Differentiation and Integration using OPAMP and active low pass filter

Objectives:

(I) To study OPAMP as a differentiator
(II) To study OPAMP as an integrator

Apparatus:

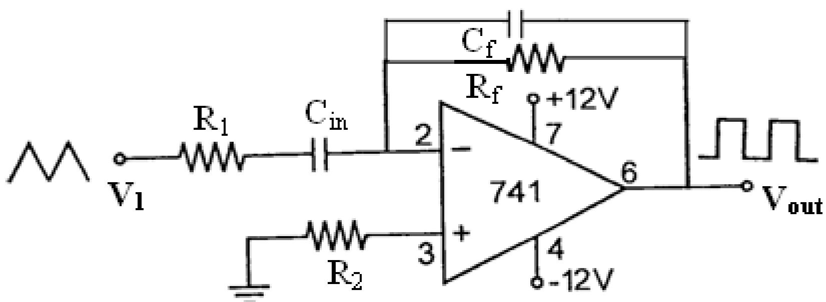
1. OPAMP IC 741
2. D.C. power supply
3. Resistors
4. Digital multimeter
5. Connecting wires
6. Breadboard
7. Function generator
8. Digital storage oscilloscope

Theory:

Please refer to the supplementary note.

(I) To study OPAMP as a differentiator

Circuit Diagram of practical differentiator:



Differentiator action can be performed by the circuit given in supplementary material, which consists of only R_f in the feedback and input capacitor C_{in} with a gain equal to R_f/C_{in}. With increase in frequency gain, R_f/C_{in} increases which makes differentiator unstable. Further input impedance decreases at high frequency, which makes noise to amplify and override the signal. For the practical differentiator, C_f is added in parallel to R_f to control the gain and a small resistance R_1 at the input in series with C_{in} drops the noise at the input. R_2 is known as offset minimizing resistor (R_{OM}) which reduces output offset voltage due to input bias current.

Procedure:

1. Assemble the circuit as shown in circuit diagram choosing R_1, R_2 = 1KΩ each, R_f = 10KΩ, C_{in}= 0.1 µF and C_f= 0.01µF. Use 0- ±15V terminal output to provide supply to the IC.
2. Feed a triangular input signal of required amplitude from the function generator, which is set at 1K frequency.
3. Feed both the input and output signals to an oscilloscope and save. The output should be approximately a square wave.
4. Check the output waveform with sine and square waves as inputs and save.

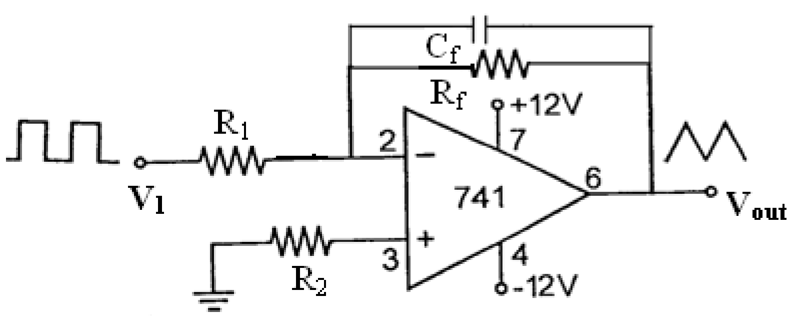
Observations: (Paste the various input and corresponding output waveforms here)

Observation	Waveform		
Input	triangular	sine	square
Output			

Discussions

(VII) To study OPAMP as an integrator

Circuit Diagram of practical integrator



In this practical integrator circuit R_f is connected parallel with C_f which is absent in the integrator circuit given in supplementary material. R_f discharges left over charges present in the capacitor before next pulse being applied and limits the gain of the circuit at low frequencies, which is infinite at D.C. R_2 is known as offset minimizing resistor (ROM) which reduces output offset voltage due to input bias current.

Procedure:

2. Assemble the circuit as shown in circuit diagram choosing R_1, R_2 = 10KΩ each, R_f = 100KΩ, and C_f= 0.1µF. Use 0- ±15V terminal output to provide supply to the IC. Feed a

square wave input of required amplitude from the function generator, which is set at 1KΩ frequency.

3. Feed both the input and output signals to an oscilloscope. The output should be a triangular wave.

Observations: (Paste the various input and corresponding output waveforms here)

Observation	Waveform
Input	
Output	

Active filter using OPAMP

Objective:

(I) To construct a low pass active filter using OPAMP

Filters: The main disadvantage of passive filters (as you have already seen in one of your previous labs) is the fact that the maximum gain that can be achieved with these filters is 1. In other words, the maximum output voltage is equal to the input voltage. If we make filter circuits using Opamps, then the gain can be greater than 1.
The circuits employed are all based on the inverting Opamps with the addition of a capacitor placed in the correct position for the particular type of filter. These circuits are called active filter circuits because they use Opamps which require a power supply.

