Analysis of the results: Analysis of the results

1. As Figure 2 shows, the waveform of input is a step wave, which verifies that our input is correct.

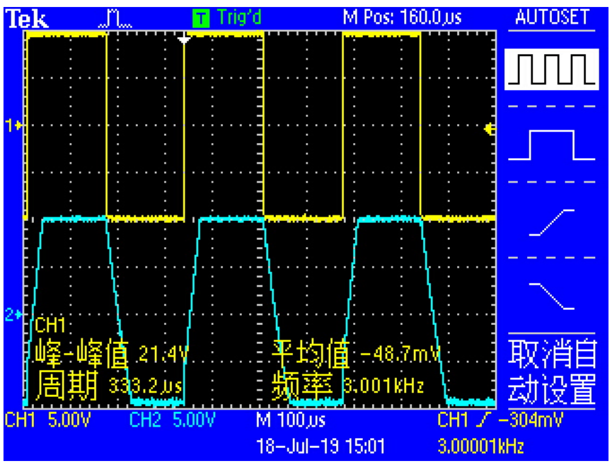

Fig. 2: The waveform of input signal

In the meanwhile, the waveform of output also is a step wave but with a positive slope appeared, indicating the correctness of the circuit connection and a non-ideal op-amp is used.

The data we measured and calculated are listed below:

$$\Delta t = 42.4\ s \qquad slew\ rate(SR) = \frac{\Delta V}{\Delta t} = 0.47\ V/s$$

According to the references, typical value of slew rate is 0.5 V/ s, so the error is 5.6%, which is within the error tolerance. In addition, the waveform displayed by the oscilloscope is very similar to that shown in the datasheet, indicating our correctness of the circuit connection.

2. The frequency for the onset of the distortion is 25.8 kHz. The theoretical value calculated in the prelab is about 26.5 kHz, so the error is 2.6%. Obviously, this result is also within the error tolerance.

3. The data we measured are listed below:

$$A_{10Hz} = 1.07 \qquad f_{\frac{1}{2}low-frequency\ gain} = 1.58MHz$$

However, the value of the frequency at which the voltage gain is half of the low-frequency gain simulated in the Multisim is about 5.61MHz. After the analysis of the results, there are following factors that can cause the error

- the connection between components in the circuit
- the non-ideal components in the circuit (non-ideal op-amp, inaccurate capacitor, etc)
- the frequency is high (on the order of MHz), so the wires and non-ideal components will make a non-negligible difference

B. Summing Amplifier

1) Testing procedure: In the first task, we build a summing amplifier circuit as Figure 3 shows.

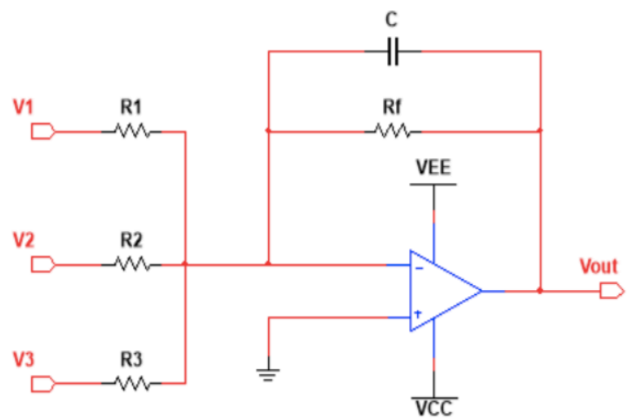

Fig. 3: The diagram of summing amplifier circuit

We use power supplies to make VCC equals 12 V, and VEE equals -12 V. Then set the function generator to provide input voltage one as a sinusoidal waveform which is $\cos(2\pi \times 1000 \times t)$V, while input two and three are all 0 voltage. Set four variable resistances are all 100 kΩ and the capacitor is 22 pF. Then we adjust the input frequency of input 1 from 10 Hz and varying it using 1-2-5 sequence up to 1 MHz while keeping the amplitude the same. We use the oscilloscope Channel 2 to measure the output voltage and record the amplitude of the output signals.

In the second task, we use our mobile phones to play music as input signals to the three input point and a speaker to play the audio sound. Then display the output signal voltage with oscilloscope.

