Salahaddin University – Erbil
College of Science
Physics Department

Electrical Measurements Lab.

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List of Experiments

1- Some Measurements Using Cathode Ray Tube (CRT)
   a- Measurement of DC Voltage
   b- Measurement of AC Voltage
   c- To verify the relation between maximum Voltage (V_{max}) and root mean square value ($V_{r.m.s}$)
2- a- Calibration of the frequency of AC signal
   b- Determination of the frequency of the unknown signal by Lissajous figures.
3- To Determine the value of unknown resistance (R), capacitance (C) and inductance (L).
4- Damping factor in electrical resonance circuit.
5- RC filters (High Pass and Low Pass).
6- Differentiating and integrating Circuit.

OSCILLOSCOPE

An oscilloscope is an electronic test instrument that displays electrical signals graphically, usually as a voltage (vertical or Y axis) versus time (horizontal or X axis) as shown in figure 1. The intensity or brightness of a waveform is sometimes considered the Z axis. There are some applications where other vertical axes such as current may be used, and other horizontal axes such as frequency or another voltage may be used.

Oscilloscopes are also used to measure electrical signals in response to physical stimuli, such as sound, mechanical stress, pressure, light, or heat. For example, a television technician can use an oscilloscope to measure signals from a television circuit board while a medical researcher can use an oscilloscope to measure brain waves.

Oscilloscopes are commonly used for measurement applications such as:

- observing the wave shape of a signal
- measuring the amplitude of a signal
- measuring the frequency of a signal
- measuring the time between two events
- observing whether the signal is direct current (DC) or alternating current (AC)
- observing noise on a signal

An oscilloscope contains various controls that assist in the analysis of waveforms displayed on a graphical grid called a graticule. The graticule, as shown in figure 1, is divided into divisions along both the horizontal and vertical axes. These divisions make it easier to determine key parameters about the waveform. In our oscilloscope, there are 10 divisions horizontally and 8 divisions vertically.

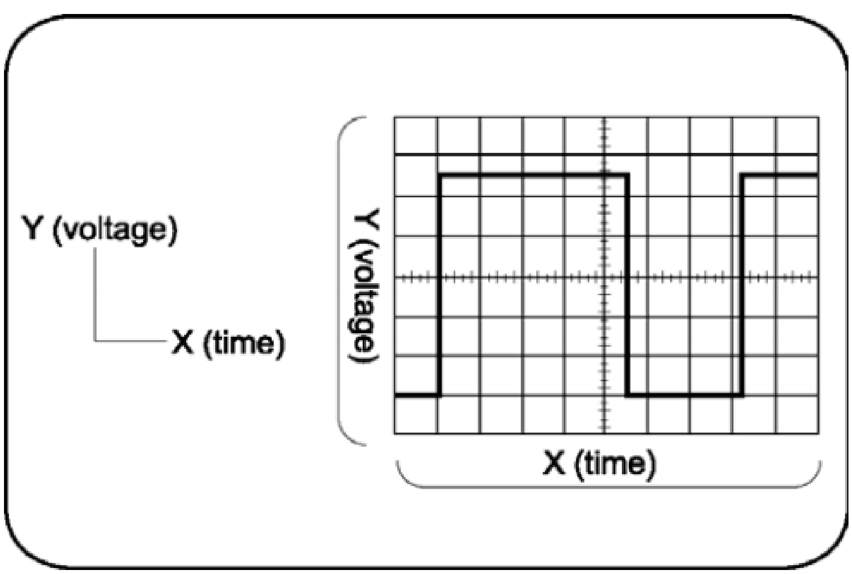
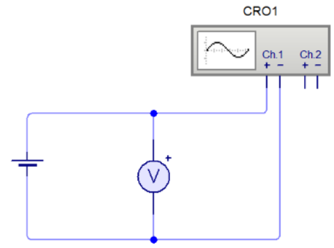


Figure 1: Typical Oscilloscope Display

Experiment No.1

Some Measurements Using Cathode Ray Tube (CRT)

a- Measurement of DC Voltage
b- Measurement of AC Voltage
c- To verify the relation between maximum Voltage (V_{max}) and root mean square value ($V_{r.m.s}$)



a- Measurement of DC Voltage:

Apparatus:

C.R.O , Dc Voltmeter and DC Power supply

Method of experiment:

Connect the circuit as shown in figure.

Switch off the C.R.O time base to obtain a stationary spot of light on the screen. In this and all experiments where the deflection of the C.R.O spot is measured, turn down the brightness control until the actual moment of measurement has arrived. Then turn the brightness up make the measurement and reduce the brightness again.

For a given setting of the Y-sensitivity control (Y- amplifier) apply suitable DC voltage to the Y- plates by means of the given circuit, and measure the corresponding deflection (in cm) of the spot of light and read the corresponding voltmeter reading.

Repeat your measurement and then tabulate your data in the table below:

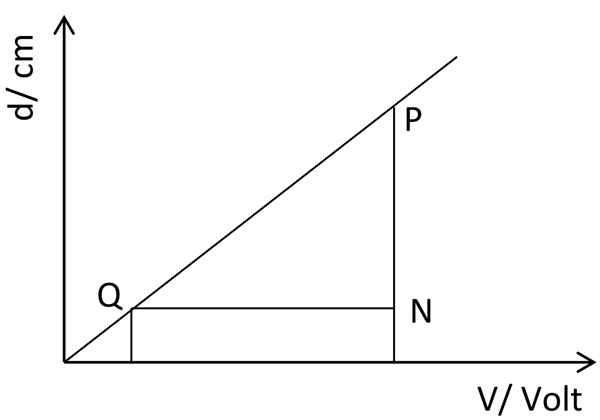
Voltmeter Reading (Volt)	Deflection or C.R.O Reading (cm)
1- ------ 2- ------ 3- ------ ….	

Plot a graph with values of (d) (oscilloscope reading) in the ordinates against the corresponding value of applied voltage (voltmeter reading).

