EXPERIMENT : 2

OBJECTIVE: To familiarise with the use of a signal generator and oscilloscope and to verify the output of sine wave through various circuit steps using thevenin's model of voltage divider.

APPARATUS REQUIRED:

- Printed circuit board
- Probes
- Signal generator
- connecting wires
- Cathode Ray Oscilloscope (CRO)

THEORY:

Oscilloscope: It is a device to view oscillations by a display on the screen of a cathode ray tube. It analyses and displays the waveform of electronic signals, and hence draws a graph of the instantaneous signal voltage as a function of time.

In this experiment, we shall use cathode ray oscilloscope. It contains a vacuum tube with cathode at one end and an anode to accelerate the electrons towards a phosphor screen that exhibit fluorescence when an electron strikes it (electron gun). The tube contains two set of electrodes - one horizontal effecting the 'sweep rate', i.e., movement of the horizontal scale and one set of electrodes where input/output voltage is fed to be observed.

We can observe the trace of two channels available in CRO at once. It is a graph of voltage against time, whose shape is determined by nature of input voltage.

The different properties of a signal are shown in the adjacent figure.

Scale in y-axis (voltage) can be changed for two channels independently by adjusting respective volts/cm control (Y-amplifier) while the time sp scale is same for both channels and controlled by the time scale knob – time base control (Time/cm control).

The circuit drawn is the circuit being used in the experiment. The input voltage is applied to at CH1 and output voltage at CH2. V_0 (output voltage) is seen across load (R_L).

$$V_{TH} = \frac{V \times R_2}{(R_1 + R_2 - j/\omega C_0)}$$

$$X_{TH} = (R_1 - j/\omega C_0) \parallel R_2$$

$$= \frac{(R_1 - j/\omega C_0) \cdot R_2}{(R_1 + R_2 - j/\omega C_0)}$$

$$V_L = \left(\frac{V_{TH}}{X_{TH} + X_L}\right) \times X_L = \frac{V R_2 \times X_L}{(R_1 + R_2 - j/\omega C_0)} \times \frac{1}{\left(X_L + \frac{R_2 (R_1 - j/\omega C_0)}{(R_1 + R_2 - j/\omega C_0)}\right)}$$

This is the voltage shown in the CH2 (V_{out}).

OBSERVATIONS :

a) when X_L has only resistance:

SL NO.	R_L, KΩ	Vo observed (in V)	Vo calculated (in V)
1.	∞	1.93	1.975
2.	R_3	1.12	~~1.703~~ 1.170
3.	R_4	1.80	1.702
4.	$R_3 \parallel R_4$	1.13	1.069

b) when X_L includes both resistance and capacitance:

SL.NO.	X_L, Ω	R_L, KΩ	Vo observed (V)	Vo calculated (V)
1.	7.95×10^{-2}	∞	3.2×10^{-3}	1.27×10^{-3}
2.	7.95×10^{-2}	2.16	3.2×10^{-3}	1.27×10^{-3}
3.	7.95×10^{-2}	10.16	3.2×10^{-3}	1.27×10^{-3}
4.	7.95×10^{-2}	1.78	3.2×10^{-3}	1.27×10^{-3}

$C_b = 100 \mu F$ (electrolytic)

✓

PROCEDURE:

- Input from the signal generator is fed into CRO CH1 ~~after~~ after completion of circuit. The appropriate scales on the x-axis (time axis) and y-axis, i.e., amplitude axis are chosen.

- The signal generator is set to produce 6V p-p, 20KHz sine wave. The amplitude and frequency are traced.

- V_L is measured and traced in CH2 for following cases:
  - → $R_L = \infty$ (no load)
  - → $R_L = R_3$ (connecting T7 to T4)
  - → $R_L = R_4$ (connecting T6 to T4)
  - → $R_L = R_3 || R_4$ (connecting T4 with T6, T7).

  The values of V_L are compared with value of V_L calculated by Thevenin model.

- The third step is repeated with capacitor C_0 connected parallel to R_L. All cases of V_L are traced.

The Vo (calculated) is found by putting respective values in the equation:

$$V_L = \frac{V R_2 X_L}{(R_1 + R_2 - j/\omega C_0)\left(X_L + \frac{R_2 (R_1 - j/\omega C_0)}{(R_1 + R_2 - j/\omega C_0)} \right)}$$

The equation was calculated on the basis of Thevenin model of voltage divider.

