EXPERIMENT # 1

AC MEASUREMENTS
OSCILLOSCOPE, FUNCTION GENERATOR
FREQUENCY COUNTER

OBJECTIVES:

To introduce the oscilloscope, the function generator, and the frequency counter in measuring AC parameters of signal.

EQUIPMENT:

Oscilloscope
Function generator
Frequency counter
Resistor substitution box
Capacitor substitution box

BACKGROUND:

An AC (time varying) signal requires several parameters to be completely described. The problem of measuring AC signals is how to determine these parameters. The frequency counter can be used to measure the frequency or the period of a periodic signal of any waveform. AC multi-meters produce a DC value proportional to an AC parameter of the signal to be measured. Most multimeters are calibrated to display the RMS value of sinusoid waveforms only. The oscilloscope can be used for any AC measurement. The wave-shape can be visually examined on the screen of the instrument. It should be emphasized that only periodic waveforms can generate a stationary pattern on the screen of an analog oscilloscope. Modern digital scopes can capture, store, and display sections of arbitrary waveforms. The function generator is a versatile AC signal source. It can provide several wave-shapes, and the amplitude and the frequency can be adjusted

PREPARATION:

a) Familiarize your selves with the instruments in your station on the bench.
b) Study the instrument's user manuals if available.
c) Calculate the period of a waveform of frequencies 100 Hz, 1kHz, 100 kHz.

EXPERIMENT:

A) **Oscilloscope general**

1) Connect the output of the function generator to ch.1 of the scope, and also to the input of the frequency counter. Set the trigger to ch.1, coupling DC.

2) Select sinusoidal waveform on the generator. Vary the frequency and the amplitude on the generator and observe the results on the scope.

3) Vary the gain and the time-base of the scope and observe the results.

4) Set the frequency counter to measure frequency and compare the reading with the frequency indication on the function generator.

5) Set the amplitude on the generator for 5V peak. Adjust the "level" control on the scope until the waveform just becomes stationary.

6) Decrease the amplitude from the generator, and observe that triggering is lost (waveform starts running). Why?

7) Readjust the "level" control for stationary waveform.

8) Select any waveform and frequency and adjust the "DC offset" control on the generator. Observe the result on the scope.

9) Set the coupling on the scope to AC and repeat step 8. What do you observe? Make comments.

B) **Voltage measurements**

1) Set the generator to a sine wave of frequency 100 Hz and 10V amplitude.

2) Connect the DMM to the output of the generator and set it to measure AC voltage. Verify that the DMM reads the correct RMS value of the sinusoid (equal to 7.07V).

C) **Frequency measurements**

1) Set the generator to sinusoid of frequency 100 Hz and measure the period of the waveform on the scope. Repeat for 1 kHz and 100 kHz, and confirm the results. Set the frequency counter to measure period to get an additional confirmation that your measurements are correct.
   Note: The period can be measured on the oscilloscope as the time between two successive peaks or two successive zero crossings.

2) Repeat step (1) for triangular and square-wave.

REPORT:

In your report describe the work you have done in the lab, and present the measurements you have taken. Compare theoretical and experimental results and make comments. Write all conclusions.

EXPERIMENT # 2
FIRST-ORDER CIRCUITS

OBJECTIVES: To study the step response of first order circuits

EQUIPMENT:

Oscilloscope
Function Generator
100 mH inductor
Resistor substitution box
Capacitor substitution box

BACKGROUND:

Consider the series RC circuit shown in fig.1a. The capacitor voltage is given by:

$$V_c(t) = E(1 - e^{-t/RC}), \qquad t \geq 0$$

This voltage is illustrated in fig.1b. The voltage across the resistor can be found to be:

$$V_R(t) = Ee^{-\frac{t}{RC}}, \qquad t \geq 0$$

and it is plotted in Figure1.c. Similar analysis can be done for the RL circuits of fig.2.

PREPARATION:

a) Consider the circuits in Figure 2. For each circuit derive analytical expressions for $V_o(t)$ when $V_i(t)$=Eu(t) (step of amplitude E). Assume zero initial conditions. Plot $V_i(t)$ for each circuit.
b) Repeat part (a) assuming that $V_i(t)$ is a symmetric square-wave of amplitude ±E, and period T_s=10 RC. (Hint: use superposition).

