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Title: Study of op-amp amplifiers and analyze the frequency response of an inverting amplifier. .

Abstract:

This experiment deals with operational amplifier with inverting and non-inverting configurations. Closed-loop gains of these amplifiers are observed and recorded.

Introduction:

In this experiment the op-amp is used as one of its important applications-making an amplifier. An amplifier is a circuit that receives a signal at its input and delivers an undistorted larger version of the signal at its output. All circuits in this experiment have an external feedback resistor is connected between the output terminal and (-) input terminal. This type of circuit is called a negative feedback circuit. There are many advantages obtained with negative feedback, all based on the fact that circuit performance no longer depends on the open-loop gain of the op-amp, A_{OL}. The resulting circuit now has a closed-loop gain or amplifier gain, A_{CL}, which is independent of A_{OL}.

Frequency response is an important concept in many areas - within electrical engineering and outside of electrical engineering. An amplifier receives an input signal and increases the magnitude of the output. It is desired to have the output with no distortion and the increase in magnitude to be constant for the expected range of frequencies. Failure to amplify all frequencies in the bandwidth uniformly will distort the wave shape. So it is important to have an idea about the frequency response to understand the range of frequencies until which the system can amplify signals without any distortion. In case of different filters, to understand the filter's bandform it is necessary to realize its frequency response characteristics which can compensate any lose incurs in the output signal compared to the input signal of the system.

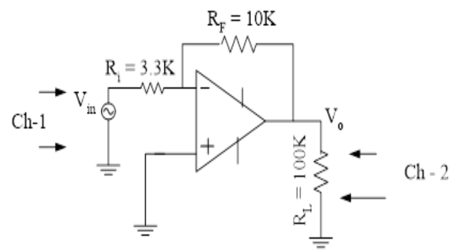
The main objective of this experiment is

- To be familiarized with basic op-amp amplifiers.
- To learn how to measure both practical and theoretical gain of the amplifieers.
- To be familiarized with the concepts of frequency response characteristics and behavior of an inverting amplifier.

Theory and Methodology:

An amplifier is a circuit that receives a signal at its input and delivers an undistorted larger version of the signal at its output. While designing inverting and non-inverting amplifier, an external feedback resistor is connected between the output terminal and (-) input terminal. The closed loop amplifier gain depends on external resistors only.

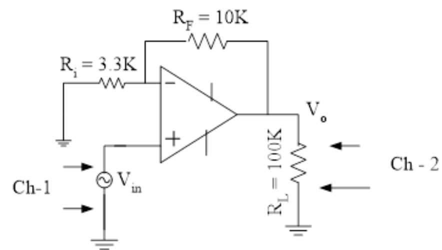
An inverting amplifier inverts and scales the input signal. As long as the op-amp gain is very large, the amplifier gain is determined by two stable external resistors (the feedback resistor R_F and the input resistor R_{in}) and not by op-amp parameters which are highly temperature dependent. The operational amplifier is in a negative-feedback configuration, its internal high gain effectively fixes the inverting (i.e., −) input at the same 0 V (**ground**) voltage of the non-inverting (i.e.,+) input. Relative differences between the R_{in} and R_F resistors allow small voltages on one side of the network to generate large voltages (with opposite sign) on the other side of the network. Thus, the device **amplifies** (and inverts) the input voltage. The output voltage of the device is as follows:



$$V_{out} = -\frac{R_F}{R_{in}} V_{in}$$

Fig. 1. Inverting amplifier and its output

The input impedance of the non-inverting amplifier circuit is infinite since no current flows into the inverting input. Output impedance is zero since output voltage is ideally independent of output current. Closed loop gain can be any desired value above unity. Such circuits are widely used in control and instrumentation where non-inverting gain is required.



$$V_{out} = \left(1 + \frac{R_2}{R_1}\right) V_{in}$$

Fig. 2. Non-inverting amplifier and its output

Frequency Response Curve

The frequency response curve is a visual representation of the quality of the amplitude of a system or device over the frequency, and is used to characterize the dynamics of the system. The response graph depicts such curve which will have a vertical axis labeled as amplitude or gain in decibels (dB) and a horizontal axis labeled as frequency in hertz (Hz). A frequency response curve for a low-pass filter is shown in Figure [9.1] to understand different terms which are used in a response curve. The range of low frequencies passed by a low-pass filter within a specified limit is called the passband of the filter. And the range of frequencies which are blocked by the system is called stop band. Bandwidth is the range of frequencies that can be amplified to more than $\frac{1}{\sqrt{2}}$ (70%) of the maximum value.