Teacher's Signature :

TRACES OF Vout :

SCALES:

Time scale: 20µs/cm (x-axis)

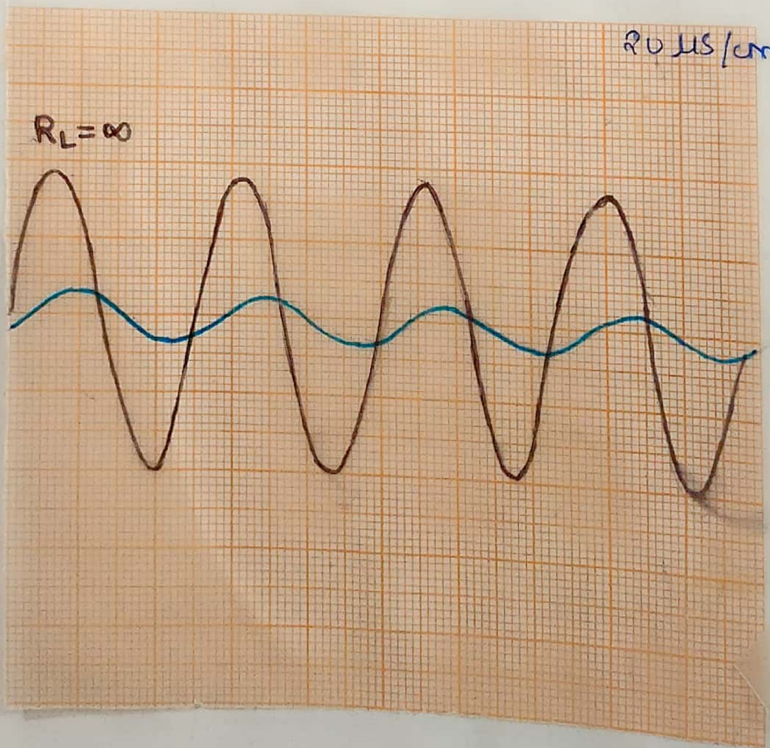
Output voltage (without capacitance): 0.5V/cm.
Input voltage: 1V/cm. ~~E~~
Output voltage (with capacitance): 5mV/cm.
} (Y-axis).

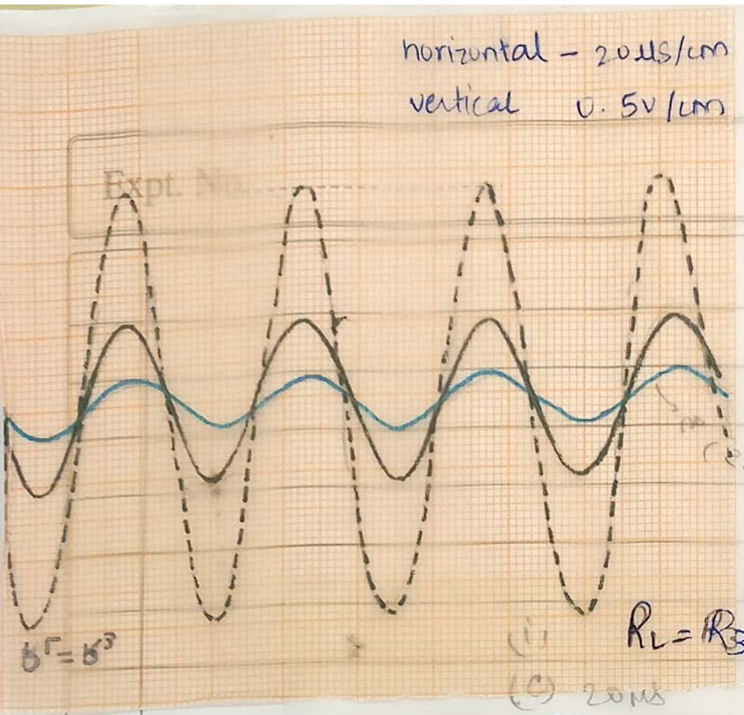
— (blue line) represents output when capacitor is in parallel with resis
— black line represent output when only resistor is connected

Input voltage 6V_{PP}

(i)

