EE254: Electronic Instrumentation

Applications of Operational Amplifiers II

Group No.		Reg. No.	

Note 1 :: Objectives

This lab studies some of the advanced uses of op amps. The circuits studied in this lab will include the summing amplifier, integrator and differentiator.

Note 2 :: Materials and Equipment

- 741 Op-Amp
- Assorted Resistors
- Assorted Capacitors
- DC dual power supply
- Function generator

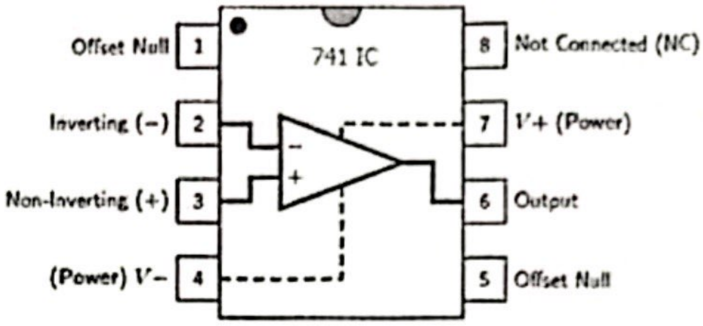

Fig. 1: 741 Op-Amp

Pre-Lab 1 :: Summing Amplifier

The simple summing amplifier output voltage, is proportional to the weighted sum of the input voltages. Show that the output of circuit in Fig. 2 is given by,

$$v_o = -\frac{R_f}{R_1}v_1 - \frac{R_f}{R_2}v_2 = -A_1v_1 - A_2v_2$$

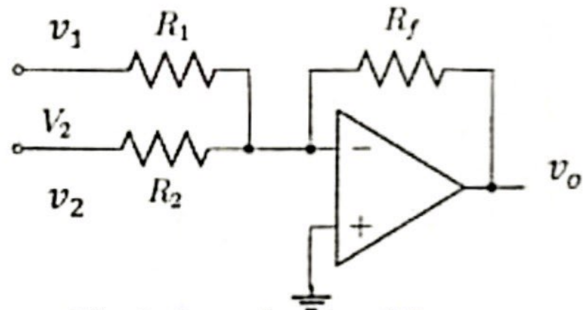

Fig. 2: Summing Amplifier

Activity 1 :: Summing Amplifier

1. Construct a summing amplifier with R_1=1.2 kΩ, R_2=18 kΩ and R_f=39 kΩ. Take Op-Amp supply voltage as $+v_s = 15\ V$ and $-v_s = -15\ V$.
2. Apply a 0.4V p-p, 1kHz triangular input signal to v_1 and 3V DC signal to v_2 (Hint: use a potential divider to achieve 3V from 15V power supply of op-amp).
3. Observe the composite output v_o on CH2 of the scope while observing v_1 on CH1.
4. Sketch the waveforms, v_o and v_1 to the scale in one plot.

Note: -Make sure that the ground reference point (on the oscilloscope) is the same for CH1 and CH2.
-Make sure DC coupling is ON in the oscilloscope.
-Clearly mention the VOLTS/DIV setting in each channel which you obtained the waveforms.

5. Ground v_2 input and find the gain A_1. Ground v_1 input and find the gain A_2.

$A_1 =$ ______________________ $A_2 =$ ______________________

7. Calculate theoretical values of A_1 and A_2.

$A_1 =$ ______________________ $A_2 =$ ______________________

8. Mention any reason for why the theoretical values of A_1 and A_2 differs from measured.

Note 3 :: Integrator

An op-amp integrator simulates mathematical integration which is basically a summing process that determines the total area under the curve of a function. The output voltage is given by,

$$v_o = -\frac{1}{RC}\int_0^t v_{in}dt + V_c(t=0)$$

$V_c(t=0)$ is the initial voltage on the capacitor.
For proper integration, ***RC* should be much greater than the period of the input signal.**

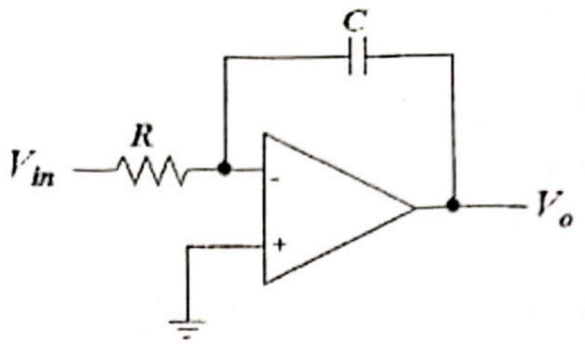

Fig. 3: Integrator

The gain of the integrator decreases with the increasing frequency. However, at **low frequencies such as at DC, the gain becomes infinite.** Hence the op-amp saturates (i.e., the capacitor is fully charged and it behaves like an open circuit).