Sensitivity (S) = 1 division / Volt

The relation between voltmeter reading and oscilloscope reading is:

$d = S.V$



From the slope of the graph (PN/QN) calculate the deflection sensitivity in mm per volt (mm/V)

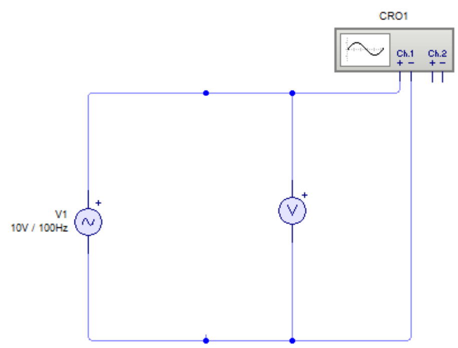
b- Measurement of AC Voltage:

Apparatus:

C.R.O , AC Voltmeter and function generator (AC Power supply)

Method of experiment:

Switch off the C.R.O time base to obtain a stationary spot of light on the screen. For a given setting of Y- sensitivity control apply suitable A.C voltage to the Y-plates by means of the given circuit (R being 1k) and measure the length *l* of the vertical line of the C.R.O which is the peak value voltage of the signal.



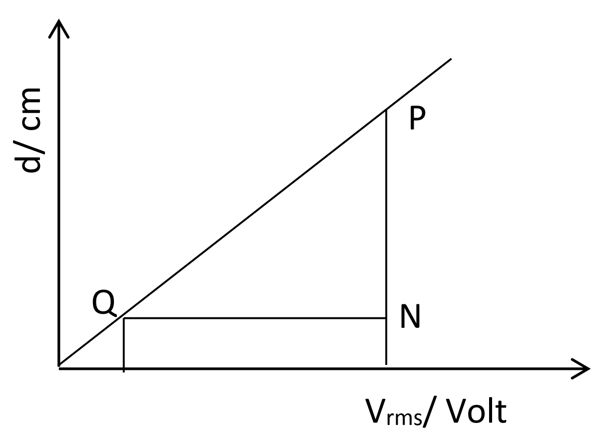
For a given setting of the Y-sensitivity control (Y- amplifier) apply suitable A.C voltage to the Y- plates by means of the given circuit, and measure the corresponding peak value (in cm) of the signal and read the corresponding voltmeter reading (Note: the A.C voltmeter reads the R.M.S value of the voltage)

Repeat your measurement and then tabulate your data in the table below:

Ac Voltmeter Reading (V_{rms}) (Volt)	C.R.O Reading *l* (cm)
1- ------ 2- ------ 3- ------ ….	

Plot a graph with values of (d) (oscilloscope reading) in the ordinates against the corresponding value of applied voltage (voltmeter reading).

From the slope of the graph (PN/QN) calculate the deflection sensitivity in mm per r.m.s volt (mm/V_{rms}) which provided the a.c supply is truly sinusoidal, should be $2\sqrt{2}$ times the result obtained in the previous experiment with dc voltages.



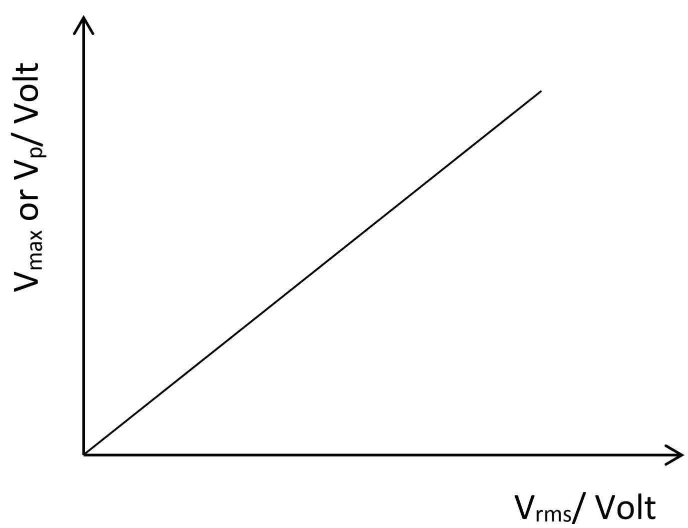
c- <u>To verify the relation between (V_{max})and (V_{rms}):</u>

The relation between maximum voltage V_{max} and root mean square voltage V_{rms} is :

$$V_{max} = \sqrt{2}\, V_{rms}$$

By using the table in the A.C measurement voltage and sensitivity determinant value experiment calculate the V_{max} to each *l* value then tabulate your reading as below:

Ac Voltmeter Reading (V_{rms}) (Volt)	Vmax (volt) = *l*/S
4- ------ 5- ------ 6- ------ ….	



Experiment No.2

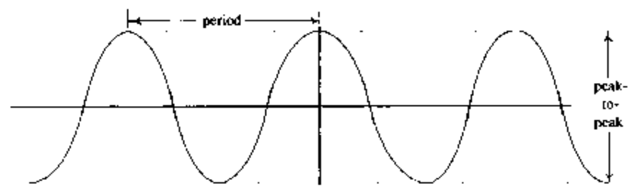
a) Determination of the frequency of A.C signal using Oscilloscope
b) Determination of the frequency of A.C signal using Lissajous figures

a) Determination of the frequency of A.C signal using Oscilloscope:

In order to determine the frequency the period of the signal is first found, then the reciprocal of this quantity is the frequency (f = I/T). The period is the time for one complete oscillation and is represented on the oscilloscope by the horizontal distance from one crest to the next adjacent crest. The value of the period is found by multiplying the TIME/DIV setting of the oscilloscope by the number of divisions from crest to crest. For example, if the TIME/DIV setting is 0.5 ms/div and the number of divisions is 6.3, then the period is (6.3 divisions) x (0.5 ms/div) = 3.15 ms = 3.15 x 10^{-3} sec. The corresponding frequency is 1/(3.15 x 10^{-3} sec) = 317 Hz. (Remember that the calibration knobs (CAL'D) must be turned all the way in the clockwise direction until they click.)