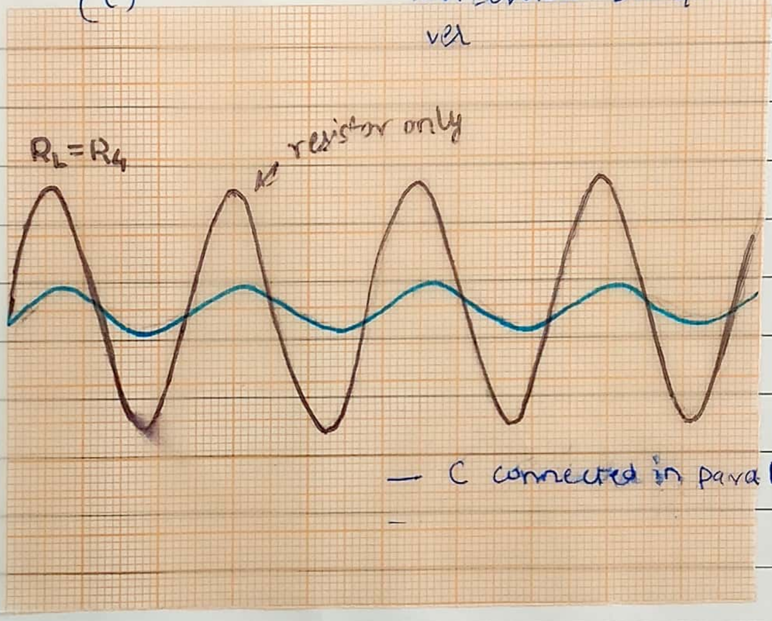
output voltage (6pp).
20µs.





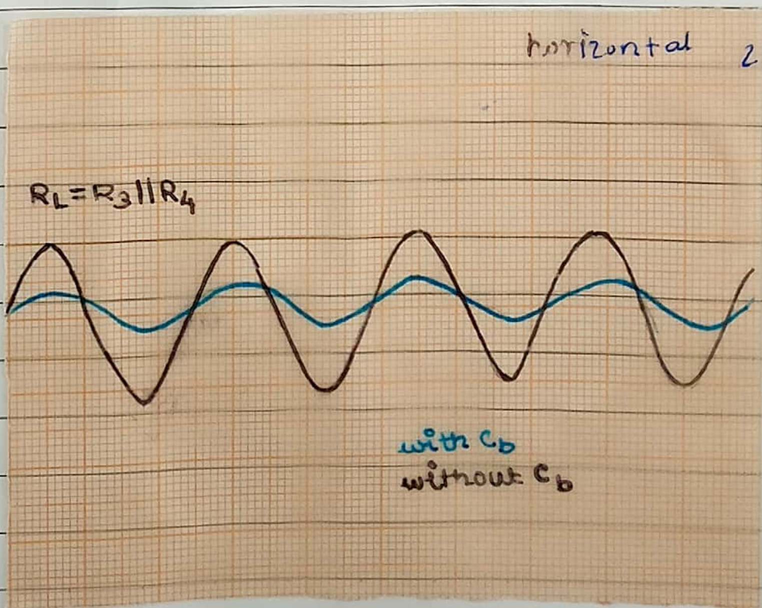
(C)

horizontal 20µs/cm
vel



horizontal 20µS/cm

(d)



Teacher's Signature : ____________

EXPERIMENT : 2-B

AIM : To study frequency response and pulse response of RC, CR and RL circuits.

APPARATUS REQUIRED :

- Signal generator
- Cathode Ray Oscilloscope (CRO)
- Connecting wires
- Probes
- Printed circuit board.

THEORY :

I. The amplitude of input voltage is fixed and frequency is varied to study the effect of frequency on output voltage in different circuits:

a) R-C circuit :

The input voltage is fed into simple RC circuit and output is taken across capacitance.

Thus, $v_o = v_i \times \frac{X_C}{R+X_C} = \frac{v_i}{1+\omega CRj}$

Transfer function $= H(f) = \frac{1}{[1+(\omega RC)^2]^{1/2}}$, $\theta = -\tan^{-1}(2\pi f RC)$

Thus for higher frequencies v_o/v_i is very low, i.e., amplitude of v_o is less and thus it acts as a low pass filter.