SIMULATION:

For the circuits of figures 1 and 2 assume R = 1K, C = 0.1 μF, L = 100 mH, R1 = 2.2 K, R2 = 2.2 K. The input is a symmetric square-wave of amplitude ±5V and frequency of 1 kHz. Run simulations to plot $V_o(t)$.

EXPERIMENT:

The purpose of the experiment is to experimentally verify the results you have derived in the preparation, and also have simulated using. The steps below apply to all circuits in figures 1, and 2. Use the same component values as in simulations.

a) Wire one circuit at a time. Connect $v_i(t)$ to the function generator, set at 1 kHz frequency, and square-wave output of amplitude ±5V.
b) Connect ch.1 of the oscilloscope to v_i and ch.2 to v_o. Set the trigger to ch.1
c) Observe and sketch the output voltage and compare it to the expected one.
d) Take measurements on the oscilloscope to determine the time constant of the circuit, and compare the result with the actual one.

REPORT:

In your report present and compare the results that you have obtained theoretically, experimentally, and via computer simulation, and make comments. Write all conclusions.

FIGURES

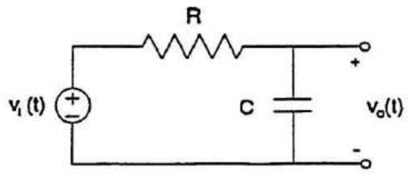


Figure 1.A

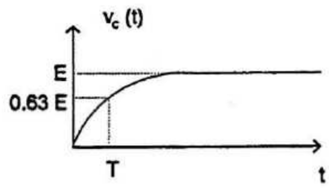


Figure 1.B

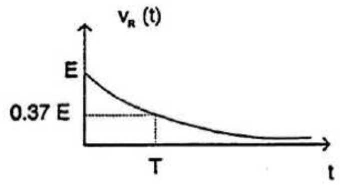


Figure 1.C

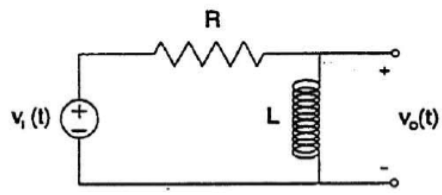


Figure 2.A

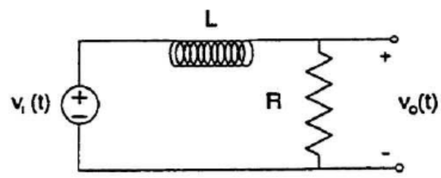


Figure 2.B

EXPERIMENT # 3

SECOND ORDER CIRCUITS

OBJECTIVES: To study the step response of RLC circuits.

EQUIPMENT:

Oscilloscope
Function Generator
100 mH inductor
Capacitor Box
Resistance Box

BACKGROUND:

Second-order circuits have a step-response depending on the nature of the roots of the characteristic equation.

PREPARATION:

A) Consider figure 1. Assume zero initial conditions.

1) For L = 100 mH and C = 0.01 μF, calculate the ranges of values of R for overdamped, critically damped, and under damped response.
2) Assume the response to be the voltage across the capacitor. Plot the response due to a step input for:
   a) R = 22 K ; b) R = 6.8 K ; c) R = 2.2 K
3) Let R = 470 Ohm. Calculate α, ω_n, and ω_d. Plot the voltage across the capacitor due to a square-wave input of frequency of 400 Hz, and amplitudes of ±4V.

B) Consider figure 2:

1) Find the characteristic equation and the poles.
2) Repeat part (A.1) for the same values of L, C.
3) Repeat part (A.2) for:
   a) R = 680 Ohm; b) R = 1.5 K; c) R = 4.7 K;
4) Repeat part (A.3) for R = 22 K

SIMULATION:

Simulate parts A.2, A.3, B.3 and B.4 of the preparation.