Apparatus

- Oscilloscope
- Signal generator



Procedure

1) Connect the leads of the oscilloscope to the signal generator - red to red and black to black. Plug the oscilloscope and signal generator into the sockets. Turn on the oscilloscope and the signal generator.
2) Adjust the frequency knob on the signal generator until it is generating a sinusoidal signal of arbitrary amplitude and one kHz frequency.
3) Adjust the horizontal (X) and vertical (Y) position knobs until the pattern is centered on the screen of the oscilloscope.
4) Change the setting of the VOLTS/DIV knob until the signal fills vertically as much of the screen as possible.
5) Change the setting of the TIME/DIV knob until approximately four full cycles of the signal fill the screen horizontally and then read the crest to crest distance *l in (cm)*.
6) For different values of frequency (200 Hz, 300 Hz …. 1000 Hz) and measure the corresponding values of *l and (A*= TIME/DIV).

$$\boldsymbol{f = \frac{1}{T} = \frac{1}{A.l}}$$

7) Tabulate your reading as in the table:

$f_{\text{theoretical}}$ (Hz)	l (cm)	A (sec/cm)	A.l (sec)	$f_{experimental} = \frac{1}{A.l}$ (Hz)

b) <u>Determination of the frequency of A.C signal using Lissajous figures:</u>

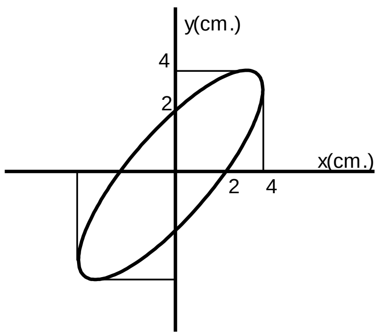
When a body affected by two S.H.M perpendicular to each other then their resultant motion will be ellipsoid and its shape depends on:

1- Amplitude of the two wave signals
2- Frequency of each signal
3- Phase difference between them

If the first signal v_x applied to CH_2-X and second signal v_y is applied to CH_1-Y where:

$v_x = V_x \sin wt$ *and* $v_y = V_y \sin(wt + \theta)$

Then the shape will be ellipsoid, for signal with the same frequency.



Mathematically let :

1st signal $x = a \sin wt$ -------- (1) and 2nd signal $y = b \sin(wt + \theta)$ ------------ (2)

From (1) and (2) $\sin wt = \frac{x}{a}$ -------------- (3)

$$\therefore \cos wt = \sqrt{1 - \left(\frac{x}{a}\right)^2}$$

And $\frac{y}{b} = \sin(wt + \theta) \Longrightarrow \sin wt \cos\theta + \cos wt \sin\theta$

Substituting for sinwt and coswt we get : $\frac{y}{b} = \frac{x}{a}\cos\theta + \sqrt{1 - \left(\frac{x}{a}\right)^2}\ \sin\theta$ ------------------------- *(4)*

Squaring both sides of equation (4), after arrangement we get:

$$\frac{x^2}{a^2} - \frac{2xy}{ab}\cos\theta + \frac{y^2}{b^2} = \sin^2\theta$$ ---------------- (Ellipsoid Equation)

1- For $\theta = 0, 180$ the shape is will be straight line.
2- For $\theta = \frac{\pi}{2}$ the shape will be a circle.

Therefore the shape depends on the phase angle θ

When the frequency of the first signal is multiple of the second signal, the ratio (1:1; 1:2; 2:1; 1:3; 3:1; 3:2; 2:3) then the shape will be one loop or more, these shapes are called Lissajous figures.

The frequency of the unknown signal can be calculated from:

$$f_y = f_x . \frac{T_h}{T_y}$$

Where:

f_x: frequency of the signal connected to CH2 or X-channel.

f_y: frequency of the signal connected to CH1 or Y-channel.

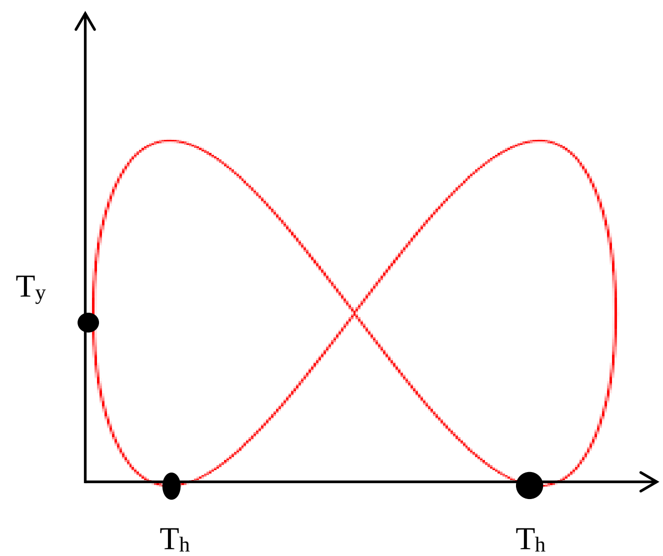
T_h: Number of the horizontal tangential with the curve.

T_y: Number of vertical tangential with the curve.

For example in the given 2:1 figure:

$T_h = 2$ and $T_y = 1$

$$f_y = f_x . \frac{T_h}{T_y} = 2f_x$$

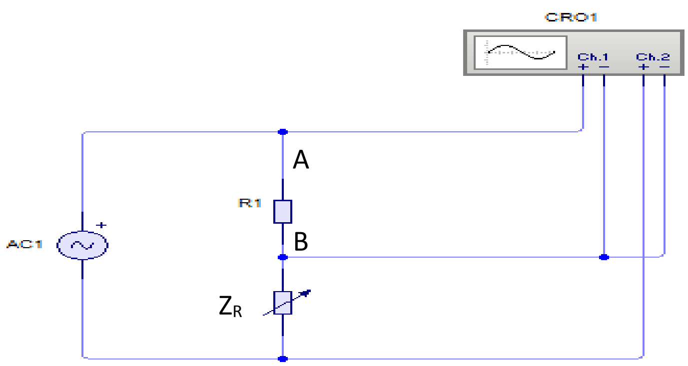


Experiment No.3

Determination the values of resistance (R), inductance (L) and capacitance (C)

a) <u>Resistance measurement (R):</u>

1- Connect the unknown resistance (R) between the points A and B as shown in figure 1:



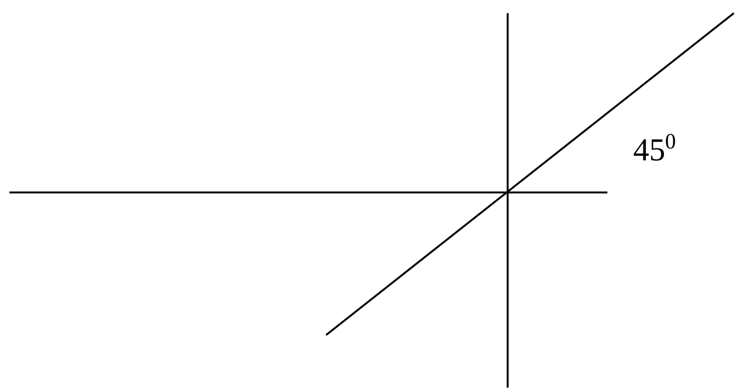
(Figure 1)

2- change the values of resistance box to get a line inclined 45^0 with X-axis on the screen same as in figure 2. i.e $Z_R = R$

3- Change the frequency of the AC signal and measure the corresponding resistance from resistance box that cause to get back the line into 45^0 if it changes with frequency.

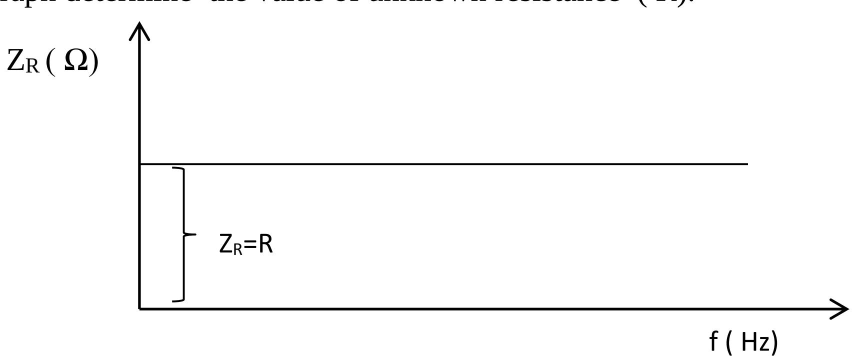
4- Record your reading as in table below:

Frequency (Hz)	Resistance box Z_R
200	
300	
..	
..	
..	
1000	



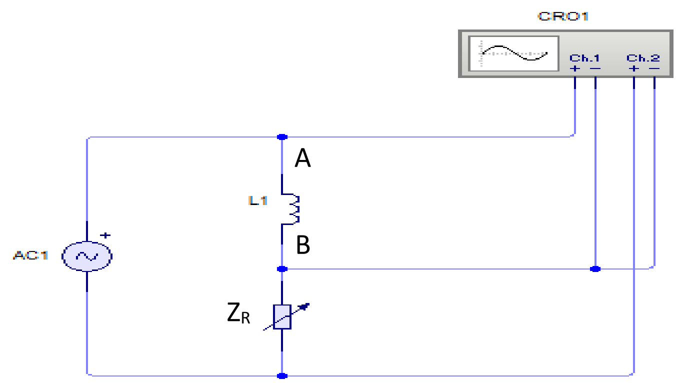
(Figure 2)

5- Draw the graph between the values of resistance box (Z_R) and frequency (f) and then from the graph determine the value of unknown resistance (R).



b) Inductance measurement (L):

1- Connect the unknown inductor (L) between the points A and B as shown in figure3:

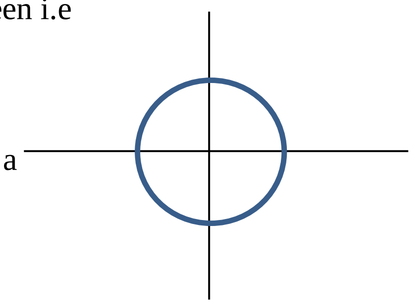


(Figure 3)

2- Change the value of the resistance box (Z_R) to get a circle on the screen i.e

$$Z_R = X_L$$

and $2\pi f L = X_L \Longrightarrow L = \frac{Z_R}{2\pi f} = \frac{slope}{2\pi}$

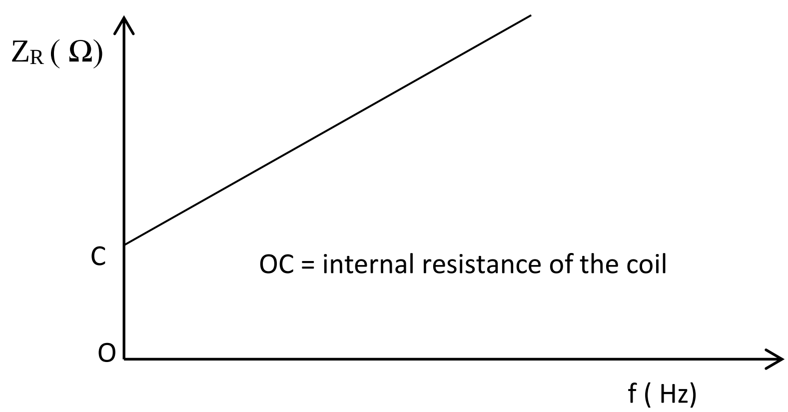


3- Repeat the experiment with different values of frequency, and obtain a circle for each frequency value by changing the resistance box.

