Summary Report - Week 2

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1. Introduction

The overall objective of week 2 was to analyse and observe how inverting, non-inverting and differential configurations of Op-Amp can be used as summing amplifiers.

2. Simulation Details

- Environment: LTspiceXVII
- Important Component(s): LM741 Op-Amp IC
- Reference Book: Gayakwad[1]

2.1 Inverting Configuration

A. Theory

Inverting configuration with two or more inputs, (in our case two) namely v_a, v_b can be used as summing amplifier, scaling amplifier or averaging amplifiers depending on the relationship between the feedback resistor R_F and the input resistors R_a, R_b. Note that we will restrict our discussion to analysis of inverting Op-Amps used as summing amplifiers but formulation of scaling and averaging amplifiers using inverting Op-Amp will be shown in brief.
The circuit's function is verified by examining the expression for the output voltage V_0 obtained by using Kirchoff's current equation at node V1 as shown in fig[1][a]. The equation is shown below:

$$I_a + I_b = I_B + I_F$$

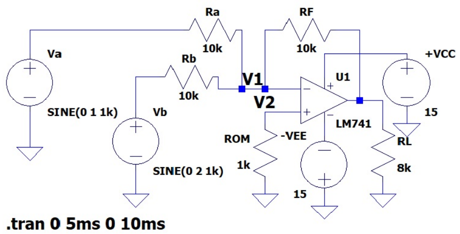
where,
I_a, I_b = Current flowing through the branches with voltage source v_a, v_b
I_F= Current flowing through the RF resistor in the feedback loop.
I_B= Current flowing into the Op-Amp which is ideally 0 Ampere since the input resistance and gain of ideal Op-Amp is infinite.
Therefore

$$V_a/R_a + V_b/R_b = -V_0/R_F$$
$$V_0 = -(V_a R_F/R_a + V_b R_F/R_b)$$

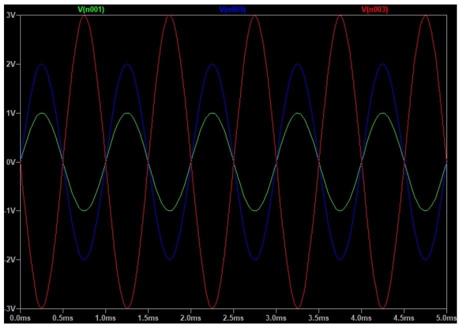
In case of summing amplifier, $R_a = R_b = R$ and the equation can be changed as,

$$V_0 = -R_F/R(V_a + V_b)$$

This shows that the output voltage is equal to the negative sum of all the inputs times the gain of the circuit R_F/R.Hence the circuit is called a summing amplifier.
If each output voltage is amplified by a different factor, that is, R_a, R_b are different in values, then the circuit is called a scaling or weighted amplifier.



(a) Circuit



(b) Waveform

Figure 1: Summing Amplifier using Inverting Configuration of Op-Amp

B. Schematic and Waveform

In fig[1][a], we have two sinusoidal inputs provided to the inverting terminal of the Op-Amp of amplitudes 1V and 2V respectively having a common frequency of 1kHz. All the resistances R_a, R_b, R_F were set to 10kΩ, thus making the gain of the circuit unity. Hence the output voltage becomes equal to the negative sum of all input voltage as shown in fig[1][b] which exactly satisfies the equation obtained above.
Also notice that an offset minimising resistor R_{OM} is used to minimize the effect of input bias currents on the input offset voltage.

2.2 Non-inverting Configuration

A. Theory

If input voltage sources and resistors are connected to the non-inverting terminal of the Op-Amp, the circuit can be used either as summing or averaging amplifiers depending on the appropriate selection of the values of resistors R_F and R_1.
We know that for an ideal Op-Amp the gain and the input resistance is infinite. Hence to obtain the expression of output voltage of the non-inverting Op-Amp with multiple inputs we use the superposition theorem at the non-inverting terminal to obtain voltage V1, which is,(Refer to [1] for complete derivation)

$$V1 = (V_a + V_b)/2$$

Hence the output voltage V_0 is

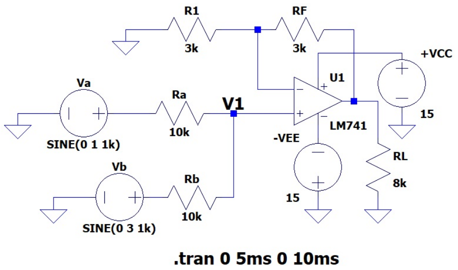
$$V_0 = (1 + R_F/R_1)(V_a + V_b)/2$$

If the gain of the non-inverting amplifier $1+R_F/R_1$ is equal to the number of inputs, the output voltage becomes equal to the sum of all input voltages. Hence, the circuit is called a non inverting summing amplifier.

