وزارة التعليم العالي والبحث العلمي

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 **المرحلة : المرحلة الثانية**

**المحاضرة الاولى (عملي )**

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**Experiment no.) (1**

**Low –pass filter (integrator R.C. circuit)**

**OBJECT:**

 To steady the behavior and response of R.C. Circuit.

 **APPARTUS:**

By using computer (multisim) program.

1. Signal function generator
2. Oscilloscope

3-) Resisters, capacitors)

 **THEORY:**

**Consider the circuit shown in fig. (1) If the output is taken off the capacitor, as shown in Fig. (1) , it will respond as a low-pass filter**.



**Fig.(1) integrator R.C. circuit (low-pass filter)**

**At *F= 0 HZ ;***

## $xc=\frac{1}{2πFC} $=$\infty $ *Ω*

## and the open-circuit equivalent can be substituted for the capacitor, as shown in Fig. (2), resulting in Vo = Vi.

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## fig.(2) R-C low-pass filter at low frequencies.

## At very high frequencies, the reactance is:

## $xc=\frac{1}{2πFC} $=0 *Ω*

## and the short-circuit equivalent can be substituted for the capacitor, as shown in Fig. (3), resulting in Vo = zero V

##

**fig.(3) R-C low-pass filter at high frequencies.**

## A plot of the magnitude of Vo versus frequency will result in the curve of Fig. (4).

##  fig.(4) Vo versus frequency for a low-pass R-C filter.

## For filters, a normalized plot is employed more often than the plot of Vo versus frequency of Fig. (4).

## Normalization is a process whereby a quantity such as voltage, current, or impedance is divided by a quantity of the same unit of measure to establish a dimensionless level of a specific value or range.

## A normalized plot in the filter domain can be obtained by dividing the plotted quantity such as Vo of Fig. (4) with the applied voltage Vi for the frequency range of interest. Since the maximum value of Vo for the low-pass filter of Fig. (1) is Vi, each level of Vo in Fig. (4) is divided by the level of Vi. The result is the plot of Av = Vo/Vi of Fig. (5). Note that the maximum value is 1 and the cutoff frequency is defined at the 0.707 level.

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## fig.(5) Normalized plot of Fig. (4).

## At any intermediate frequency, the output voltage Vo of Fig. (1) can be determined using the voltage divider rule:

## $Vo=\frac{Xc⦟-90 Vi}{R-jXc}$ *---------------- 1*

## *OR:*

## $Av=\frac{Vo}{Vi}=\frac{Xc⦟-90 }{R-jXc}=\frac{Xc⦟-90 }{\sqrt{R^{2}+Xc^{2}⦟-tan-1(\frac{Xc}{R})}} $ --------------2&3

## AND:

##  $Av=\frac{Vo}{Vi}=\frac{Xc}{\sqrt{(R^{2}+Xc^{2})}} ⦟-90+ tan-1(\frac{Xc}{R})$

## The magnitude of the ratio Vo/Vi is therefore determined by:

## $Av=\frac{Vo}{Vi}$=$\frac{Xc}{\sqrt{(R^{2}+Xc^{2})}}=\frac{1}{\sqrt{\left(\frac{R}{Xc}\right)\^2+1}} $---------------- 4

## and the phase angle is determined by :

## θ=-90+tan -1( $\frac{Xc}{R}) =-tan-1(\frac{R}{Xc})$ ------------- 5

## For the special frequency at which XC = R, the magnitude becomes:

## $Av=\frac{Vo}{Vi}=\frac{1}{\sqrt{\left(\frac{R}{Xc}\right)\^2+1}}=\frac{1}{\sqrt{1+1}}=\frac{1}{\sqrt{2}}=0.707$ --------------6

## which defines the critical or cutoff frequency of Fig. (5). The frequency at which XC = R is determined by:

## $\frac{1}{2ᴨFc C}=R $ -------------- 7

## AND :

## $Fc=\frac{1}{2ᴨR C}$ -------------- 8

## The impact of Eq. (8) extends beyond its relative simplicity. For any low-pass filter, the application of any frequency less than fc will result in an output voltage Vo that is at least 70.7% of the maximum. For any frequency above fc, the output is less than 70.7% of the applied signal.

## Solving for Vo and substituting Vi = Vi < 0° gives

## Vo= [$\frac{Xc}{\sqrt{(R^{2}+Xc^{2})}}⦟θ$]Vi = [$\frac{Xc}{\sqrt{\left(R^{2}+Xc^{2}\right)}}⦟θ$] Vi ⦟0 -----------9

## AND :

## Vo= $\frac{Xc Vi}{\sqrt{(R^{2}+Xc^{2})}} ⦟θ$

## The angle Ө is, therefore, the angle by which Vo lag Vi. this angle change from 0 to 90° ,if the input voltage is sine wave with angle =0 then the out put voltage become sine wave with angle =90° (i.e. cosine wave ) Vin = Asin(ωt) Vo= B sine(ωt-90°)= - B cos (ωt) for this reason ,this circuit called integrator . Since Ө = -tan −1 (R/XC) is always negative (except at f = 0 Hz), it is clear that Vo will always lag Vi, leading to the label lagging network for the network of Fig. (1). At high frequencies, XC is very small and R/XC is quite large, resulting in Ө=- tan −1 (R/XC) approaching -90°. At low frequencies, XC is quite large and R/XC is very small, resulting in v approaching 0°. At low frequencies, XC is quite large and R/XC is very small, resulting in Ө approaching 0°.

## At (XC = R) , or (f = fc) , -tan −1 (R/XC) = -tan −1 1 = - 45°. A plot of v versus frequency results in the phase plot of Fig. (6).

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## fig.(6) Angle by which Vo lags Vi.

## PROCEDURE:

##  1-Connect the cct. Shown in fig .(7):

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## very the frequency and measure Vo for every setting of (f). Tabulate your result as in table (1)

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## 2- using the oscilloscope to measure the phase shift θ for each frequency setting

## 3-apply a sine-wave voltage at the input terminals of +the cct. of fig. (7).with Vin=10Vp.p.

##  For the values of ( f , R, C ) as in the table (2). Draw Vo & Vin

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## REQUERMENTS:

## 1-draw a graph between the gain (A=Vo/Vin ) versus frequency, find (fc) and Compare it with that obtained from equation (8).

## 2- draw a graph between(θ ) and (f), from the graph find fc at θ =45 and compare it with that obtained from equation (8).

## DISCUSSION:

## Sketch the output voltage Vo versus frequency for the low-pass R-C filter of Fig. (8).

##

## Fig.(8)

## Determine the voltage Vo at f = 100 kHz and 1 MHz, and compare.

## the results to the results obtained from the curve of part (a). c. Sketch the normalized gain Av = Vo/Vi.