4- Tabulate your reading as table below:

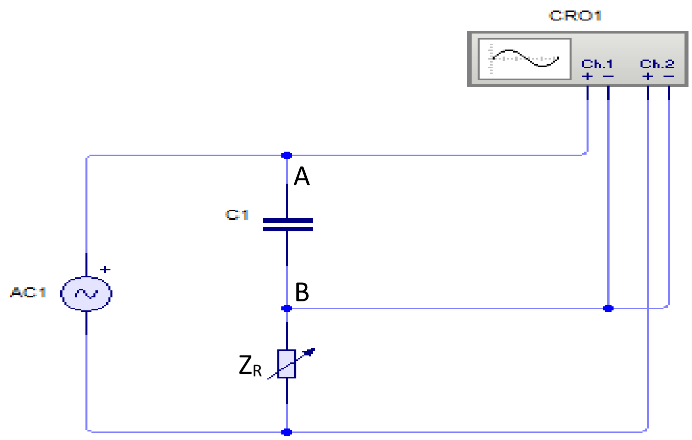
Frequency (Hz)	Resistance box Z_R
200	
300	
..	
..	
..	
1000	

5- Draw a graph between the values of resistance box and frequency, then use the equation ($L = \frac{Z_R}{2\pi f} = \frac{slope}{2\pi}$) to determine the value of L.



c) <u>Capacitance measurement (C):</u>

1- Connect the unknown capacitor (C) between the points A and B as shown in figure4:

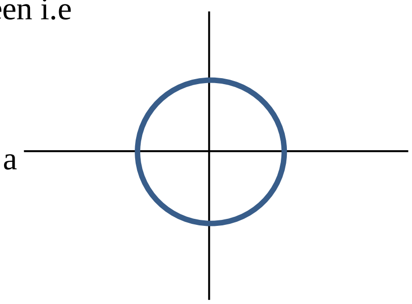


(Figure4)

2- Change the value of the resistance box (Z_R) to get a circle on the screen i.e

$$Z_R = X_C$$

$$and\ Z_R = X_C = \frac{1}{2\pi f C} \Longrightarrow C = \frac{1}{2\pi f Z_R} = \frac{1}{2\pi .Slope}$$

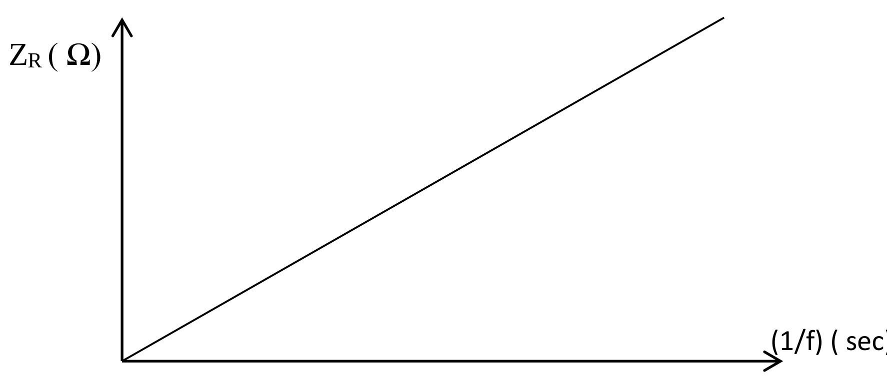


3- Repeat the experiment with different values of frequency, and obtain a circle for each frequency value by changing the resistance box.

4- Tabulate your reading as table below:

Frequency (Hz)	Resistance box Z_R
200	
300	
..	
..	
..	
1000	

5- Draw a graph between the values of resistance box and (1/f), then use the equation ($C = \frac{1}{2\pi .Slope}$) to determine the value of C.



Experiment No.4

Damping factor in electrical resonance circuit

The aim of this experiment is to investigate the resonance in an RLC circuit and to determine the damping factor .

Apparatus :

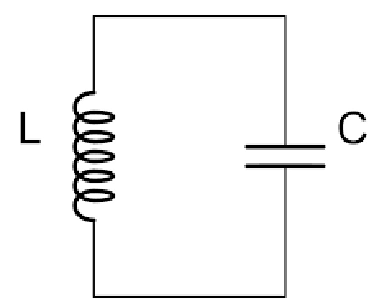
Signal generator, resistor, capacitor, inductor and oscilloscope.

Theory:

An electric circuit is called in resonance if there is no dissipation of electrical energy in the circuit. This is satisfied if electrical ohmic resistance is zero in the circuit and this is an ideal case which can not be obtained empirically. Since resistance can not be zero for circuit element, therefore energy can be oscillating between capacitor and inductor as electric and magnetic energy respectively.

In ordinary case the electric circuit in damping resonance, the electrical energy dissipated with time during its oscillation between the capacitor and inductor. This condition implies the existence of ohmic resistance of the circuit which dissipates the electrical energy.

For case 1: If R = 0 no energy dissipation, then the voltage equation is:



$V_L + V_C = 0$ ----------------- (1)

$L\frac{d^2q}{dt^2} + \frac{q}{C} = 0$ ---------------- (2)

Therefore $\frac{d^2q}{dt^2} + \frac{q}{LC} = 0$ ---------------- (3)

The solution of this second order differential equation is given by:

$q = Q\cos(wt)$ ---------------- (4)

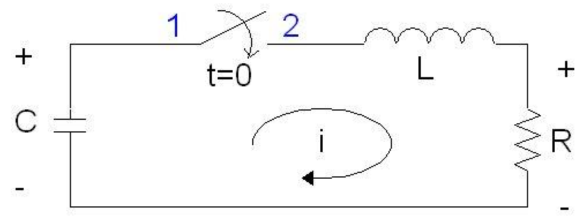
Where $w_0 = \sqrt{\frac{1}{LC}}$ --------------- (5)

Therefore $f_0 = \frac{1}{2\pi}\sqrt{\frac{1}{LC}}$ --------------- (6)

For case 2: If R ≠ 0

The voltage equation is :

$V_L + V_C + V_R = 0$ ----------------- (1)