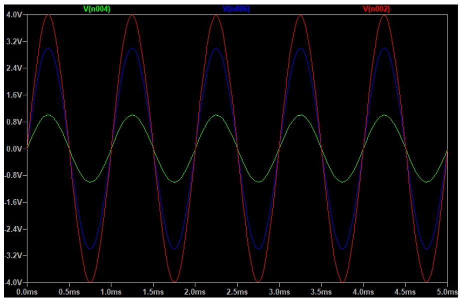
If the gain of the non-inverting amplifier is not equal to the number of inputs, then depending on the requirements we can set the gain to a specific value to make it act as an averaging amplifier.

B. Schematics and Waveform

In fig[2][a], we have two sinusoidal inputs provided to the non-inverting terminal of the Op-Amp of amplitudes 1V and 3V respectively having a common frequency of 1kHz. We set the values of the resistors R_F and R_1 in such a way that the gain of the Op-Amp becomes equal to the number of inputs, which in our case is 2. Hence the output voltage becomes equal to the sum of all input voltage without any phase change as shown in fig[2][b] which exactly satisfies the equation obtained above.

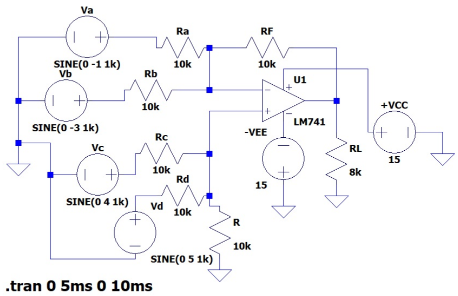


(a) Circuit

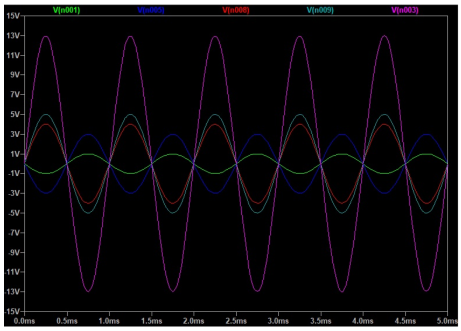


(b) Waveform

Figure 2: Summing Amplifier using Non-inverting configuration of Op-Amp



(a) Circuit



(b) Waveform

Figure 3: Summing Amplifier using Differential Configuration of Op-Amp

2.3 Differential Configuration

A. Theory

Using a basic differential configuration of Op-Amp, a four input summing amplifier can be constructed if two additional input sources are connected, one each to the inverting and non-inverting input terminals through resistor R as shown in fig[3][a].
The output voltage equation for this circuit can be obtained by using superposition theorem at each of the input terminals. Refer to [1] for complete derivation.
Thus the output voltage obtained by using superposition theorem due to all four input voltages is given by,

$$V_0 = -V_a - V_b + V_c + V_d$$

Thus the output voltage is equal to the sum of the input voltages applied to the non-inverting terminal plus the negative sum of the input voltages applied to the inverting terminal.

B. Schematics and Waveform

In fig[2][a], we have four sinusoidal inputs, two input signals of amplitude -1V and -3V provided to the inverting terminal of the Op-Amp and two input signals of amplitudes 4V and 5V provided to the non-inverting terminal of the Op-Am, with all the input signals having a common frequency of 1kHz. We set the values of the resistors $R_a = R_b = R_c = R_d = R_F$= 10k$\Omega$ in such a way that the gain of the Op-Amp becomes equal to unity. Hence the output voltage becomes equal to the sum of the input voltages applied to the non-inverting terminal plus the negative sum of the input voltages applied to the inverting terminal as shown in fig[3][b].

References

[1] Ramakant A. Gayakwad. *Op-Amps and Linear Integrated Circuits.* PHI Learning Pvt. Ltd., New Delhi-110001, fourth edition, 2010.