Inverting_Amplifier -- Overview

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Inverting Amplifier

Objectives:

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

- Understand and comprehend working of opamp
- Design & build 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:

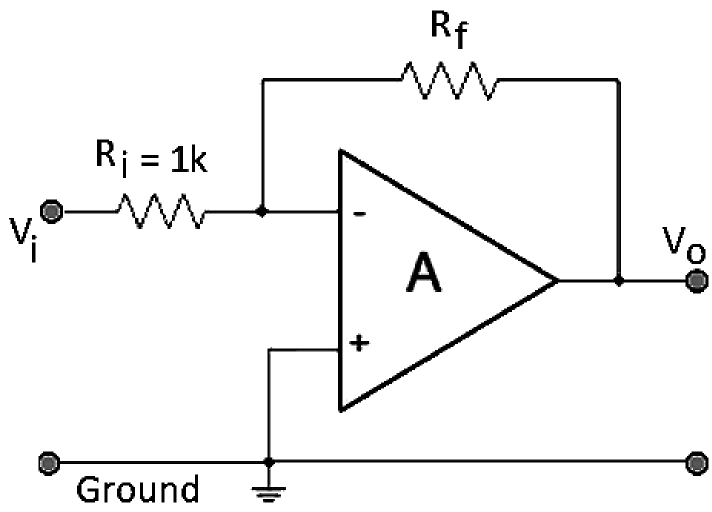
- An opamp is a high-gain differential amplifier with very high input impedance. Very high open-loop gain allow for creating amplifiers with stable gain using feedback.
- In an inverting amplifier, the input signal is applied to inverting pin of the opamp and there is a phase inversion (180 degree phase difference 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:

$$Gain = -\frac{R_f}{R_i}$$

- 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 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	-1.00
2.2	1.0	-2.20
4.7	1.0	-4.70
10.0	1.0	-10.00

* - sign on the gain indicates phase inversion (output is 180 degree out of phase with respect to input)

Inverting_Amplifier -- Procedures

Step 1

Check Your Understanding:

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

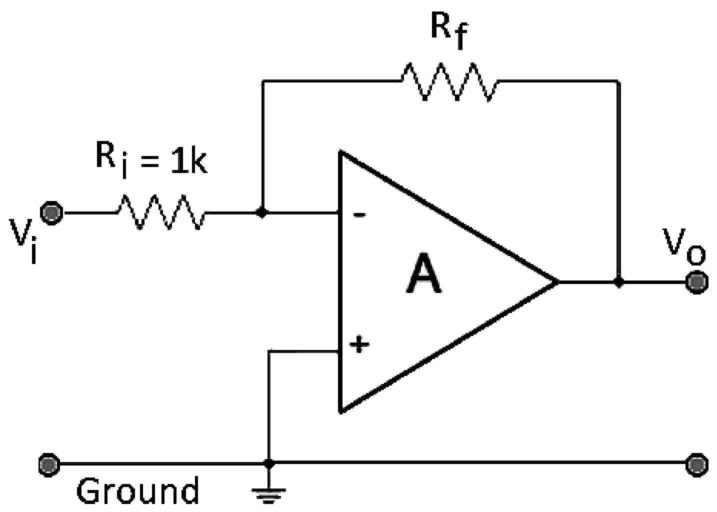
- For an inverting amplifier circuit, if $R_f < R_i$, the phase shift between output and input will be:
  - 0 Degree
  - less than 90 Degree
  - 180 Degree
  - more than 90 Degree
- For an inverting amplifier circuit, is it possible to reduce the voltage to less than 1?
  - Yes, by choosing R_f less than R_i
  - Yes, by choosing $R_f = R_i$
  - No. Not possible.
  - Yes, by choosing R_i = 0 ohms

- In an 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 reduce to 1/100th of its previos value

Step 2

Circuit diagram / Connection Details

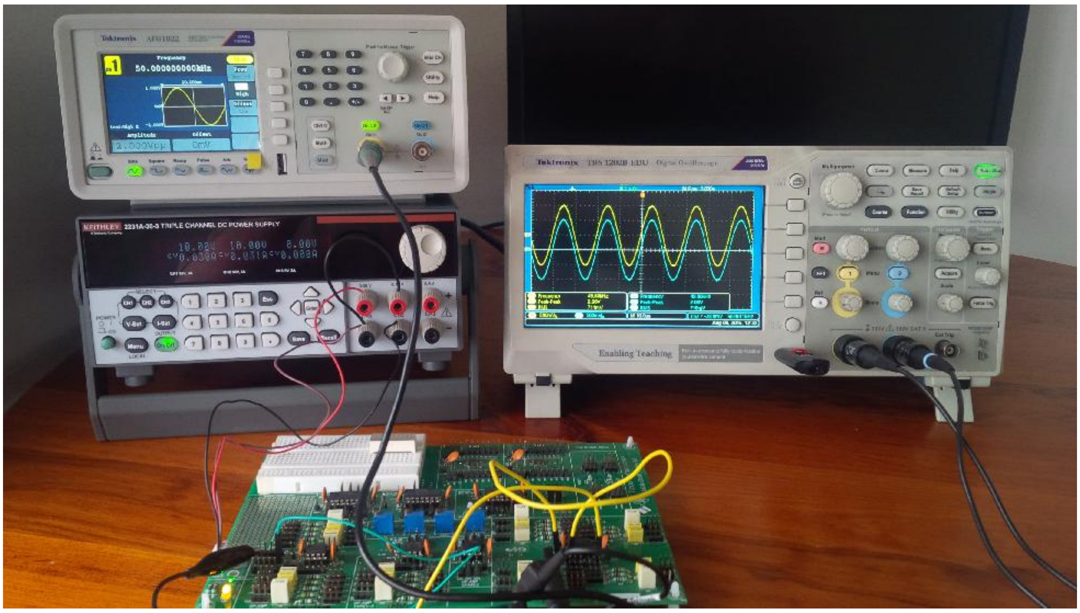
- Using the jumper / connecting wires prepare the circuit as shown below - Choose R_f = R_i = 1k ohm:



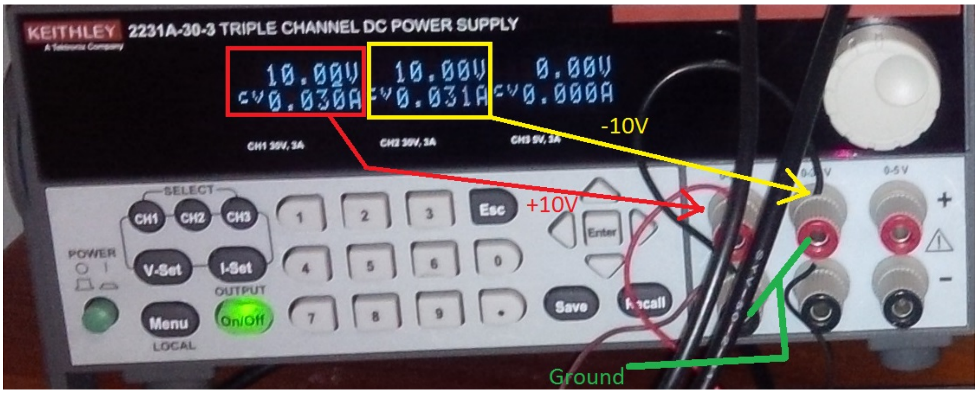
Step 3

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

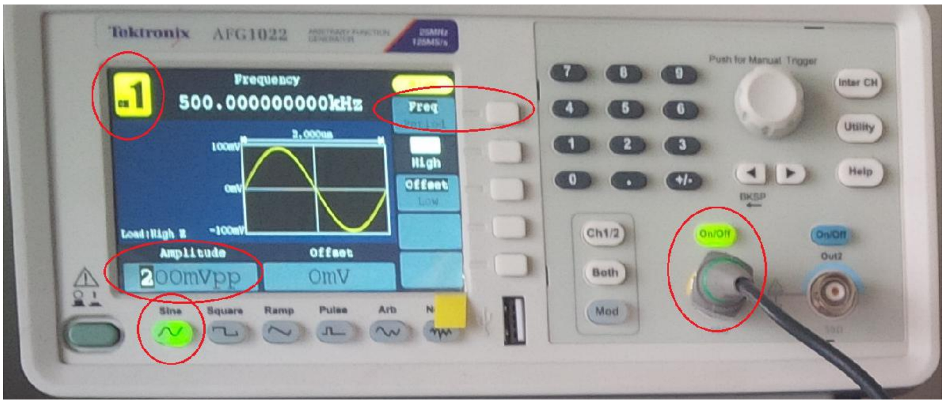
Make the Circuit Work

- Use signal from AFG/signal generator to feed to opamp input
- Set sinusoidal signal from channel 1 of the AFG
  - amplitude = 200 mV_{pp}
  - frequency = 50 kHz
- Autoset the oscilloscope to see both input and output waveforms