Finally,we use supplemental audio sounds as three input tracks as the function of this summing amplifier is to mix sounds of all tracks in the audio mixer. .Adjust the four potentiometers to hear the change in the output sound.

2) Analysis of the results: 1. According to circuit in Figure 4.1, we set the function generator to provide a sinusoidal wave with amplitude of 1 V and frequency of 1 kHz as V_1. Then, We ground the second and third input signals to achieve $V_2 = V_3 = 0$. Then, we sweep the frequency of V_1 from 10 Hz and varying it using 1-2-5 sequence up to 1 MHz while keeping the amplitude

the same. What we need to record is amplitudes of the output signals. The original datas of the experiment are as follows.

TABLE I: Original data of one-stage RC circuit

f/Hz	$\|V_{out}\|/V$	f/Hz	$\|V_{out}\|/V$	f/Hz	$\|V_{out}\|/V$
10	1.03	1k	1.03	100k	0.50
20	1.03	2k	1.03	200k	0.29
50	1.03	5k	1.02	500k	0.14
100	1.03	10k	1.02	1M	0.047
200	1.03	20k	0.98		
500	1.03	50k	0.77		

Therefore, we plot the amplitude of the output voltage in terms of frequency in Figure.

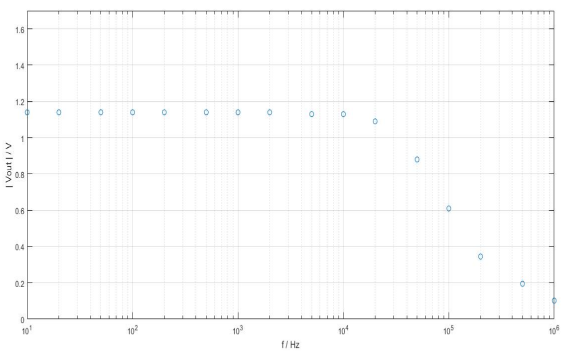

Fig. 4: The amplitude of the output voltage in terms of frequency

To make the results more obvious, we plot both the theoretical values and measured values in terms of frequency in Figure 5

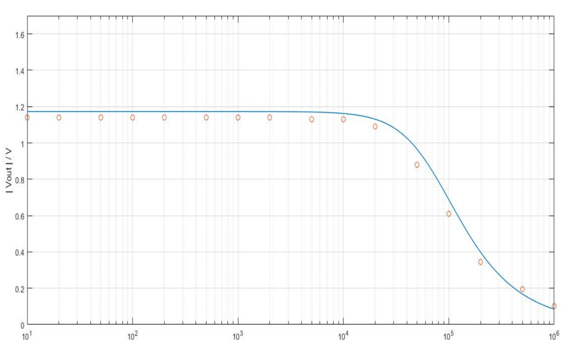

Fig. 5: Comparison of theoretical and measured values

According to Figure 5, the experimental results are in good agreement with the theoretical results. With the increase of frequency, the amplitude of voltage decreases constantly, and the gradient of the curve is slow, then urgent, and finally tends to slow down.

In addition, we find that when the frequency of the input signal is small (< 10kHz), the amplitude of the output signal remains almost stable and stabilizes around 1.03; when the input signal frequency is large(> 1MHz), the amplitude of the output signal decays rapidly and finally stabilizes below 0.1, which indicates that the circuit has the characteristics of a low-pass filter and has a strong shielding effect on the high-frequency signal.

2. We use supplemental audio sounds from three mobile phones as input signals to V_1, V_2andV_3. Then, we can hear the audio sound with the speaker. The sound we heard is a combination of video sounds played by three mobile phones and the three sound components are mixed together.Then, we displayed the output signal voltage with oscilloscope. Figure 6shows the waveform of the audio sound.