EXPERIMENT:

a) Connect the circuit of fig.1. In place of the resistor and the capacitor use the substitution boxes.
b) Connect the input to the function generator. Set to a square-wave of 400 Hz and amplitudes of ±4V.
c) Connect ch.1 of the oscilloscope to the generator output, and ch.2 at the capacitor voltage. Set the trigger to ch.1.
d) Observe and sketch the capacitor voltage for R = 22 K, R = 6.8K, and R = 2.2 K. For each case indicate whether the response is over damped or under damped.
e) Let R = 470 Ohm. Sketch the output voltage and using the oscilloscope measure ω_d.
f) Repeat part (d) for the circuit of fig.2 and resistor values R = 680 Ohm, R= 1.5 K, and R = 4.7 K.
g) Repeat part (e) for fig.2 with R = 22 K

REPORT:

In your report, present and compare theoretical, computer simulated, and experimental results, and make comments. Write all conclusions.

FIGURES

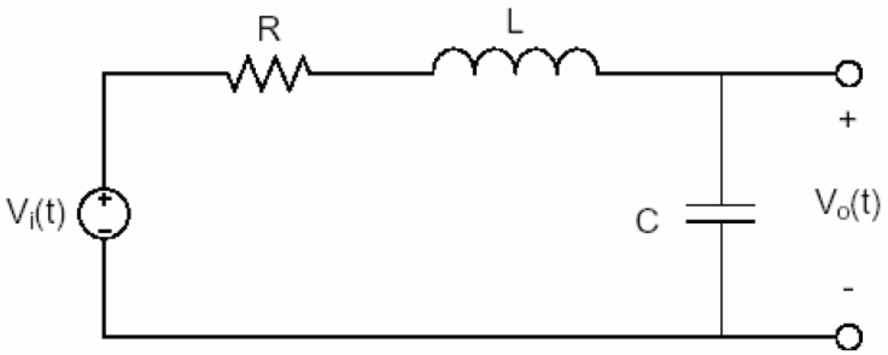


Figure 1

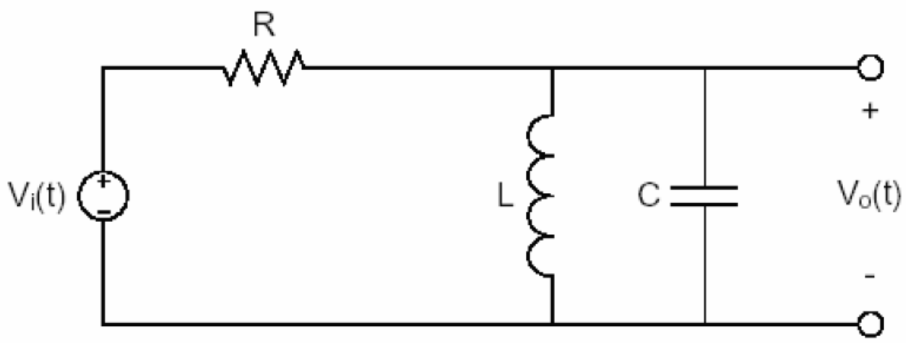


Figure 2

EXPERIMENT # 4

TRANSFER FUNCTIONS

OBJECTIVE: To study the transfer functions of various RC network.

EQUIPMENT:

- Oscilloscope
- Function generator
- Frequency counter
- Resistors
- Capacitors

BACKGROUND:

A two-port linear network can be in general described by a transfer function $H(j\omega) = Vi(\omega) / Vo(\omega)$
Given a sinusoidal input voltage $V_i(t) = V_m \sin(\omega_o t)$, the output voltage will be :

$$V_o(t) = \left|H(j\omega_o)\right| \cdot V_m \sin(\omega_o t + \theta(\omega_o))$$

where $|H(j\omega_o)|$ and $\theta(\omega_o)$ are the magnitude and the phase of the transfer function at frequency ω_o.

PREPARATION:

For all circuits select component values so that RC is any value from 0.1 mS to 0.01mS.

A) Refer to the circuits in fig.1.a and 1.b.