If we now apply kirchoff's voltage law we obtain the following:

$$L\frac{di}{dt} + Ri + \frac{1}{C}\int_0^t i\,dt = 0$$

to remove the integral from the equation we differentiate the equation once and divide through by L to give:

$$\frac{d^2 i}{dt^2} + \frac{R}{L}\frac{di}{dt} + \frac{i}{LC} = 0$$

Now let:

$$i(t) = Ae^{st}$$

hence:

$$\frac{di}{dt} = sAe^{st}$$

and:

$$\frac{d^2 i}{dt^2} = s^2 Ae^{st}$$

thus substituting into differential equation above and dividing through by Ae^{st} gives:

$$s^2 + \frac{R}{L}s + \frac{1}{LC} = 0$$

which is a quadratic equation in terms of s. The roots of this equation can be found by using:

$$s = -\frac{R}{2L} \pm \sqrt{(\frac{R}{2L})^2 - \frac{1}{LC}}$$

this equation gives us three different sets of roots:

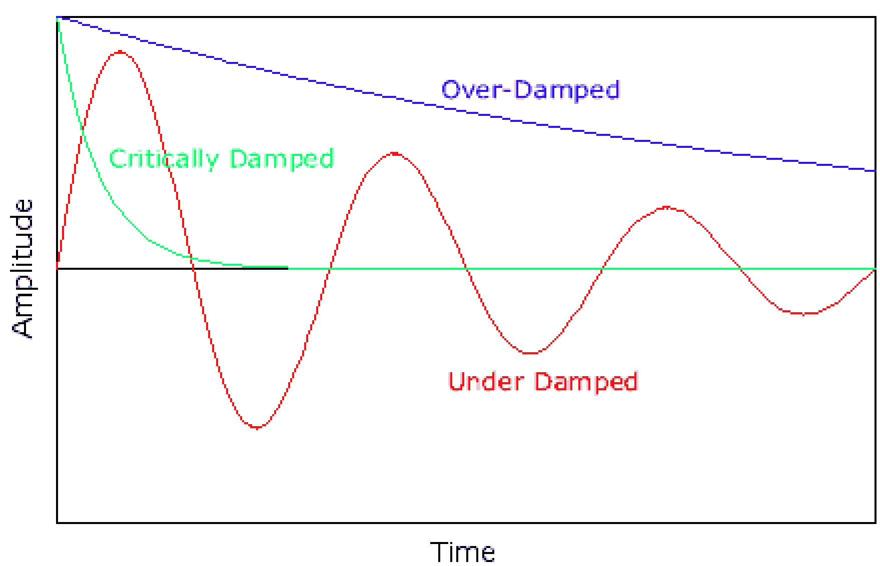
(i) when $(\frac{R}{2L})^2 > \frac{1}{LC}$ which means there are two real roots and relates to the case when the circuit is said to be over-damped.

(ii) when $(\frac{R}{2L})^2 < \frac{1}{LC}$ which means there are two complex roots (as root(-1) is imaginary) and relates to the case when the circuit is said to be under-damped.

(iii) when $(\frac{R}{2L})^2 = \frac{1}{LC}$ which means that the two roots of the equation are equal (i.e. there is only one root) and relates to the case when the circuit is said to be critically damped

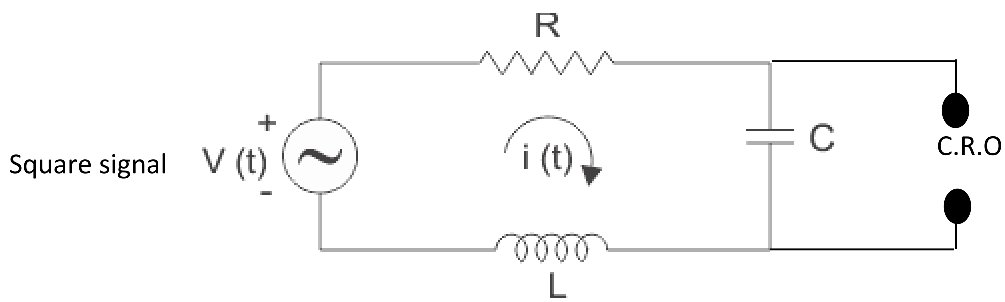
The solution of this equation is hence given by:

$$i(t) = Ae^{st} + Be^{st}$$



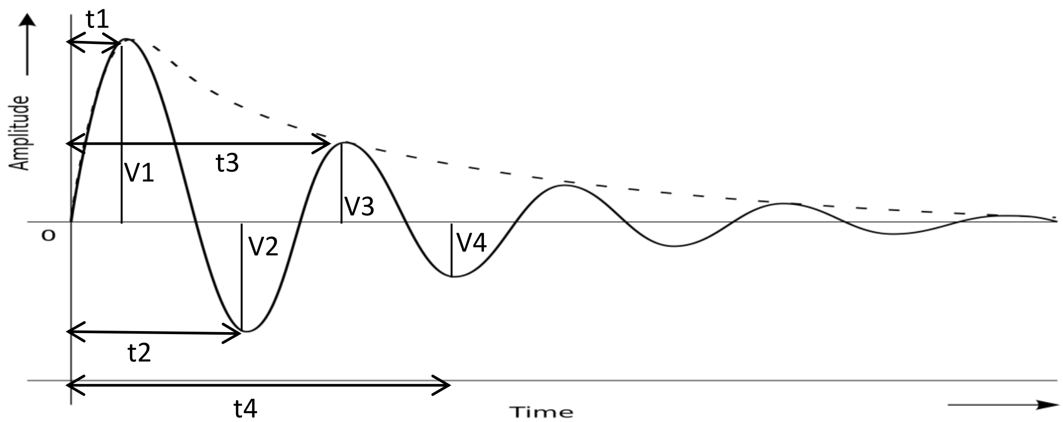
Experimental Method:

1- Connect the given circuit.



2- Choose the convenient values of for R, L and C and adjust the frequency of the signal generator such that to get damping oscillation pattern on the C.R.O screen as shown in the figure.

