CONTROL ENGINEERING LABORATORY, NSIT

EXPERIMENT – 5

AIM:

Study the 1st order electrical system by **(a)** Obtaining Step response, **(b)** Obtaining Frequency response of a typical first order system and correlative experiment with theoretical results, and **(c)** Obtain the transfer function of the system.

OBJECTIVES:

The aim of this experiment is to obtain the step-response and frequency response of typical first order electrical system and correlate the experimental results with the theory.

MOTIVATION:

The study of first order electrical system occupies an important place in control engineering. Closed from experiment for the step and frequency responses of this system is available in the literature. The responses of this system is quite often used as a standard for comparison and a basis for the design of compensators for high-order feedback control system.

THEORETICAL BACKGROUND

First Order System:

First order systems are characterized by a transfer function of the form

$$G(s) = \frac{K}{1+Ts} \qquad (1)$$

Where K is the 'gain' and T is the 'time constant' of the system

T = RC

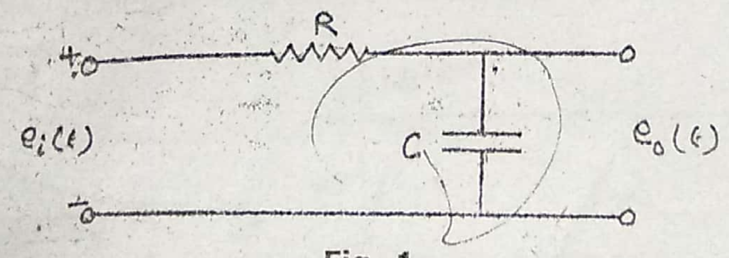


Fig.-1

A simple first-order electrical system employing a resistance and a capacitance is shown in figure. The transfer function $E_0(s)/E_1(s)$ can be shown to be equal to

$$\frac{E_0(s)}{E_1(s)} = \frac{1}{1+Ts} \qquad \text{where } T = RC$$

Step Response:

For a step input of magnitude V the response of the above system can be shown to be equal to

$$e_0(t) = V\left(1 - e_i^{-t/T}\right) \qquad T \geq 0$$

Where it is assumed that the system is initially at rest with no charge on the capacitor. A sketch of the step-response is shown in Fig.-2.

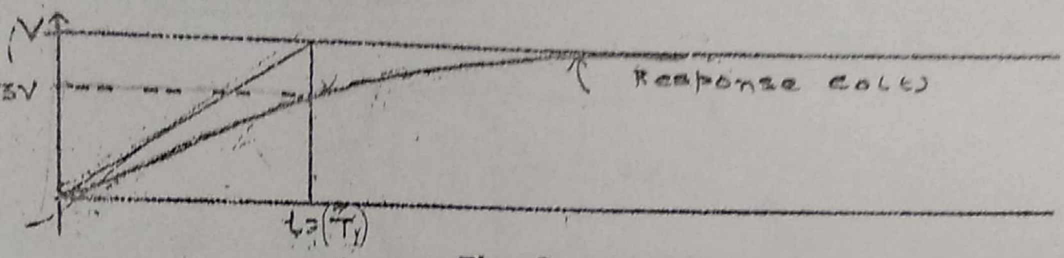


Fig.-2

It is seen that at time $t = T$ the response $e_0(t)$ reaches approximately 63% of its steady-state value V. It can be shown that if $e_0(t)$ were to maintain its initial rate of increase it would reach the final value in time $t = T$.

Frequency Response:

Substituting $S = jw$ in equation (1) we get the frequency response function as

$$G(jw) = \frac{K}{1 + Tjw}$$

for which it follows that

$$|G(jw)| = \frac{K}{\sqrt{1 + w^2T^2}} \quad \text{and} \quad \angle G(jw) = -\tan^{-1} wT$$

It can be seen that when $w = \dfrac{1}{T \angle G(jw)} = -45^0$ and $|G(jw)| = \dfrac{K}{\sqrt{2}}$.