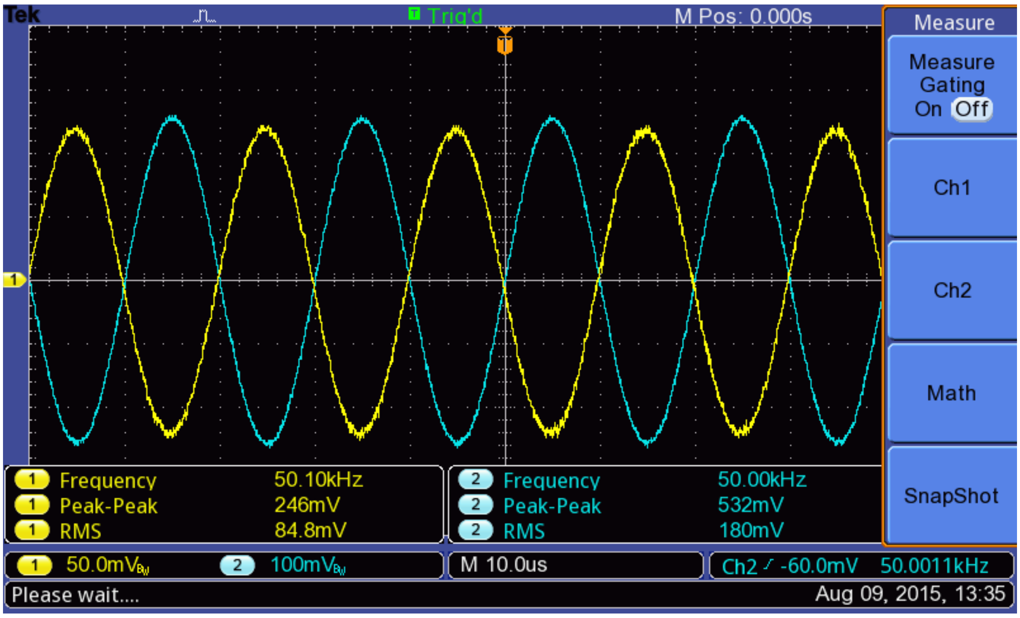
Step 5

Taking the Measurements

- Set input
  - Sinusoidal, 200 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 (200mV / 300mV and 400mV 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.



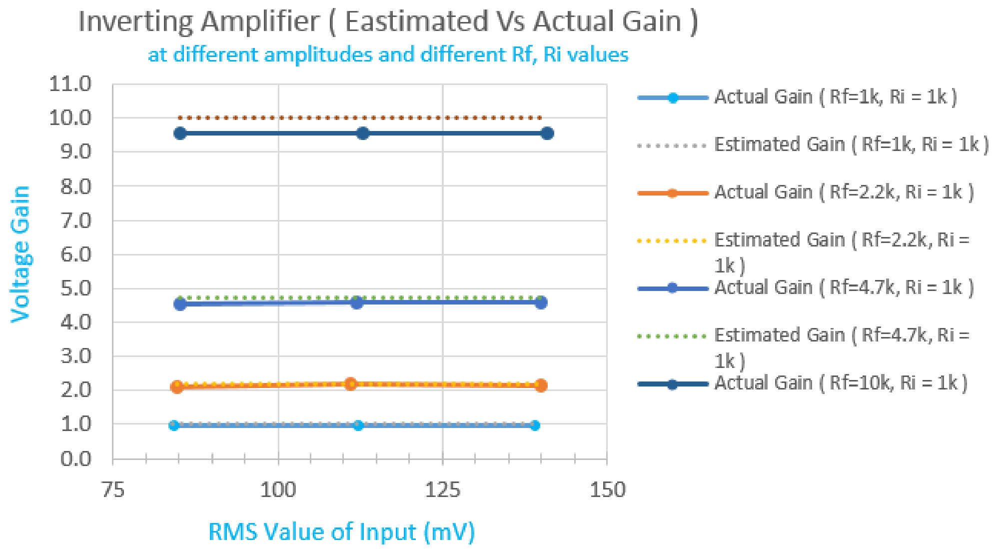
Step 6

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)	Peak-to-Peak (mV)		Voltage Gain		%	RMS (mV)		Voltage Gain		%
			INPUT	OUTPUT	Estimated	Actual	Deviation	INPUT	OUTPUT	Estimated	Actual	Deviation
1	1.0	1.0	246.0	244.0	1.00	0.99	-0.8%	84.1	82.9	1.00	0.99	-1.4%
2	1.0	1.0	336.0	324.0	1.00	0.96	-3.6%	112.0	110.0	1.00	0.98	-1.8%
3	1.0	1.0	408.0	404.0	1.00	0.99	-1.0%	139.0	138.0	1.00	0.99	-0.7%
4	2.2	1.0	246.0	532.0	2.20	2.16	-1.7%	84.8	180.0	2.20	2.12	-3.5%
5	2.2	1.0	344.0	712.0	2.20	2.07	-5.9%	111.0	242.0	2.20	2.18	-0.9%
6	2.2	1.0	424.0	880.0	2.20	2.08	-5.7%	140.0	302.0	2.20	2.16	-1.9%
7	4.7	1.0	250.0	1120.0	4.70	4.48	-4.7%	85.1	387.0	4.70	4.55	-3.2%
8	4.7	1.0	328.0	1500.0	4.70	4.57	-2.7%	112.0	514.0	4.70	4.59	-2.4%
9	4.7	1.0	412.0	1880.0	4.70	4.56	-2.9%	140.0	642.0	4.70	4.59	-2.4%
10	10.0	1.0	256.0	2340.0	10.00	9.14	-8.6%	85.1	813.0	10.00	9.55	-4.5%
11	10.0	1.0	340.0	3100.0	10.00	9.12	-8.8%	113.0	1080.0	10.00	9.56	-4.4%
12	10.0	1.0	416.0	3920.0	10.00	9.42	-5.8%	141.0	1350.0	10.00	9.57	-4.3%

- 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 output is inverted w.r.t. input - there is a phase inversion as it is 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.