Non_Inverting_Amplifier -- Overview

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Non-Inverting Amplifier

Objectives:

After performing this lab exercise, learner will be able to:

- Understand and comprehend working of opamp
- Design & build non-inverting amplifier of desired voltage gain using opamp
- Establish relationship between input and output signal
- Practice working with measuring equipment and laboratory tools like digital oscilloscope, signal generator, multimeter and power supply
- Use digital oscilloscope to debug/analyze the circuit

Equipment:

To perform this lab experiment, learner will need:

- Digital Storage Oscilloscope (TBS1000B-Edu from Tektronix or any equivalent)
- Power Supply (2231A-30-3 Power Supply from Keithley or any equivalent power supply capable of supplying +/- 10V DC)
- Signal generator (AFG1000 from Tektronix or equivalent) for providing AC input to circuit
- Multimeter
- Electronic Components
    - Opamp 741 / TL082 or equivalent - as single IC or as part of any analog circuit kit (like ASLK board from TI)
    - Resistor (1K, 2.2K, 4.7K and 10K ohms)
- BNC cables
- Breadboard and connecting wires

Theory / Key Concepts:

Before performing this lab experiment, it is important to learn following concepts:

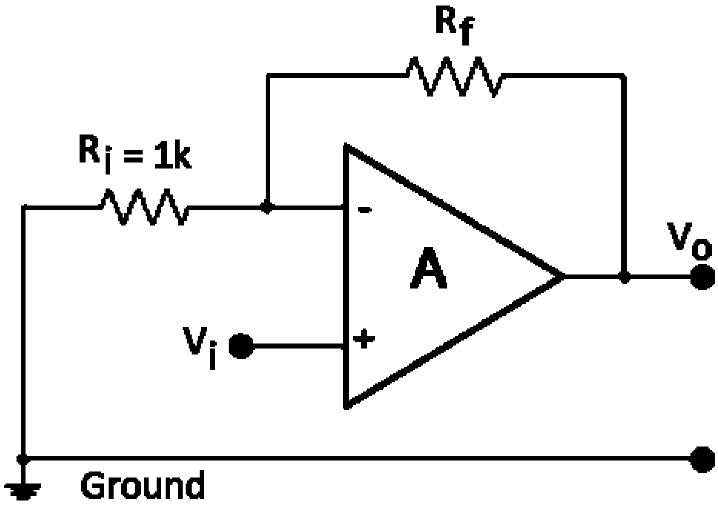
- An opamp is a high-gain differential amplifier with very high input impedance. Very high open-loop gain allow for creating amplifiers with stable gain using feedback.
- In a non-inverting amplifier, the input signal is applied to non-inverting pin of the opamp and there is no phase inversion between output and input.
- The amplification factor or gain can be controlled by external components - Resistor in feedback path R_f and input path R_i.
- Voltage gain of the non-inverting amplifier is given by:

$$Gain = 1 + \frac{R_f}{R_i}$$

- While designing opamp circuits, one has to be careful about output saturation - if the gain or input signal is high enough to drive output beyond the supply voltages (V_{cc} and V_{ee}), the amplifier goes into saturation and output is limited to supply voltages.

Circuit Design:

Learner can use the theoretical design rules to calculate the circuit component values:



- For non-inverting amplifier, the gain depends on R_f and R_i. .
- followign table shows the estimated (and expected) voltage gain for different combinations of R_f and R_i :

Rf (kΩ)	Ri (kΩ)	Voltage Gain Estimated
1.0	1.0	2.00
2.2	1.0	3.20
4.7	1.0	5.70
10.0	1.0	11.00

Non_Inverting_Amplifier -- Procedures

Step 1

Check Your Understanding:

Before performing this lab experiment, learners can check their understanding of key concepts by answering these?

- For a non-inverting amplifier circuit, if $R_f < R_i$, the phase shift between output and input will be:
  - 0 Degree
  - less than 90 Degree
  - 180 Degree
  - more than 90 Degree
- For a non-inverting amplifier circuit, is it possible to reduce the voltage to less than 1?
  - Yes, by choosing R_f less than R_i
  - Yes, by choosing $R_f = R_i$
  - No. Not possible.
  - Yes, by choosing R_f = 0 ohms
- In a non-inverting amplifier circuit the ratio of R_f to R_i is 10. What will be the effect on its voltage gain if positions of R_f and R_i are