R - C Network:

$R = 10.33\,K\Omega$ $\quad C = 93.4 \times 10^{-9} F$

$f_c = \frac{1}{2\pi RC} = 164.957\ Hz$

Experimental value observed = 170 Hz

S. No	Frequency (Hz)	Output Voltage	gain $\left(\frac{V_o}{V_{in}}\right)$	$20\log\left(\frac{V_o}{V_{in}}\right)$
1.	50	1.2	1	0
2	100	1.16	0.967	-0.445
3.	130	1	0.83	-1.5836
4.	150	0.88	0.73	-2.694
5.	170	0.84	0.7	-3.098
6.	300	0.6	0.5	-6
7.	500	0.4	0.33	-9.542
8	1000	0.22	0.183	-14.73
9.	10K	0.022	0.0183	-34.73
10	50k	.0045	3.75×10^{-3}	-48.51
11	100K	.0025		-53.6
12	400k	.0012		-60

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cutoff frequency: Frequency at which V_0 is .70 times the input frequency or $\left(\left(\frac{V_0}{V_i}\right)_{db}\right.$ is -3dB).

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

b) C-R circuit:

In this circuit, input is fed across a R-C series circuit and output is taken across the resistance.

If V_i is input voltage,

$$V_0 = V_i \frac{R}{R + X_C} = \frac{V_i R}{R + \frac{1}{j\omega C}}$$

$$\text{Transfer function} = \frac{1}{[1 + 1/\omega^2 C^2 R^2]^{1/2}} \text{ (or gain)}$$

$$\theta = \tan^{-1}\left(\frac{1}{\omega RC}\right)$$

By the transfer function, V_0 is small for lower frequencies and thus, ~~at~~ amplitude of V_0 is significant only for higher values of frequency and thus it acts as a high pass filter.

Similarly, there exists a cutoff frequency denoted by

$$f_L = \frac{1}{2\pi RC}.$$

Teacher's Signature :

C-R Circuit (i):- $C_2 = 9.05\,nF$ $R_2 = 10.53\,K\Omega$ $f_c = \frac{1}{2\pi RC} = 1.670k$

S. No.	Frequency (Hz)	Output Voltage (V)	gain ($\frac{V_{out}}{V_{in}}$)	$20\log\left(\frac{V_{out}}{V_{in}}\right)$ (dB)
1.	50	1.8 x 20 mV	0.03	-30.457
2.	100	3.6 x 20 mV	0.06	-24.436
3	500	.354 mV	0.295	-10.954
4.	1000	0.6 V	0.5	-6.020
5.	1300	0.74 V	0.62	-4.2
6.	1600	0.84	0.7	-3.09
7	1800	0.86	0.72	-2.89
8.	3000	1	0.83	-1.583
9.	5000	1.14	0.95	-0.445
10	10K	1.2	1	0
11	100K	1.2	1	0
12	500K	1.2	1	0

C-R Circuit (ii) $C_3 = .11\,nF$ $R_3 = 10.25\,K\Omega$ $f_c = \frac{1}{2\pi RC} = 141.157k$

S. No.	Frequency (Hz)	Output Voltage (V)	gain ($\frac{V_{out}}{V_{in}}$)	$20\log\left(\frac{V_{out}}{V_{in}}\right)$ (dB)
1.	100	.0008	6.7×10^{-4}	-63.5
2.	500	.004	3.33×10^{-3}	-49.5
3.	5K	.04	0.33×10^{-1}	-29.54
4.	1K	.008	6.6×10^{-3}	-43
5.	10K	0.075	0.0625	-24.08
6.	50K	0.32	0.267	-11.48
7.	100K	0.6	0.5	-6.02
8.	150K	0.84	0.7	-3.09
9.	300K	1.1	0.92	-0.75
10.	400K	1.2	1	0
11.	500K	1.2	1	0

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c) R-L circuits :

In this type of circuit, input is fed into series R-L circuit and output is taken across inductance.

Let v_i be input and V_o be the output ; by thevonin model;

$$v_0 = \frac{X_L}{R+X_L} \cdot v_i = \frac{j\omega L}{j\omega L + R} v_i = \frac{v_i}{1 - \frac{R}{\omega L} j}$$

Again, transfer function = $\frac{1}{\sqrt{1+\left(\frac{R^2}{\omega^2 L^2}\right)}}$ (gain)

$\theta = \tan^{-1}(R/\omega L) \rightarrow$ phase difference between v_o and V_i.

