Lab 3: Using Opamps for amplification and Filtering

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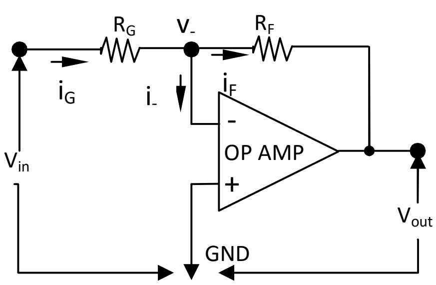
Purpose:

1) Understand the working characters of operational amplifier.
2) Get to understand the operation principle of inverting amplifier and non-inverting amplifier, be able to theoretically analyze the gains of both inverting and non-inverting amplifier.
3) Be able to use operational amplifier im1458 to build the inverting amplifier and non-inverting amplifier and Sallen Key low-pass filter, and use oscilloscope to test the responses of amplifiers with the input sine wave.

Content:

1) Build the inverting amplifier as following on breadboard



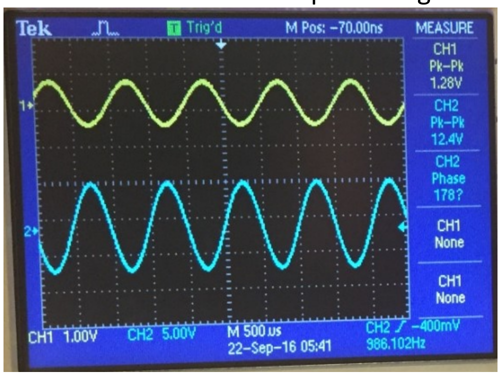
Circuit 1

In the circuit 1, V_{in} is sin wave with frequency of 1kHz, fed by power supply, the op-amp was powered with voltage of +12V and -12V, $R_G = 1k\Omega$, $R_F=10k\Omega$， the circuit built in lab is show in the above picture (right)

Theoretical analysis:
Because inverting input point of op-amp is virtual ground, then $V- \approx 0$,
Because the input impedance of op-amp is infinite, then $i_- \approx 0$
According Ohm's Law: $i_G=(V_{in}-V_-)/R_G=V_{in}/R_F$; $i_F=(V_- - V_{out})/R_F=-V_{out}/R_F$
According Kirchoff's current law: $i_G=i_F$
So $V_{in}/R_G=-V_{out}/R_F$, Hence $Gain=V_{out}/V_{in}=-R_F/R_G$ Namely **Gain=$-R_F/R_G$**
We can decide the gain of this inverting amplifier by choose the proper ratio of resistance of R_F and R_G
In circuit 1, $G=-R_F/R_G=-10k\Omega/1k\Omega=-10$ (that means the peak-peak value of output voltage is ten times as many as the peak-peak value of input voltage, and phase of output voltage is opposite to the phase of input voltage)

Observation:

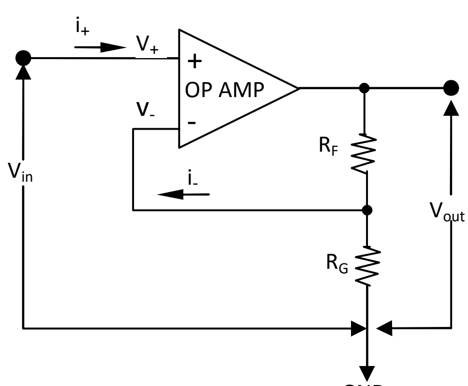
The measured waves of input voltage and output voltage in the lab are shown as following picture



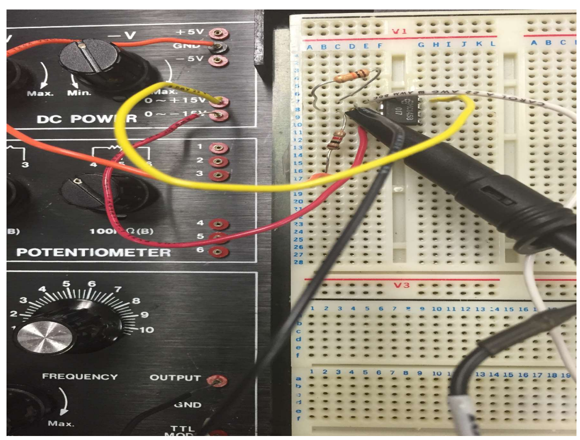
In the left picture, it can be seen that, V_{in}=1.28v, V_{out}=12.4v, then $G=V_{out}/V_{in}$=9.69≈10; the phase of V_{out} is178 degree, almost 180degree.