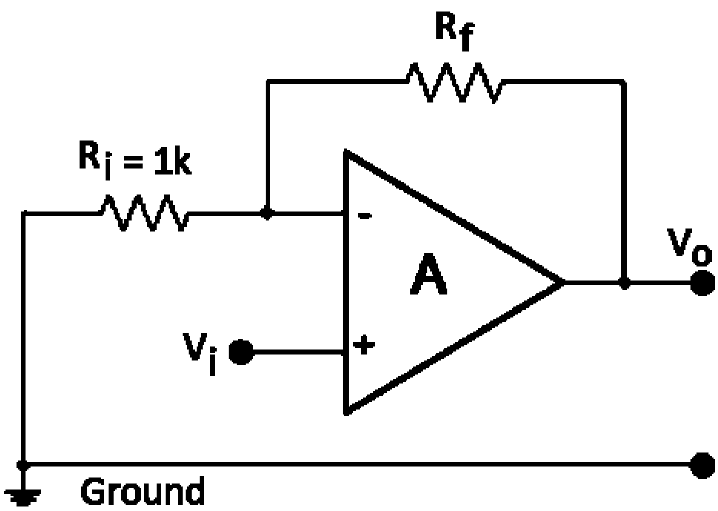
interchanged?

- Gain will be 10 times of its previous gain
- Gain will remain unchanged
- Gain will reduce to 1/10th of its previos value
- Gain will increase by 10

Step 2

Circuit diagram / Connection Details

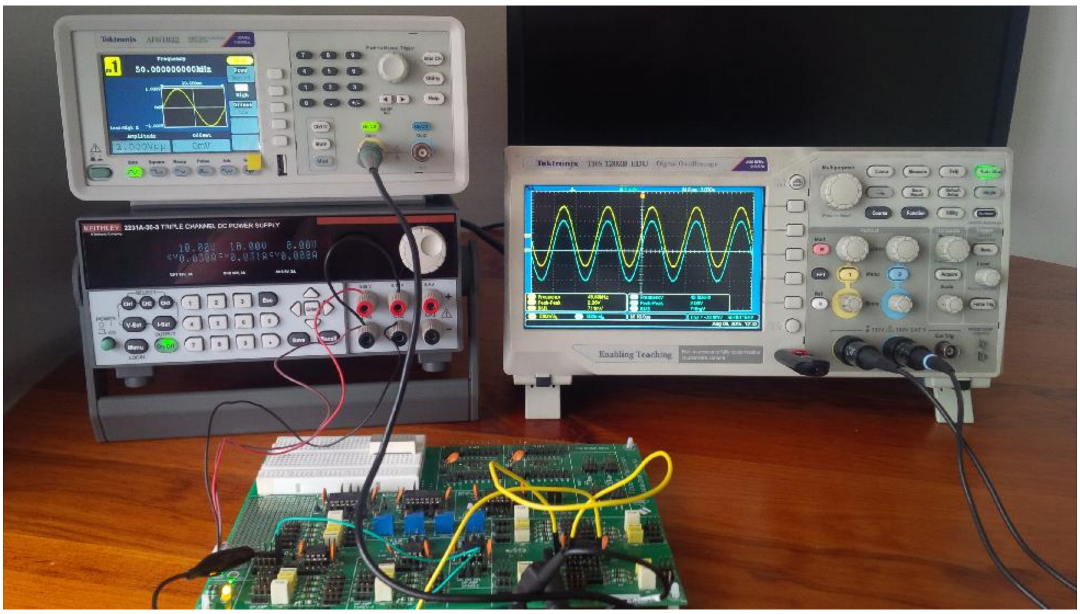
- Using the jumper / connecting wires prepare the circuit as shown below - Choose R_f = R_i = 1k ohm:



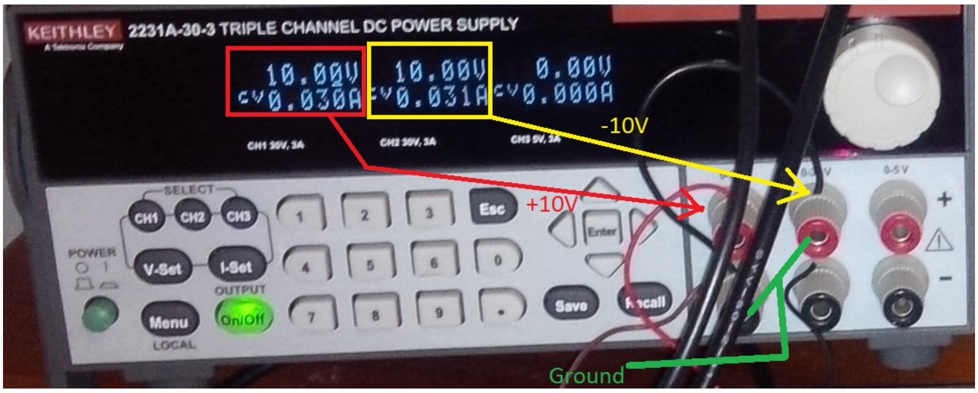
Step 3

Experiment Setup

- Make the arrangement as shown in figure below -



- Turn on the DC power supply, ensure that +/- 10V is applied to ASLK /Opamp circuit
  - You can use '2 channels' of 2231A DC power supply in independent mode and combine negative one channel with positive of other to be treated as common or ground point



- Use signal from AFG/signal generator to feed to opamp input
- Probe at input and output pins of the amplifier to view the signal on oscilloscope - View input on channel 1 and output on channel 2

Step 4

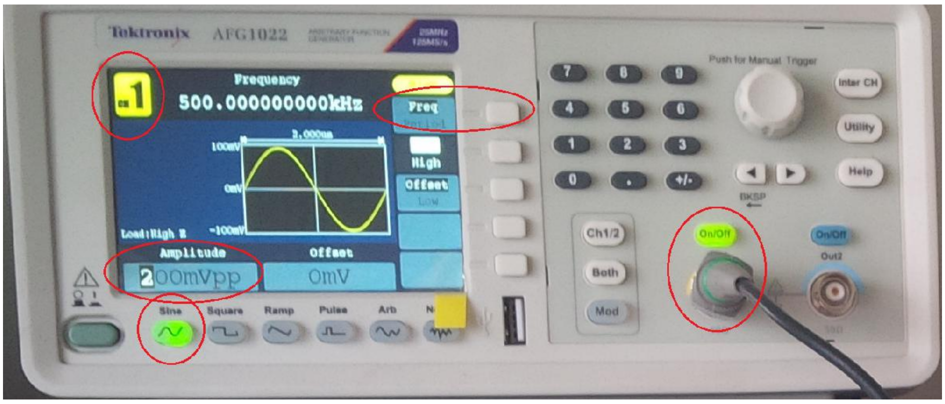
Make the Circuit Work

- Use signal from AFG/signal generator to feed to opamp input
- Set sinusoidal signal from channel 1 of the AFG
  - amplitude = 0.5 V_{pp}
  - frequency = 50 kHz
- Autoset the oscilloscope to see both input and output waveforms

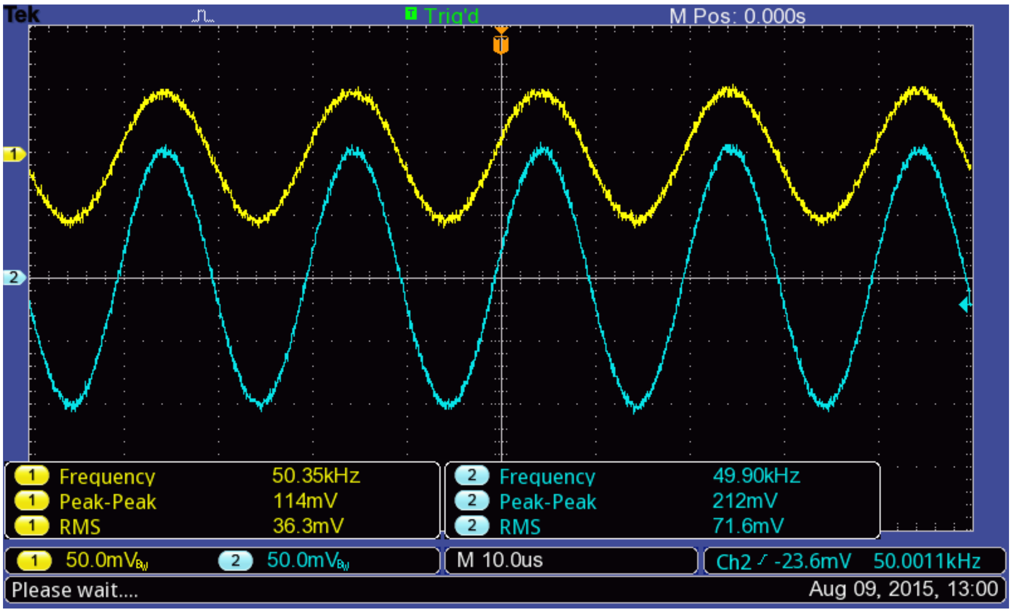
Step 5

Taking the Measurements

- Set input
  - Sinusoidal, 100 mV peak-to-peak amplitude
  - 50kHz frequency
  - Continous mode (on AFG)
  - enable the channel 1 output on AFG



- Autoset the oscilloscope to optimally see both input and output signal
- Set up following measurements:
  - On Ch1 - V_{pp}, V_{rms}, Frequency
  - On Ch2 - V_{pp}, V_{rms}
- Read the measurements in a tabular format, for different input amplitude (100mV / 200mV and 500mV peak-to-peak) for different values of R_f (1K / 2.2K / 4.7K and 10K ohms). You can also capture screenshot for each measurement set.