3- Measure the values of voltages V_1, V_2, V_3, …….. and their corresponding times t_1, t_2, t_3, ……



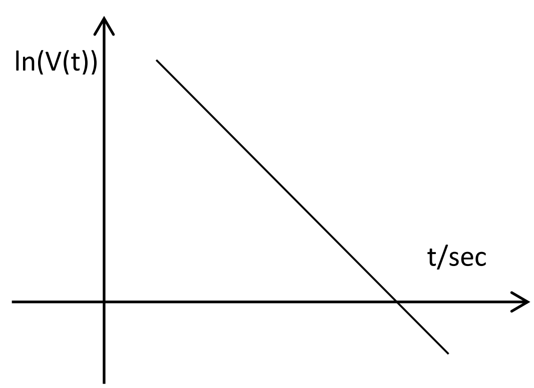
4- Tabulate your reading as in the table below:

V(t) /volt	t/sec	ln(V(t))
V1	t1	ln(V1)
V2	t2	ln(V2)
V3	t3	ln(V3)
V4	t4	ln(V4)

5- From the decay amplitude factor of the damping equation

$$V(t) = V_0 e^{-\left(\frac{R}{2L}\right)t} \Longrightarrow \ln[V(t)] = \ln V_0 - \left(\frac{R}{2L}\right)t$$

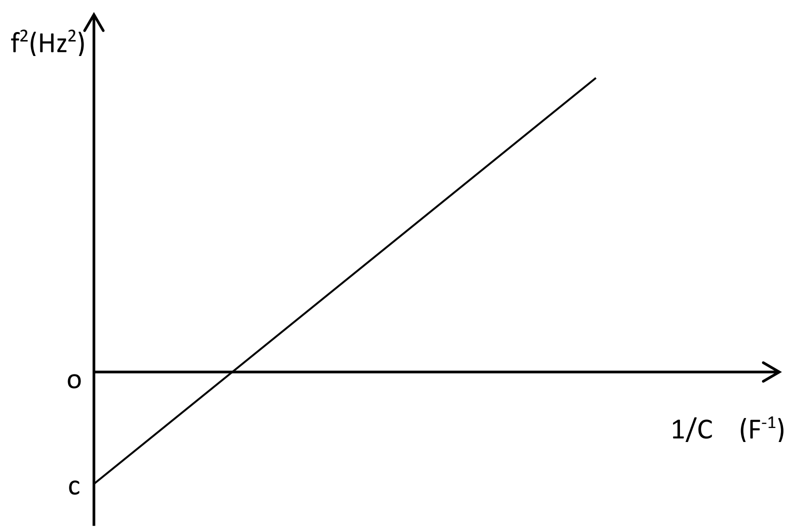
6- Plot a graph between (ln(v(t)) versus time (t) as shown, for each correct measurement value of voltage amplitude, where the value of (C) is constant, then the slope of the straight line is equal to:



$$m = \frac{R}{2L} \text{ damping factor}$$

7- Repeat step (4) for different values of (C = 1, 2, 3, …….100 pf) and measure the corresponding frequency for each value of C, tabulate your reading as in table below:

R (Ω)	C pf	T (sec)	f=1/T (Hz)	f^2 $(Hz)^2$
100				
100				
100				
100				



8- Slope of the graph is :

$$m = \frac{1}{4\pi^2}\frac{1}{L}$$

And the negative intercept (OC) equal to the $\frac{1}{4\pi^2}(\frac{R}{2L})^2$

Experiment No.5

RC Filters

INTRODUCTION

A filter is a device that changes the amplitude (height) of an AC voltage (a voltage in the form of a sine wave) as the frequency of the input voltage changes. Filters have two terminals. The input terminals take in the input voltage, which passes through the filter and onto the output terminals, where the resulting output waveform can be observed. Figure 1.1 is a basic representation of a filter.

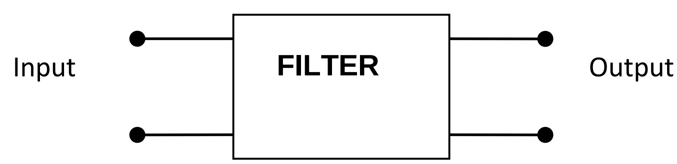


Figure 1.1

There are several types of filters, but in this experiment, we will be looking at three types.

A low-pass filter is a filter that allows a signal of a low frequency (i.e. a low amount of oscillations per second) to pass through it. Consequently, it attenuates (reduces) the amplitude of an input signal whose frequency is higher than the cutoff frequency.

A high-pass filter is a filter that passes high frequencies well, but attenuates (or reduces) frequencies lower than the cutoff frequency.

These two filters will be investigated in this experiment.

a) LOW-PASS FILTER

CIRCUIT

Figure 5.1 shows a simple low-pass filter consisting of a resistor and a capacitor, which should be constructed on your breadboard. Notice that the input is connected in series with the resistor, and the output is the voltage across the capacitor. The input and output have one common terminal, which is the low (ground, or reference) side of each.

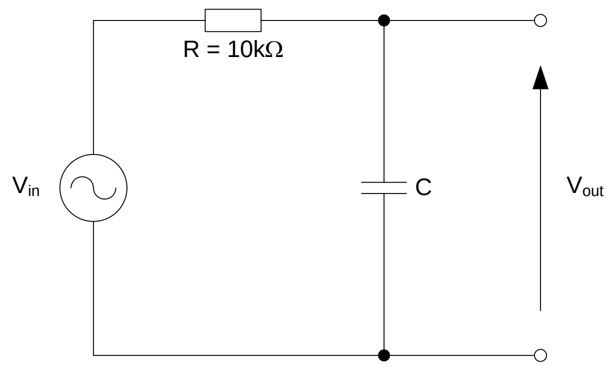


Figure 5.1

TESTS

Set up the function generator so that it produces a sinusoidal waveform, with a peak to peak voltage of 10V. Use the oscilloscope to verify this.

Use Channel 1 of the scope to display Vin, and Channel 2 to display Vout. You may need to set up the triggering function of the scope, especially for the lower frequencies.