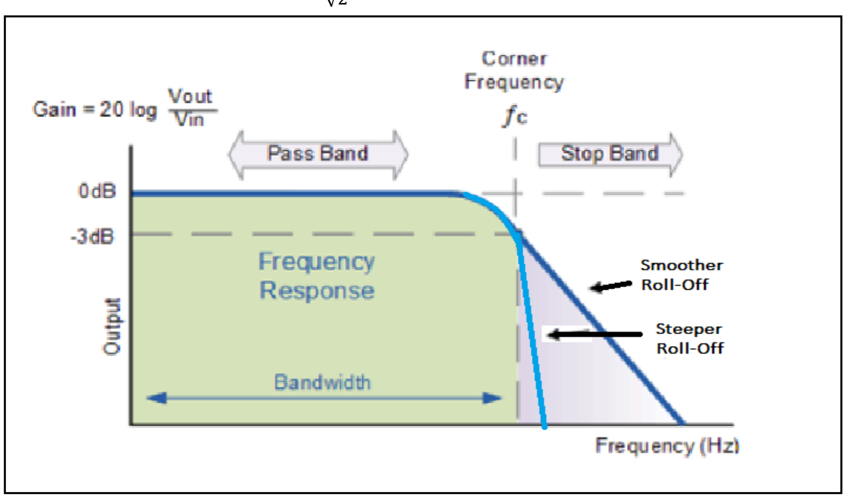


Fig. 3: Frequency response of a low-pass filter.

The corner frequency, f_c, as illustrated in Fig. 1 is the point from where the slope of the curve starts and also at which the output voltage is 70.7% of the maximum. It is also called the cutoff frequency, break frequency, critical frequency or – 3 dB frequency because the output voltage is down 3 dB from its maximum at this frequency. Slope/Roll-off is a term, refers to how sharply the frequencies are cut when filtering. A *sharper* or *steeper* slope or roll-off means that frequencies are cut very close to the set cut-off value while a 'smoother' slope means that some of the frequencies before or after the cut-off frequencies (depending on the bandform(low-pass or high-pass)) will still be existed.

The main function of an operational amplifier is to amplify the input signal. When there is no feedback between input and output then it is called open loop operation. The gain of the op-amp device under this condition is defined as the open loop gain and for an ideal op-amp it is infinite but typical real values range from about 20,000 to 200,000. Hence an op-amp is almost never used in this way, because an open loop gain is too high to be useful.

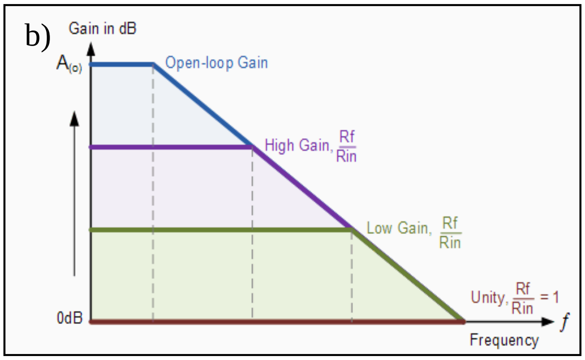


Fig. 4: Frequency response of an inverting amplifier

Therefore feedbacks are used to adjust the gain of an amplifier. An inverting amplifier uses a negative feedback where a fraction of output signal is feed back through feedback resistor R_F to the input connected at the negative input terminal, shown in figure [9.2(a)]. The effect produces a closed loop circuit where the gain is called closed loop gain (gain=$-\frac{Rf}{Rin}$). For **negative feedback**, the fed-back voltage is in "anti-phase" to the input voltage which causes reduction in the overall gain of the amplifier. By changing the value of R_F it is possible to control the overall gain of the inverting amplifier, illustrated in figure [9.2 (b)]. Positive feedback is also used but in non-inverting amplifier where overall gain of the system is increased.

Pre-lab Homework:

P1. Op-amp inverting configuration:

The circuit in **Fig. 1** will be used to provide gain and increase the amplitude of the voltage source, V_S. However, the V_S and R_S are not shown in the circuits. Note that V_S and R_S represent the Thevenin equivalent of the function generator; the source resistance is $R_S = 50\Omega$.

P1.1 What is the voltage gain V_{out} / V_{in} from the amplifier input to V_{out}?
P1.2 What is the voltage gain V_{out} / V_S from the signal source to V_{out}? Note that this gain will be slightly different due to the effect of the source resistance Rs. What is the advantage of having the Thevenin source resistance Rs << R1?
P1.3 What would be the expected values of V_{out} / Vin for R_2 = 100 kΩ?