Based on the lab results recorded during lab, it can be concluded that These lab results are agree with the theoretical results of previous circuit of inverting amplifier. So the lab results are valid and the theoretical analysis is also correct

2) Build the non-inverting amplifier as following on breadboard



Circuit 2



In the circuit 2, V_{in} is sin wave with frequency of 1kHz, fed by power supply, the op-amp was powered with voltage of +12V and -12V, R_G = 1kΩ, R_F=10kΩ， the circuit built in lab is show in the above picture (right)

Theoretical analysis:

Because the input impedance of op-amp is infinite, then $i_-≈0$, $i_+≈0$,

For $i_-≈0$, according to ohm's law, $V_-/R_G=V_{out}/(R_G+R_F)$, so $V_{out}/V_-=(R_F+R_G)/R_G=1+R_F/R_G$

For $i_+≈0$, $V_{in} \approx V_+$, because for op-amp, $V_+=V_-$, so $V_{in}\approx V_-$

Based on above equation, there is $V_{out}/V_- \approx V_{out}/V_{in} \approx 1+R_F/R_G$

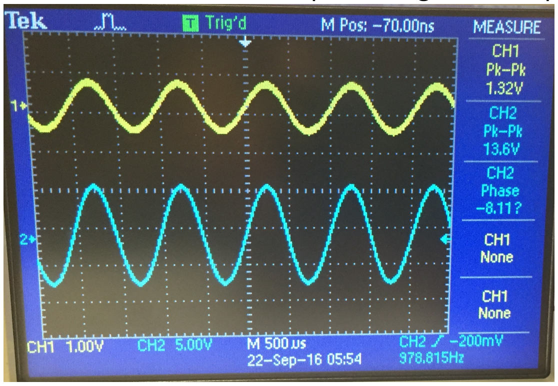
Hence Gain=$V_{out}/V_{in}=1+R_F/R_G$, Namely **Gain=$1+R_F/R_G$**

We can decide the gain of this non-inverting amplifier by choose the proper ratio of resistance of R_F and R_G

In circuit 2, G≈$1+R_F/R_G$≈1+10kΩ/1kΩ≈11 (that means the peak-peak value of output voltage is eleven times as many as the peak-peak value of input voltage, and phase of output voltage is as same as the phase of input voltage)

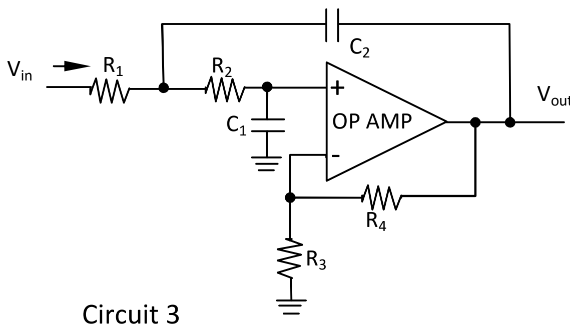
Observation:

The measured waves of input voltage and output voltage in the lab are shown as following picture



In the left picture, it can be seen that, V_{in}=1.32v, V_{out}=13.6v, then G=V_{out}/V_{in}=10.3≈11; the phase of V_{out} is-8.11 degree, almost 0 degree.
Based on the lab results recorded during lab, it can be concluded that These lab results are agree with the theoretical results of previous circuit of inverting amplifier. So the lab results are valid and the theoretical analysis is also correct

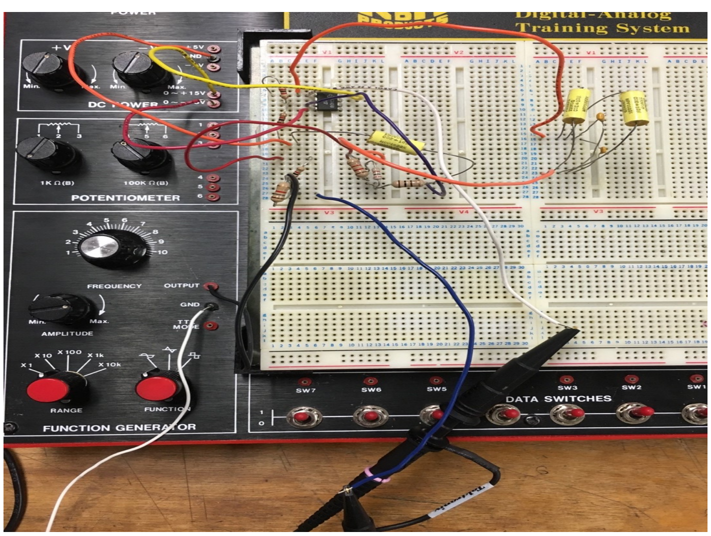
3) Build the Sallen Key low-pass filter on the breadboard as following