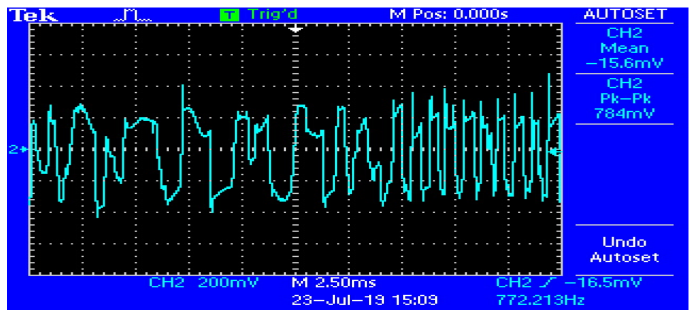

Fig. 6: The waveform of the audio sound

From the waveform of the video sound, it is not a periodic signal, and its waveform is obtained by superimposing the waveforms of the three sound signals. Obviously, it is not a pure sinusoidal signal either.

In order to figure out what the sine wave sounds like, we set the function generator to provide a sinusoidal wave with frequency of 1 kHz as the only input to summing amplifier. Then, we displayed the waveform of output signal with oscilloscope and Figure 7 shows the waveform of the audio sound. With the help of the speakers, we can clearly hear the sound of a sine wave, it sounds very sharp and stretches continuously

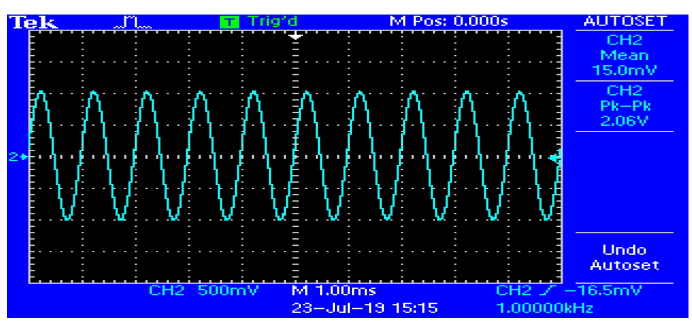

Fig. 7: The waveform of the sine wave

3. We used supplemental audio sounds as three input tracks as the function of this summing amplifier is to mix sounds of all tracks in the audio mixer.. Then, we adjusted the four potentiometers. We have found that adjusting the potentiometer affects the volume of the three sound components. Specifically, the smaller the

$R_i(i = 1, 2, 3)$ is, the greater the volume of the sound component from the $V_i(i = 1, 2, 3)$ in the output signal is. The value of R_f affects the volume of the three sound components at the same time. The larger the R_f, the higher the volume of all the sound components in the output signal. It is explained as follows:

From the equation that we obtained in 3.3.1

$$V_{out} = \frac{-R_f}{1 + j\omega R_f C}(\frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3})$$

$$-(\frac{1}{R_f} + j\omega C)V_{out} = \frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3}$$

We can conclude that, $R_i(i = 1, 2, 3)$ only affects the proportion of $V_i(i = 1, 2, 3)$ in V_{out}, and R_f affects the proportion of V_1, V_2 and V_3 in V_{out}. In general, we adjust the value of the potentiometers to change the ratio of the resistance in the input loop to the resistance in the feedback loop, thereby affecting the amplification of each supplemental audio sound, which affects the volume of each sound component in the output signal.

IV. CONCLUSIONS

The finite speed to respond to large input signal causes the finite slope of the output waveform. This will distort the output wave if frequency becomes large enough. Just as its name implies, the voltage follower serves as a buffer and blocks noises from other parts of the circuit. When frequency increases, the gain of the voltage follower keeps constant in low-frequency section and falls in high-frequency section. This reflects the frequency response characteristics of the voltage follower. Summing amplifier has the function of combine all input waves to one and output it. We hear the shrill sound of the 1kHz sine wave and the combination of sounds form several peripheral devices. We also find that the wave of the audio signal is not pure sinusoidal wave and every resistor in the circuit controls the volume of the input or output respectively.

V. APPENDIX

After we heard the voice of a sine wave with a frequency of 1000Hz, we heard a sharp voice. Then we change its frequency ,we find out the pattern of the sound is that with a lower frequency, the voice tend to be low and deep. And when the frequency get higher, the voice becomes sharper and hard to be heard. When the frequency reaches about 20000 Hz, we barely hear nothing. (We did a research on Internet and its just the upper limit of human's ability of hearing. That's amazing !!)