This gives a method of determining from the frequency response function.

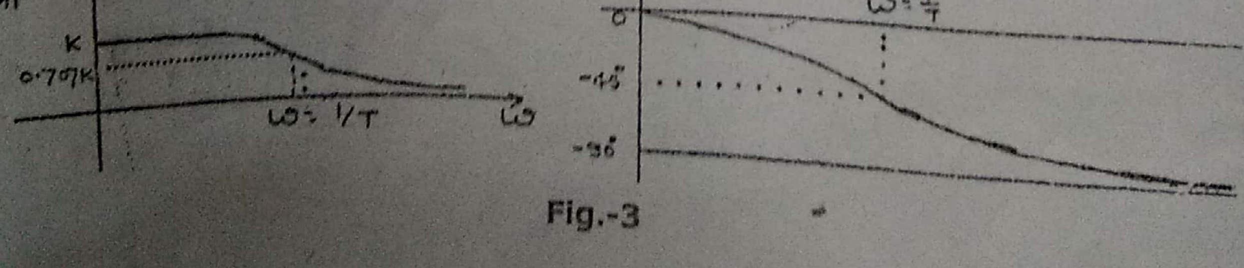


Fig.-3

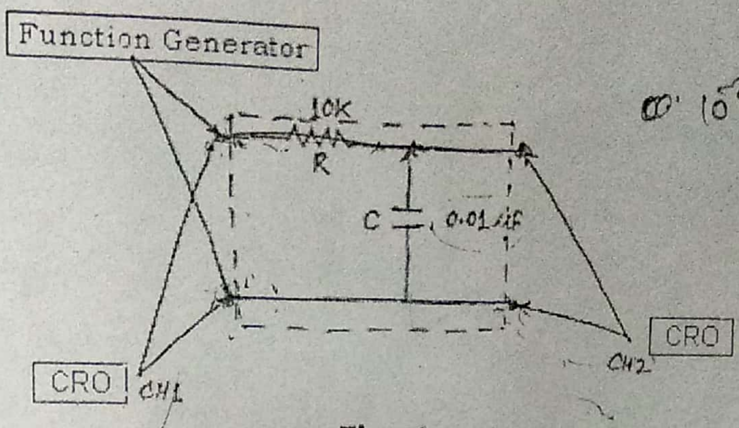
APPARATUS:

CRO, Function Generator, Power Supply, Breadboard, Connecting wires, Resistors and capacitors of appropriate value.

PROCEDURE:

Step response:

1. Connect the waveform generator and oscilloscope as shown in Fig.-4.



$10^{-2} \times 10^{-6} \times 10^{4}$

10^{-4}

10^{-4} sec

100 μsec

Fig.-4

Adjust the waveform generator to produce a square wave of suitable frequency.
Obtain the step-response on the oscilloscope screen.
Trace (or plot) the response on a graph paper to scale.
Measure the time constant and compare with the theoretical value.

Frequency Response:

Use the same setup in Fig.-4 but adjust the waveform generator to produce sine-wave of suitable frequency. (Since the time-constant = 10^{-3} sec., the frequency range of interest would be 10^2 rad/sec to 10^4 rad/sec).
From the trace on the oscilloscope determine the peak to peak amplitude of the system output and the phase angle of the system output.
Measure the peak to peak value of the voltage input to the system using the oscilloscope.
Evaluate the voltage ratio = *G(jw)*.
Repeat steps 1-4 above for different spot frequency in the range of interest and obtain for each frequency the voltage ratio and phase angle.
Tabulate the result as follows:

S.No.	Frequency W rad/sec	Input voltage Peak to Peak V_i	Output voltage Peak to Peak V_o	Voltage ratio V_o/V_i	Phase angle $\phi = \angle G(jw)$	20 log$_{10}$(G)
1.						
2.						
3.						
4.						
5.						

Use the above results to obtain the Bode-plot for the system.
Obtain the time-constant of the system using the Bode-plot and compare with the theoretical value.

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