Operational Amplifier as differentiator

Aim :- To study the gain of the OP. amp. as differentiator with the frequency of the in put, to compare the experimental out put with that of theoretical value. Also to observe the differentiating character of the circuit.

Apparatus :- Operational amplifier (IC 741), C.R.O., signal generator, power supply to the amplifier, non inductive resistor, capacitor and connecting terminals.

Formula :- Out put voltage $V_o = - R\,C\,\omega\ V_{ip}\ \cos \omega t$

(OR) Out put peak voltage $V_{op} = - R\,C\,\omega\ V_{ip}$

Where R = Resistance (Ω)

C = Capacitance (F)

ω = Angular frequency of the in put (Rad/sec) = $2\pi f$

f = Frequency of the in put (Hz)

Description :- The phase terminal of the signal generator is given to the inverting in put (2) of the operational amplifier 741 through a capacitor C. The other terminal of the signal generator and the non-inverting terminal (3) of the op. amp. are grounded. The out put terminal (6) of the op.amp. is fed back to the inverting terminal (2) through a resistor R. To measure the in put and out put voltages, the signal generator phase terminal and the out put terminal (6) of the op. amp. are connected to the phase terminals of Y_1 and Y_2 plates of C.R.O. respectively. The other two terminals of the C.R.O. are grounded. The terminals 7 and 4 of the op. amp. are connected to +12 V and -12 V of the D.C. power supplies separately.

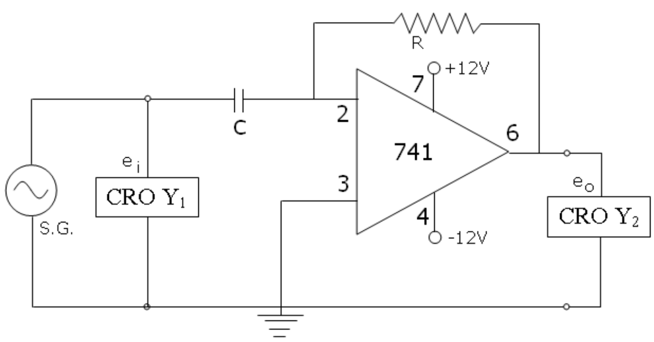
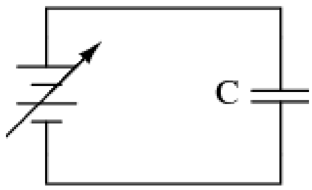


Fig – 1

Theory :- A circuit that performs the mathematical differentiation of the in put signal is called a “differentiator”. i.e. the out put of the differentiator is proportional to the rate of change of its in put signal. By introducing electrical reactance (resistance or capacitance) into the feedback loops of op-amp amplifier circuits, we can cause the output to respond to changes in the input voltage with time.

Capacitance can be defined as the measure of a capacitor's opposition to changes in voltage. The greater the capacitance, the more the opposition. Capacitors oppose voltage change by creating current in the circuit, i.e. they either charge or discharge in response to a change in applied voltage. So, the more capacitance a capacitor has, the greater its charge or discharge current will be for any given rate of change of voltage across it.



The equation for this is $I = C\frac{dV_i}{dt}$

We can build an op-amp circuit which measures change in voltage by measuring current through a capacitor, and outputs a voltage proportional to that current.

The right-hand side of the capacitor is held to a voltage of 0 volts, due to the "virtual ground" effect(This terminal is not mechanically grounded. So no current flows to ground through this terminal). Therefore, current "through" the capacitor is only due to *change* in the input voltage. A steady input voltage won't cause any current through C.

Capacitor current moves through the feedback resistor, producing a drop across it, which is the same as the output voltage. A linear, positive rate of input voltage change will result in a steady negative voltage at the output of the op-amp.

∴ The out put voltage $V_o = -IR$

$$V_o = -RC\frac{dV_i}{dt}$$

If in put voltage $V_i = V_{ip}$ Sin ωt Here V_{ip} = In put peak voltage

Then $$V_o = -RC\frac{d(V_{ip}\,Sin\,\omega t)}{dt}$$

$$V_o = -V_{ip}RC\omega Cos(\omega t)$$

OR

The peak out put voltage V_{op} = - R C ω V_{ip} = - R C 2πf V_{ip}

Conversely, a negative rate of input voltage change will result in a steady positive voltage at the output of the op-amp. This polarity inversion from input to output is due to the fact that the input signal is being sent (essentially) to the inverting input of the op-amp, so it acts like the inverting amplifier.

- The out put voltage increases with increasing frequency or the differentiator circuit has high gain at high frequencies.
- When there is change in the in put then only the out put occurs.
- If the in put is constant the out put is zero.

Procedure :- Connect the circuit as shown in the fig-1. Take the R = 1KΩ and C = 0.1µF or any convenient values. Apply the sine wave from the signal generator to the op. amp. Set the frequency of the signal generator i.e. in put frequency to 1 KHz. Also set the in put peak to peak in put voltage to a fixed value by adjusting the voltage sensitivity band switch of the Y_1- plates and time base band switch of C.R.O. to the convenient positions. The voltage of Y_1-plates on the C.R.O. screen is noted in the table as V_{ip}. Now observe the out put voltage at the Y_2- plates of C.R.O. Also keep the voltage sensitivity band switch of Y_2 plates at convenient position.

Now the input frequency is increased in equal steps (Multiples of 100 Hz) and the out put voltage is measured for each frequency. Note in put frequency(f), in put voltage (V_{ip}) and out put voltage (V_{op}) in the table. The out put peak voltage (V_{op}) is compared with that of theoretical value. The gain increases with increase of in put frequency. This one character of the differentiator.

The other character is that the out put occurs only when there is change in the in put voltage. To observe this, square wave is applied as in put. Then the out put pulses are observed only at the phase reversal time and no voltage is observed in between.

Precautions :- 1. Check the continuity of the connecting terminals before connecting them.

2. Keep the band switches of the C.R.O. such that steady wave forms are observed on the screen.

3. Observe the in put and out put voltages simultaneously on the screen when square wave is applied in order to know that the out put occurs only when there is change in the in put.

Results :-

1. The out put voltage increases with increasing frequency or the differentiator circuit has high gain at high frequencies.
2. When there is change in the in put then only the out put occurs.
3. If the in put is constant the out put is zero.

Table

R = Ω C = μ F

S. No.	Freq (f) Hz	$\omega = 2\pi f$ Rad/sec	Input peak voltage (V_{ip})			Out put peakVoltage (V_{op})				Gain
			Peak to peak (Vertical) (Divisions) (n)	Voltage Sensitivity. (Volt/Div) (d)	Voltage (V_{ip}) = nxd/2 (volts)	Peak to peak (Vertical) (Div) (n)	Voltage Sensitivity. (Volt/Div) (d)	Expt.al Voltage V_{op}= nxd/2 (volts)	Theoretical voltage $V_{op} = - R C \omega V_{ip}$ (Volts)	Experimental (V_{op}/V_{ip})