1) For each circuit, find the sinusoidal steady-state transfer function.
2) Assume that the input is a sinusoid. Find the frequency wherethe output voltage will be 45° out of phase, than the input voltage. Find the amplitude of the output voltage at this frequency.
3) Find the frequency where the amplitude of the output voltage is 1/4 of the amplitude of the input voltage.

B) Refer to the circuit in figures 2 and 3.

1) Verify that the transfer function is the one given in each figure.
2) Assume sinusoidal input. Find the frequencies where the phase difference of input and output voltages is either +90 or -90 degrees. Find the amplitude of the output voltage at these frequencies.
3) Repeat part (2) for 0° or 180° phase shift.

SIMULATION:

Run simulations to verify the theoretical results found in the preparation. The amplitude of the sinusoidal input is 10V.

EXPERIMENT:

a) Connect the circuits of figures 1.a and 1.b. Use component values as in the preparation and simulations.
b) Experimentally verify the results you have calculated in parts A.2 and A.3 of the preparation. What is the maximum phase shift that can be achieved with these circuits? Are there any limitations in achieving this phase-shift?
c) Connect the circuits of figures 2 and 3, with component values as in the preparation.
d) Experimentally verify the results you have calculated in parts B.2 and B.3 of the preparation.

REPORT:

In your report present your work, and compare the results you have obtained theoretically, via simulation, and experimentally. Write any comments and conclusions.