Circuit 3

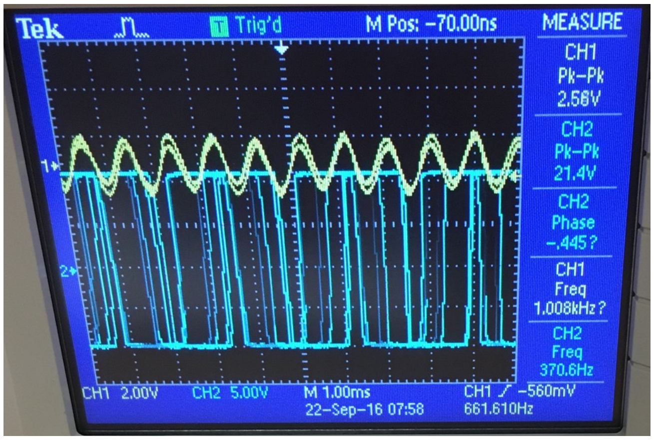
In the left circuit, V_{in} is sin wave, fed by power supply, R_1 = 3.8KΩ, R_2 = 3.9KΩ, C_1= 22nF, C_2 = 150nF, R_3=1kΩ, R_4=10kΩ

The circuit 3 was set up on breadboard as the following



Observation:

The waves of output voltage and phase are shown in the following pictures.

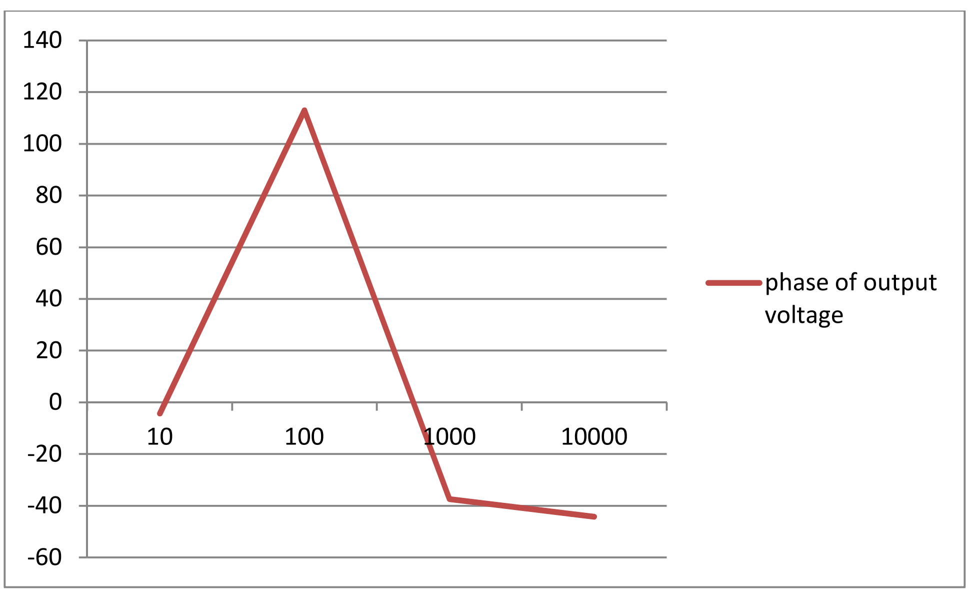


In the left observation, the output voltage were clipped off at the top of wave, this may be due to the fact that the output voltage (peak to peak value) were more than the supply power of op-amps (+12v— -12v), so the value of output voltage(peak to peak) were limited at about 24v.

The wave of output voltage appeared to be quite different from the wave it supposed to be. This may be caused by the imperfection of breadboard, the resistors and capacitors used in the circuit did not have the marked values.

The input voltage(peak-peak), output voltage (peak-peak), frequency of input voltage, frequency of output voltage and the phase of output voltage are measured at the frequency of 10Hz, 100Hz, 1000Hz and 10000Hz in the following table.

Frequency(Hz)	Input Voltage (v)	Output Voltage (v)	Input Frequency (Hz)	Output frequency (Hz)	Phase of output Voltage
10	7.28	21.4	10.52	361.9	-4.28
100	7.68	21.4	106.4	439.7	113
1000	2.88	21.4	1101	357.4	-37.4
10000	5.28	21.4	10420	367.5	-44.2



Analyze:

In the Sallen key low-pass filter above, R_4=10kΩ, R_3=1kΩ, so the gain of circuit is $1+R_4/R_3=11$, the gain is so high that the wave of output voltage seriously distorted and the filter can not work properly.

Conclusions:

From the lab 3, I got to know characters of op-amps; the circuit structure of inverting op-amps and non-inverting proportional op-amps; how to calculate the gain of inverting proportional op-amps and non-inverting proportional op-amps; how to design the inverting and non-inverting proportional op-amps; understand the characters of Sallen Key low-pass filter circuit.

What I did in Lab 2

1)build the circuit according to lab direction;
2)tune the oscilloscope;
3)take measures using oscilloscope;
4)analyze the problem and try to solve the problem

What my lab partner did:

1) Cooperate me with building the circuit;
2) Select the resistors and capacitors and measure them with multimeter;
3) Check the circuit and record the measurements;
4) Analyze the problem encountered during lab with me and try to solve the problem