Starting at 50Hz, vary the frequency of the input signal up to 2500Hz (2.5kHz) in a sufficient number of steps. For each increment, note down the peak to peak voltage of the output for each frequency, and tabulate your results in table below.

f (Hz)	Vout (Volt)	Vout/Vin

Plot a graph of the amplitude of Vout/Vin against the frequency, which should resemble Figure 5.3.

$$f_c = \frac{1}{2\pi RC}\ \text{Hz}$$

Calculate the cutoff frequency using the above formula, and account for any discrepancies between the calculated value and the measured value.

b) HIGH-PASS FILTER CIRCUIT

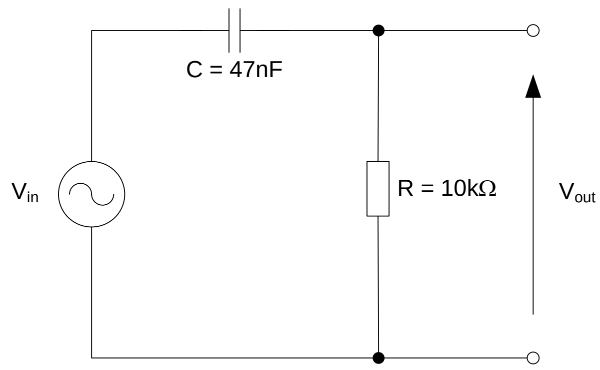


Figure 3.1

Figure 3.1 shows an RC network that behaves as a high-pass filter. Notice that the high-pass filter is the same as the low-pass filter, but with the positions of the resistor and capacitor interchanged. Here the input is in series with the capacitor and the output voltage is taken across the resistor.

TESTS

Repeat the tests as outlined in low pass test, but this time start your frequency readings at 100Hz and work your way up to 10kHz. Record all your results in your lab book. The cutoff frequency can be calculated in the same way as for the low-pass filter. Note that your corresponding graph will not be the same as that shown in Figure 5.3.

Repeat the spectrum analysis test, but this time set the frequency scale to 500Hz. Compare the two tests and explain your observations

Plot a graph of the amplitude of Vout/Vin against the frequency, which should resemble Figure 5.3.

$$f_c = \frac{1}{2\pi RC}\ \text{Hz}$$

Calculate the cutoff frequency using the above formula, and account for any discrepancies between the calculated value and the measured value.

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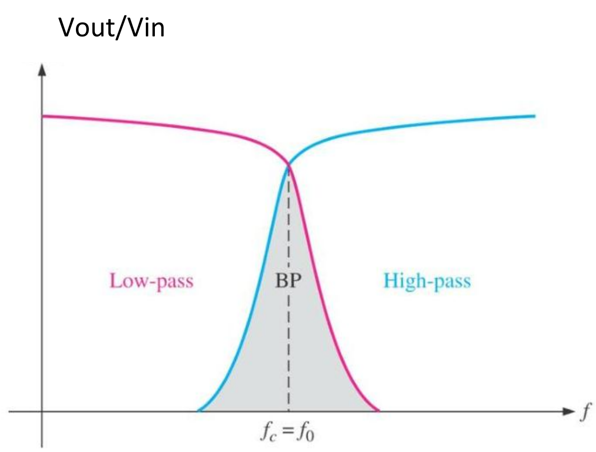


Figure 5.3

Experiment No.6

Differentiating and Integrating Circuit

a) Differential Circuit:

For the differentiating circuit, the voltage across the resistance is related to the differentiation of the input voltage . The circuit for this operation is RC circuit in which output is taken across the resistance as in figure1.

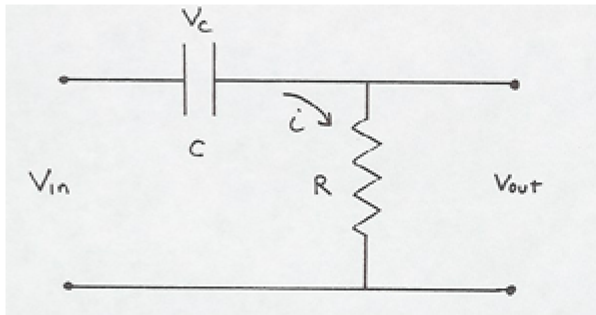


Figure1

We arrange for nearly all the input voltage to drop across the capacitor (Vc >> Vout) by making R small and Xc large using a small C . Thus the voltage drop across R measures i without disturbing Vc

$$V_{in} = V_c + V_{out} \approx V_c \qquad i = C\frac{dV_c}{dt} = \frac{V_{out}}{R}$$

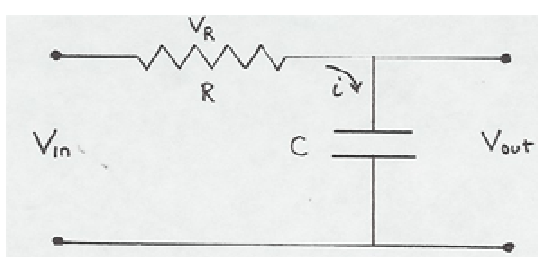
$$V_{out} = RC\frac{dV_c}{dt} = RC\frac{d(V_{in}-V_{out})}{dt} \approx RC\frac{dV_{in}}{dt}$$

i.e the output voltage approaches the form of spike to be expected from the derivative of a rectangular wave with:

RC<<Tp	(Differentiator condition)

b) Integrating Circuit:

For the integrating circuit, the voltage is taken across the capacitor is related to the integral of the input voltage . The circuit for this operation is RC circuit in which output is taked across the resistance as in figure2.



The resistance R is made large and the

Figure 2

capacitative reactance Xc is made small by using a large C . Then the current into the circuit is set by R and proportional to Vin. The capacitor stores and integrates the charge.

$$V_{in} = V_R + V_{out} \approx V_R \qquad V_{out} = \frac{1}{C}\int i\,dt$$

$$V_{out} = \frac{1}{C}\int \frac{V_{in} - V_{out}}{R}\,dt \approx \frac{1}{RC}\int V_{in}\,dt$$

i.e the output voltage approaches the form of inclined line to be expected from the integral of a rectangular wave with:

RC>>Tp (Integrator condition)

This requirement that RC>>Tp leads to the approximation in the above equation ($V_{in} \approx V_R$). The wave is then a close approach to saw tooth.

Differential	Integral