FIGURES

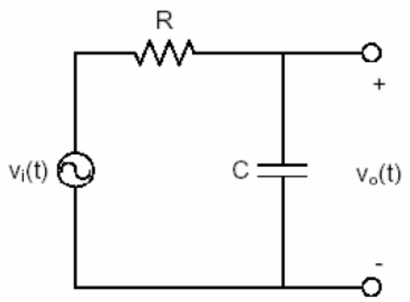


Figure 1.a

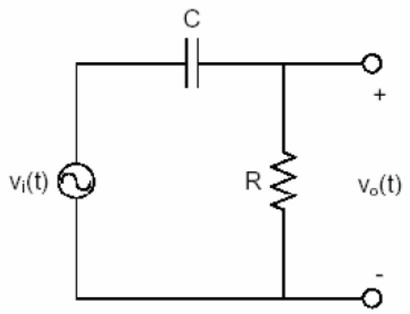


Figure 1.b

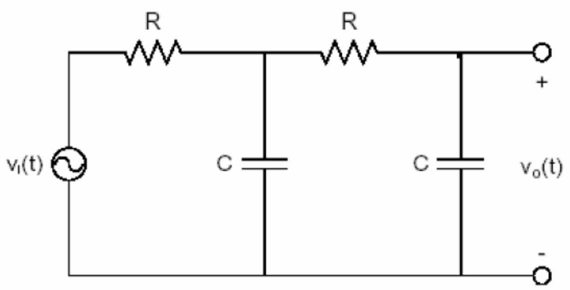


Figure 2.a

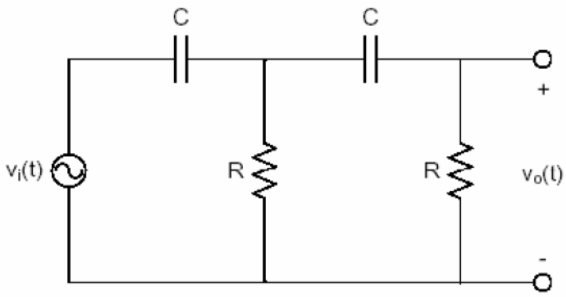


Figure 2.b

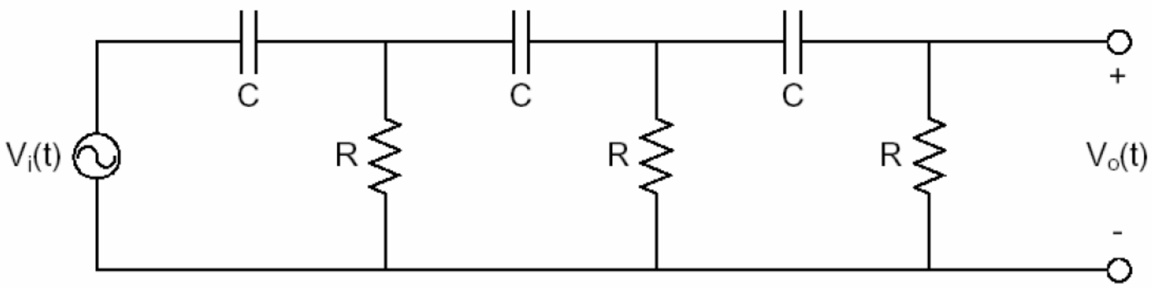


Figure 3

EXPERIMENT # 5

FREQUENCY RESPONSE

OBJECTIVES: To study the frequency response of various RC network.

EQUIPMENT:

- Oscilloscope
- Frequency counter
- Function Generator
- Resistors
- Capacitors

BACKGROUND:

Refer also to the previous experiment. Frequency response refers to the variation of $|H(j\omega)|$ and phase $\{H(j\omega)\}$, when ω varies. This variation can be plotted either in a linear or a logarithmic scale.

PREPARATION:

a) Derive the transfer function of the circuits in Figures 1 and 2.
b) Find the 3db frequencies as function of the component values.
c) Roughly sketch the magnitude and the phase plots on a linear scale, and indicate whether these circuits are low-pass or high-pass filters. For figures 1 and 2 find the phase-shift at the 3 db frequency.

SIMULATION:

For all circuits select reasonable and available component values. For the circuit of Figure 3.A select $C_1 >> C_2$. Do not use electrolytic capacitors. Use circuit simulation to obtain the frequency response of each circuit in the range 100 Hz to 100 kHz. Verify any theoretical results you have derived in the preparation.

EXPERIMENT:

The input is connected to the function generator, adjusted for a sinusoid waveform of amplitude 10V. Use the frequency counter to measure frequencies.

a) Connect the circuits of Figures 1 and 2 and vary the input frequency from 100 Hz to 10 kHz, while observing the output voltage. Take enough measurements to enable you to plot the magnitude and the phase of the transfer function.
b) Find the 3db frequency, and the phase shift at this frequency. Compare to the theoretical values.
c) Connect the circuits of fig.3 and take measurements to plot the magnitude only of the transfer functions in a frequency range of 100 Hz to 100 kHz. Measure the 3db frequencies and the bandwidth. Make comments about the shape of the curves.

REPORT:

Print the frequency responses obtained by, and on the same graphs superimpose the experimentally obtained plots. Provide these plots in your report and make comments about any discrepancies, and state all conclusions.

FIGURES

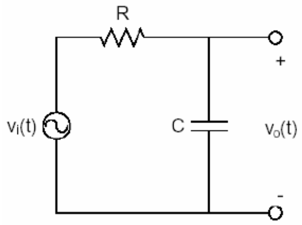
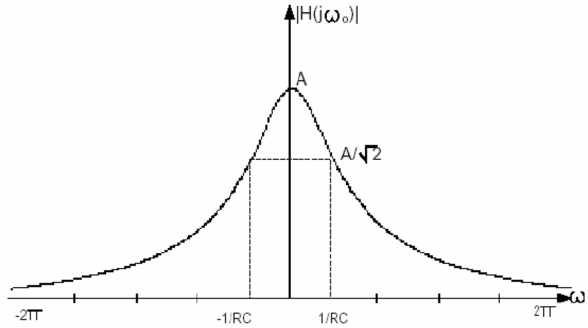
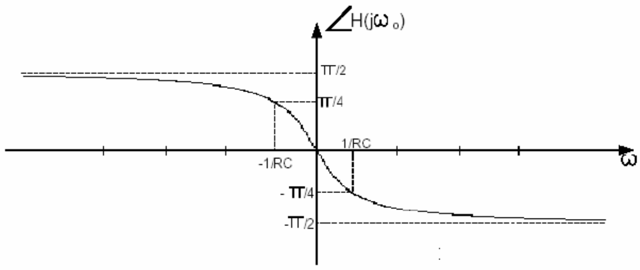