To limit the gain of the integrator at low frequencies, usually the feedback capacitor is shunted by a **resistance R_s**, and hence saturation problems can be avoided.

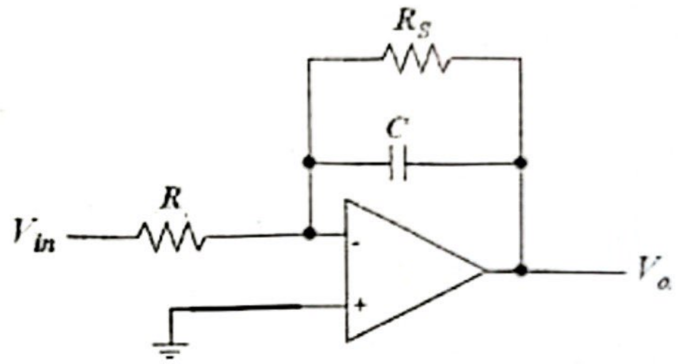

Fig. 4: Modified Integrator (Active LPF)

Activity 2 :: Integrator

1. Build the amplifier in Fig. 4. Take Rs=39kΩ, R=2.2kΩ and C=1μF. Bias the op-amp with +15V and -15V supply.
2. Apply a 200Hz, 1Vp-p sinusoidal signal to the input. Measure and capture the input and output signals. Sketch the output signal and input signal and label them.

3. Perform the same for a 1 kHz square wave input. Sketch the output signal and input signal and label them.

4. Measure peak to peak voltages V_{in} and V_o for square input signal of 1V peak-to-peak for given frequencies.

Frequency/Hz	V_{in}/Volts	V_o/Volts	Voltage Gain
100			
200			
300			
400			
500			
1k			
2k			

5. Comment on the variation in voltage gain with frequency.

Note 4 :: Differentiator

An op-amp differentiator simulates mathematical differentiation, which is a process of determining the instantaneous rate of change of a function. The output waveform is derivative of the input waveform given by,

$$v_o = -RC\,\frac{d\,v_{in}}{dt}$$

For proper differentiation, ***RC* should be much smaller than the period of the input signal.**

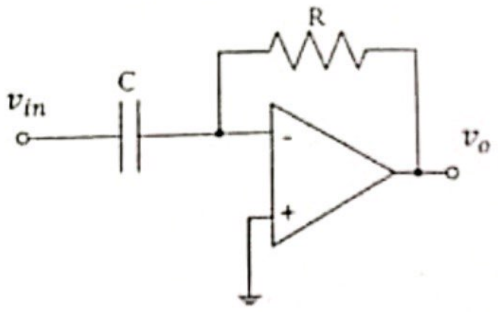

Fig. 5: Differentiator

The **input impedance of the differentiator decreases with increase in frequency,** thereby making the circuit sensitive to high frequency noise.

Therefore, to limit the gain of the differentiator at high frequencies, the input capacitor is connected in series with **a resistance R_1** and hence avoiding high frequency noise and stability problems.

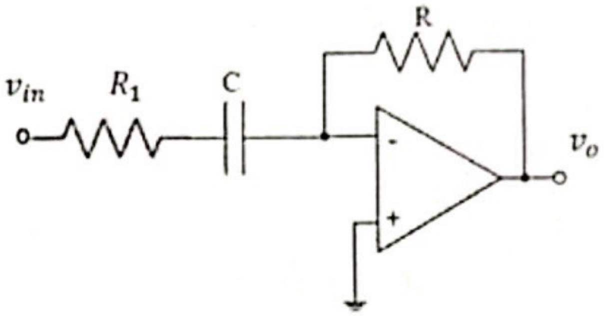

Fig. 6: Modified Differentiator (Active HPF)

Activity 3 :: Differentiator

1. Assemble the differentiator circuit in Fig. 6 with R=10kΩ and C=0.047µf. Connect a resistor R_1 of value 470Ω between the source and the capacitor.
2. Feed 1V peak-to-peak, 200 Hz triangular wave input. Observe the input and output voltages on a scope and sketch it to the scale.

3. Measure peak to peak voltages V_{in} and V_o for sinusoidal input signal for given frequencies.

Frequency/kHz	V_{in}/Volts	V_o/Volts	Voltage Gain
100			
200			
300			
400			
500			
1k			
2k			

4. Comment on the variation in voltage gain with frequency.

Homework :: Solving Differential Equations with Op-amp Circuits

In analog simulation, also termed analog computation, electronic circuits with op-amps are used to solve differential equations. The heart of the technique is the op-amp integrator circuit. Select an example differential equation of your choice and explain how you would design an op-amp circuit to solve it. You may use more than one basic op-amp circuits such as integrators, adders, inverting amplifiers etc. Use a separate sheet, if required and attach it to this work book.