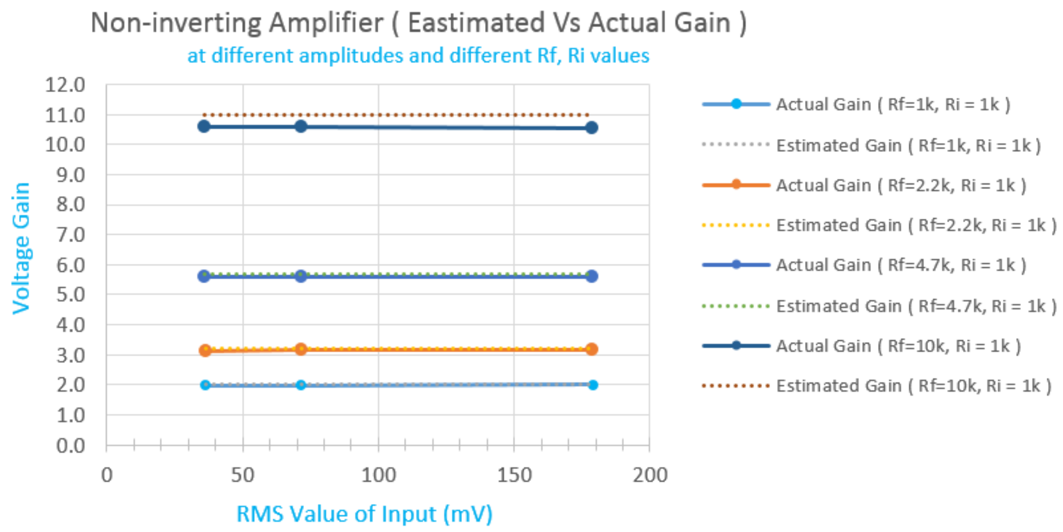
Step 6

Analyzing the Result

- The observation table would look like as shown below. Calculate actual voltage (observed from measurements) and its deviation from estimated (based on resistance values).

#	Rf (kΩ)	Ri (kΩ)	INPUT	OUTPUT	Voltage Gain		%
			Vpp (mV)	Vpp (mV)	Estimated	Actual	Deviation
1	1.0	1.0	114.0	212.0	2.00	1.86	-7.0%
2	1.0	1.0	216.0	416.0	2.00	1.93	-3.7%
3	1.0	1.0	536.0	1030.0	2.00	1.92	-3.9%
4	2.2	1.0	108.0	336.0	3.20	3.11	-2.8%
5	2.2	1.0	232.0	680.0	3.20	2.93	-8.4%
6	2.2	1.0	528.0	1640.0	3.20	3.11	-2.9%
7	4.7	1.0	112.0	592.0	5.70	5.29	-7.3%
8	4.7	1.0	216.0	1150.0	5.70	5.32	-6.6%
9	4.7	1.0	528.0	2880.0	5.70	5.45	-4.3%
10	10.0	1.0	102.0	1100.0	11.00	10.78	-2.0%
11	10.0	1.0	212.0	2200.0	11.00	10.38	-5.7%
12	10.0	1.0	536.0	5480.0	11.00	10.22	-7.1%

- Voltage gain (estimated and actual) can be plotted, for different values of input voltage and resistor combinations, to highlight the difference between actual and estimated gain.



- Brainstorm the reasons for such difference between actual and estimated voltage gain

Step 7

Conclusion

The analysis of the observation confirms that (As expected):

- The observed voltage gain follows the estimated value (calculated from resistor values)
- The voltage gain remains constant for given input voltage range
- The phase of input and output remains same - there is no phase inversion as it is non-inverting amplifier
- The deviation in observed voltage gain from estimated value is more for higher gain (higher R_f to R_i ratio) which could be because of varation in resistance values. Choosing a precise (low tolerance) resistors would reduce this deviation.