Low-Pass filters - the integrator reconsidered

A low pass filter passes only low frequency signals and attenuates signals of high frequencies. We have already considered the time response of the integrator circuit, but its frequency response can also be studied. Figure 1 shows a low pass active filter in inverting configuration.

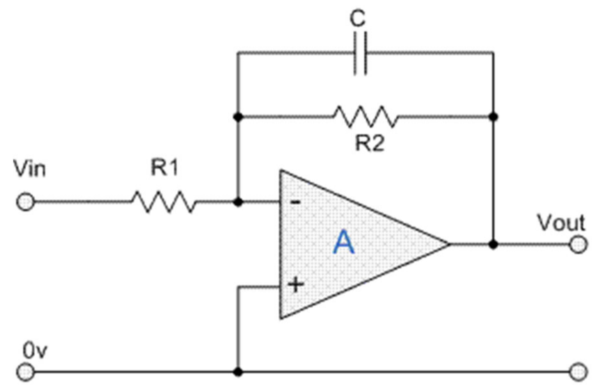


Fig. 1: First Order Low Pass Filter with Op Amp

Gain of the above circuit, $A_V = -\dfrac{R_2 \| X_C}{R_1}$,

where $X_C = \dfrac{1}{2\pi fC}$, is the impedance of the capacitor and f is the frequency of the input signal.

At high frequencies the capacitor acts as a short, so the gain of the amplifier approaches zero. At very low frequencies the capacitor is open and the gain of the circuit is $-(R_2/R_1)$. We can consider the frequency to be high when the large majority of current goes through the capacitor; i.e., when the magnitude of the capacitor impedance is much less than that of R_2. In other words, we have high frequency when $X_C \ll R_2$. Since R_2 now has little effect on the circuit, it should act as an integrator. Likewise low frequency occurs when $R_2 \ll X_C$, and the circuit will act as an amplifier with gain $-R_2/R_1$. Thus, the cut-off frequency is given as $f_C = \dfrac{1}{2\pi R_2 C}$ and the frequency response is as shown below (Fig.2). The frequency response curve of the filter decreases by 20dB/Decade or 6dB/Octave from the determined cut-off frequency point which is always at -3dB below the maximum gain value.

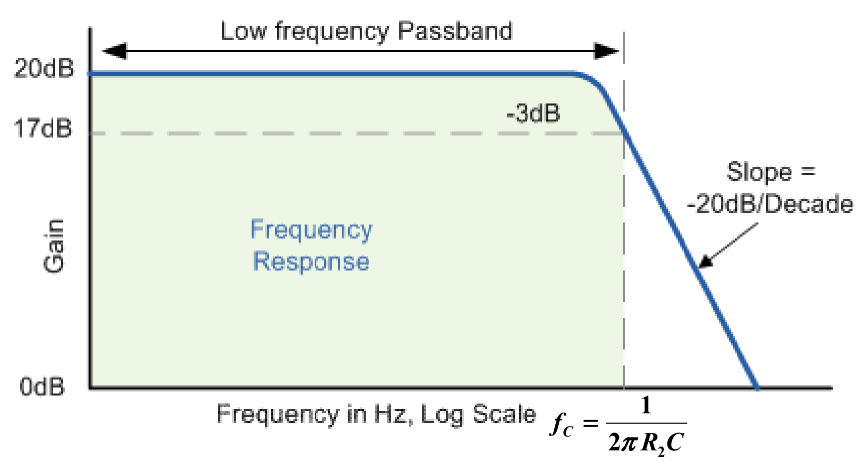


Fig. 2: Frequency response curve of an active low pass filter

Similarly high pass filter can be constructed with differentiator circuit and using a low pass filter and high pass filter, a band pass filter can be constructed.

Procedure:

1. Read/measure the values of all circuit components to be used. Calculate the cut-off frequencies in each case.
2. Using the scope set the function generator to produce an input voltage of approximately 100 mV(pp) sine wave.
3. Set up the low/high/band pass active filter on the breadboard as shown in the circuit diagrams. Connect the function generator to apply input. Use the dual trace oscilloscope to look at both V_{in} and V_{out}. Be sure that the two oscilloscope probes have their grounds connected to the function generator ground. Match the magnification control both at the probe and the oscilloscope.
4. Set the RANGE of the function generator between 20 Hz to 20 kHz. Measure the V_{in}(pp) and V_{out}(pp). Use **digital filter** or **average** options from oscilloscope to measure voltages whenever needed.
5. From your measurements determine the gain, $\frac{V_o(pp)}{V_{in}(pp)}$ and compare with the calculated value.
6. Plot log f ~ gain (dB).

Observations:

(I) For Low Pass Filter:

R_1=__________, R_2 = _______, C=__________,

Max Gain(calculated) = $-\frac{R_2}{R_1}$ =_________, $f_c = \frac{1}{2\pi R_2 C}$ = _____

Table:

Sl. No.	Frequency, f (kHz)	V_{in}(pp) (Volt)	V_o(pp) (Volt)	Gain,A_V= $\frac{V_o(pp)}{V_i(pp)}$	Gain (dB)
1					
2					
..					
..					