For high values of ω (or frequency), gain is high and hence, it is also a high pass filter.

II. In the Pulse response experiment, square waves are passed through RC, RL and CR circuits and their effects are recorded.

Low Pass integrator : RC filters have the expression

$$V = q/c = \int \frac{i\,dt}{c} \quad \text{for } T << RC.$$

High Pass differentiator : CR circuits have expression

$V = iR = C\frac{dV}{dt}R$ for $T >> RC$ and RL circuits have

$V = v_i - L\frac{di}{dt}$ for $T >> L/R$ and hence are called differentiators.

The effects of these circuits are observed on square wave input signals accordingly.

Teacher's Signature :

R-L Circuit :-

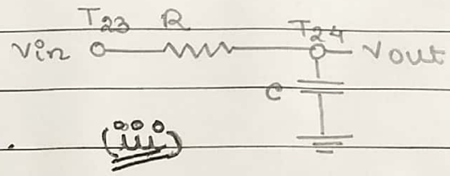
R = ~~15~~927 kΩ L = 2.2 mH $\frac{R}{2\pi L}$ = ~~1104.67~~ 117.412k

S. No.	Frequency	Vout (V)	Vout/Vin	$20\log\left(\frac{V_o}{V_i}\right)$
1.	50Hz	0.014	0.0116	-38.66
2.	100Hz	0.014	0.0116	-38.66
3.	500Hz	0.016	0.013	-37.5
4.	1k	0.02	0.017	-35.56
5	10k	0.12V	0.1	-20
6.	50K	0.6V	0.5	-6.02
7.	100K	0.8	0.66	-3.52
8.	150K	0.96	0.8	-1.94
9	200K	1.08	0.9	-0.92
10	400K	1.2	1	0
11	500K	1.2	1	0

PROCEDURE:

I. Frequency response:

a) R-C network:



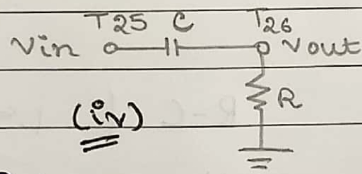
• The values of R and C are measured and the circuit is set up. (iii)

• Vin is supplied with sine signal Vin of 1.2V p-p. This signal is traced from CRO.

• The amplitude of Vin remains constant while it's frequency is varied over range of 10HZ to 500K HZ and the effect of change of frequency is recorded.

• Vout / Vin vs frequency graph is plotted. It is low pass filter.

• Theoritical and observed values of fc are compared.



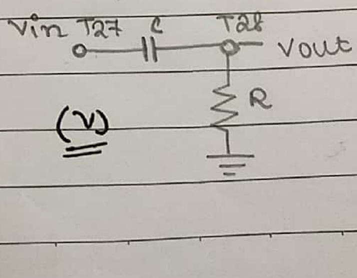
b) C-R network: Part(i):

• The values of R and C are recorded and the circuit is setup. (iv)

• Again frequency of vi is varied and Vo amplitude were taken.

• Graphs were plotted and theoritical and observed values of fc are compared.

Part (ii):