P2. Op-amp circuit design

P2.1 Design an amplifier having a voltage gain of approximately -500, with an input impedance of 1 kΩ.
P2.2 For an input sine wave of 50 mV peak at 100 Hz, what (ideally) would the output of your amplifier be?

P2.3 For an input of zero volts DC, what (ideally) would the DC output of your amplifier be?

P3. Noninverting Amplifier Design

P3.1 Design a high input impedance amplifier with gain of +100. To reduce power dissipation, minimum resistance value should be 1 kΩ.

P3. Do the simulation of all the circuits given and attach it with the lab report to justify the experimental outcomes.

Apparatus:

1. IC µA741 – (quantity: 1)
2. Resistor 3.3 kΩ, 10K, 47 kΩ, 100 kΩ – (quantity :1each)
3. DC power supply– ±30 V (quantity :1)
4. Function generator- 25 V_{p-p}, 1 MHz (quantity: 1)
5. Oscilloscope- 20MHz/100MHz, 2 Ch, 400 V_{p-p} (quantity: 1)
6. Connecting wire
7. Multimeter-(quantity: 1)

Precautions:

1. Use appropriate biasing for the op-amp.
2. Do all the simulations using PSpice.

Experimental procedure:

Gain Measurement for inverting and noninverting amplifiers:

1. Implement the circuits shown in Fig. 1.
2. Use a sinusoidal voltage of 1 kHz, 500 mV_p as input signal.
3. Observe both input and output voltages simultaneously with oscilloscope.
4. Draw wave shapes on graph papers.
5. Complete table 1.
6. Repeat step 1 to 5 with R_F = 47 kΩ.
7. Repeat step 1 to 6 for Fig. 2.

Table I Gain of an op-amp with different R_F for both inverting and non- inverting configuration

Configuration	R_F (kΩ)	V_{in} (V)	V_{out} (V)	Gain, A_{CL} = ($-R_F/R_i$)	Gain, A_{CL} = V_{out}/V_{in}	Comment*
Inverting	10					
	47					
				Gain, A_{CL} = ($1+R_F/R_i$)		
Non-inverting	10					
	47					

***Comment:** Percentage change should be calculated to measure deviation. Possibility of probable errors could be mentioned.

Frequency response analysis for inverting amplifier

1) Implement the circuit of Fig. 1
2) Use a sinusoidal signal of $100mV_p$ as input.
3) Observe both the input and output signals simultaneously in the oscilloscope.
4) Calculate gain for different frequencies and fill up table – 2.
5) Plot gain vs. frequency curve in semi – log graph paper.
6) Calculate cut off frequency, band width and roll off.

Table II Gain of an op-amp with different value of frequencies

Frequency (Hz)	Vi	Vo	Gain (Vo / Vi)	Gain (dB) = 20 Log (Vo/Vi)
10				
100				
1K				
10K				
100K				
1M				

Discussion and Conclusion:

Compare the theoretical gain of individual amplifier setup with the observed gain and comment. Discuss what you have learned about designing inverting and non-inverting amplifiers and verify the extent to which the goals of this experiment have been achieved.
Explain the characteristic of each circuit based on their frequency response curve. Determine the value of bandwidth, cut-off frequency and roll-off from the response curves for all of these three circuits. Discuss the critical steps where majority of the errors were associated with the experimental data you have obtained in table II. If you have obtained any unexpected output or response curve describe the most plausible reasons. Suggest any approaches which you find more suitable to accomplish the objective of this experiment.

Reports:

1. Complete the Data Table.
2. Draw the Graphs in the Graph paper.
3. Discuss the Experiment as a whole.
4. How inverting amplifier is used as a "trans-resistance amplifier" circuit?
5. From the frequency response curve obtained comment on the behavior of an inverting amplifier.

References:

1. Single supply op-amp circuit collection, http://instruct1.cit.cornell.edu/courses/bionb440/datasheets/SingleSupply.pdf
2. Op-amps for everyone, http://focus.ti.com/lit/an/slod006b/slod006b.pdf
3. Wayne Storr., (1999-2013). Electronics tutorial about passive low pass filter. Available: http://www.electronics-tutorials.ws/filter/filter_2.html. Last accessed 25th Sep 2013.
4. Wayne Storr., (1999-2013). Electronics Tutorial Summary of Operational Amplifiers. Available: http://www.electronics-tutorials.ws/filter/filter_2.html. Last accessed 25th Sep 2013.