Figure 1



Manitude Response of circuit in Figure 1



Phase Response of circuit in Figure 1

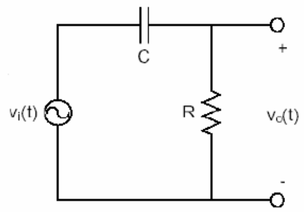


Figure 2

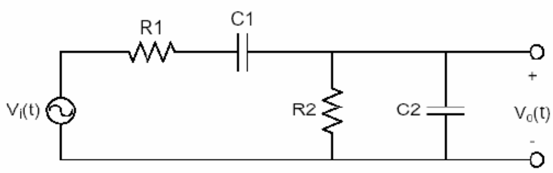


Figure 3.a

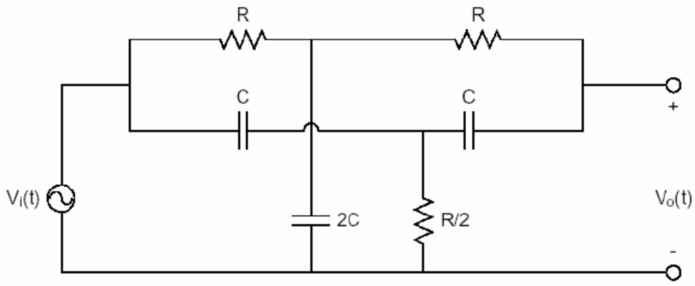


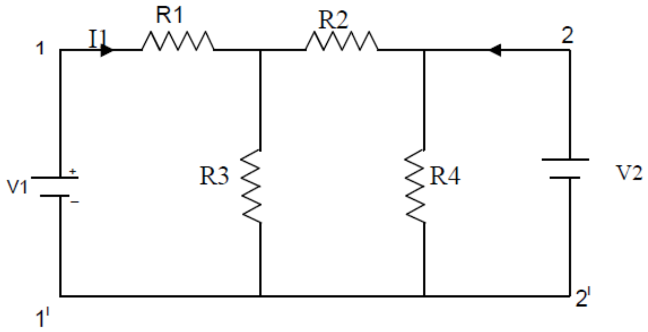
Figure 3b

EXPERIMENT NO. 6

AIM :- To measure input impedance and output impedance of a given two port network

APPARATUS :- Breadboard , resistance , multimeter , connecting wires, etc.

CIRCUIT DIAGRAM:-



THEORY:-

In two port network port variables are port currents and port voltages. To describe relationship between ports voltages and currents , two linear equations are required. In the two port network , there are four variables . These are the voltages and currents at the input and output ports , namely V1 , I1 and V2 , I2. From this two are independent and two are dependent variables.

By expressing V1 and V2 in terms of I1 and I2

V1=Z11.I1+ Z22.I2
V2=Z21.I2+Z22.I2

From these equations we can find out all Z parameters.

PROCEDURE :-

1. Connect dc power supply Va =5V at port 1-1' and keep output port open circuited i.e. I2=0.
2. Measure the current I1 by connecting milliammeter in series with R1.
3. Measure voltage V2 across R4 by Multimeter.
4. From these values of V1, V2, I1 and I2 (I2=0) find input driving point impedance where V1=Va.

$$\text{i.e. } Z11 = V1/I1 \Big|_{I2=0}$$

& Find forward transfer impedance

$$\text{i.e. } Z21 = V2/I1 \Big|_{I2=0}$$

5. Connect dc power supply Vb= 5v at port 2-2' and keep input port open circuited i.e. $I1=0$.
6. Measure the current I2 by connecting milliammeter in series with supply .
7. Measure the voltage V1 across R3 by multimeter .
8. From this value of V2 , V1 , I2 and I1(I1=0) find output driving point impedance that is

$$Z22 = V2/I2 \Big|_{I1=0}$$

&

$$Z12 = V1/I2 \Big|_{I1=0}$$

9. Calculate z-parameters theoretically. These values should be approximately equal to the practical values of z-parameters.

CONCLUSION:-Since Z12=Z21 the circuit is reciprocal and since Z11 = Z22 the circuit is symmetrical.