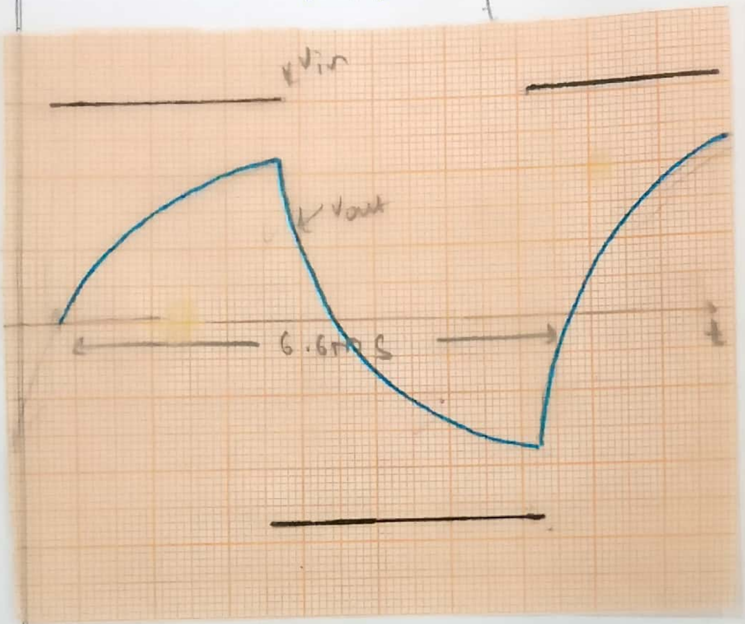


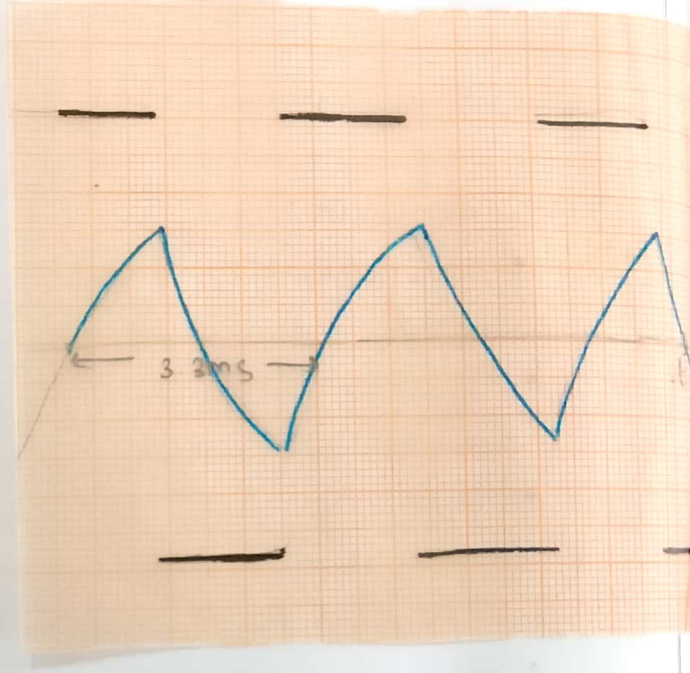
The same experiment was repeated with different circuit and the same steps were followed. (v)

R-C Circuit (T>>RC)

$V_{in} = 1.2 V_{pp}$ T>>RC 150Hz

300Hz



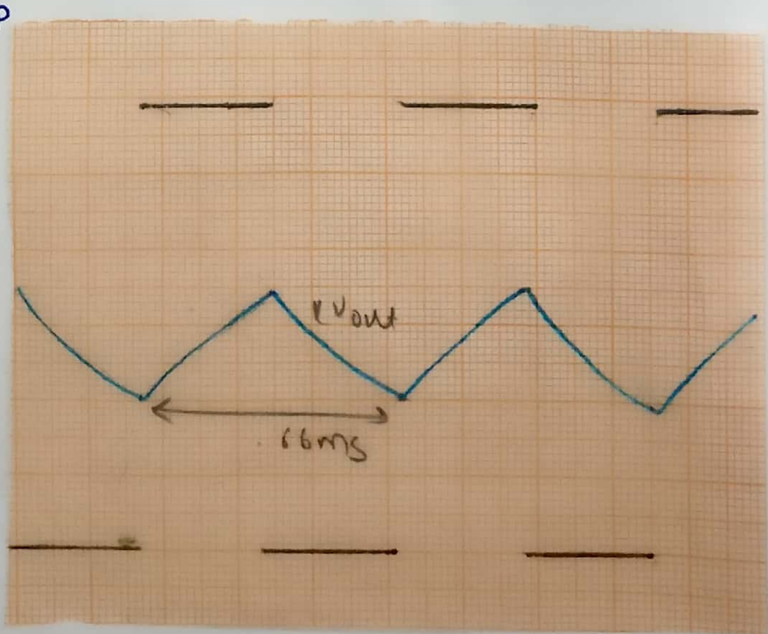


$t/d = 1ms$

$\frac{v}{d} = 0.2V$

R-C [1.5KHz] (integrator T<<RC

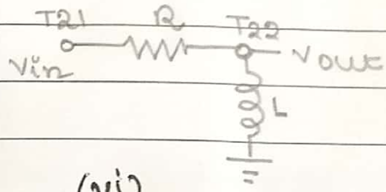
$V_{in} = 1.2 V_{pp}$



$\frac{t}{d} = 0.2ms$

$\frac{v}{d} = 0.1V$

c) R-L network:



(vi)

• The value of R in the circuit is recorded and the circuit is setup. Value of L ≈ 2.2mH.

• Again the same experiment is repeated with this circuit and graphs is plotted. $f_c = R/2\pi L$

II. Pulse Response:

• The signal generator is set to produce a 12V p-p pulse (or square) waveform. This signal is applied to CH1 of the scope and it's amplitude and pulse repitition frequencies (PRF = 1/T) are measured and traced.

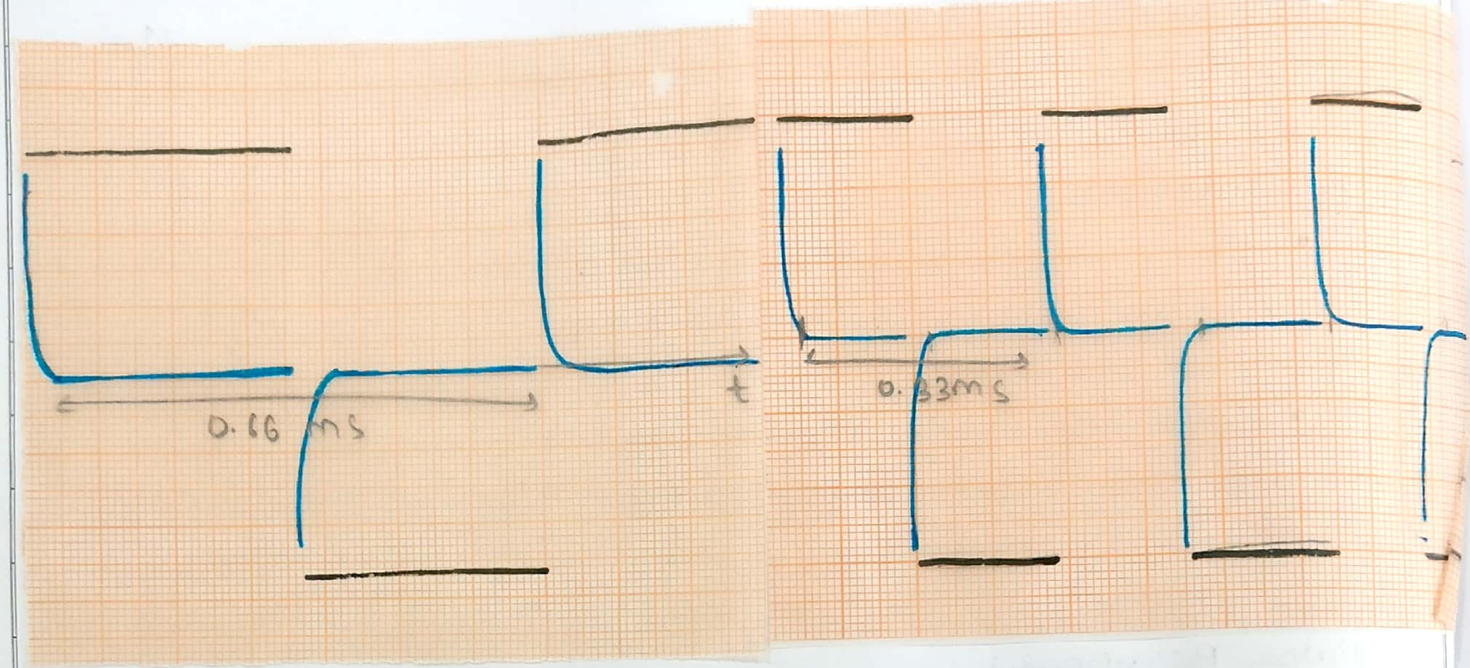
• The traces of each circuit setups are found:
The rise time for first setup is found.
Rise time: Time taken by V_o to reach 90% of V_i from 10% V_i.
Theoritically it is 2.2RC = $0.35/f_c$ ($f_c \Rightarrow$ cutoff frequency).
The different values are calculated and measured.

RESULTS:
Rise Time:

Circuit	Rise Time (observed)	Theoritical value:
RC , T>>RC	2.06×10^{-3}	2.2×10^{-3} s

Similarly, τ for figure (iv) circuit = 2.2×10^{-4} s.
(fall time)

C-R



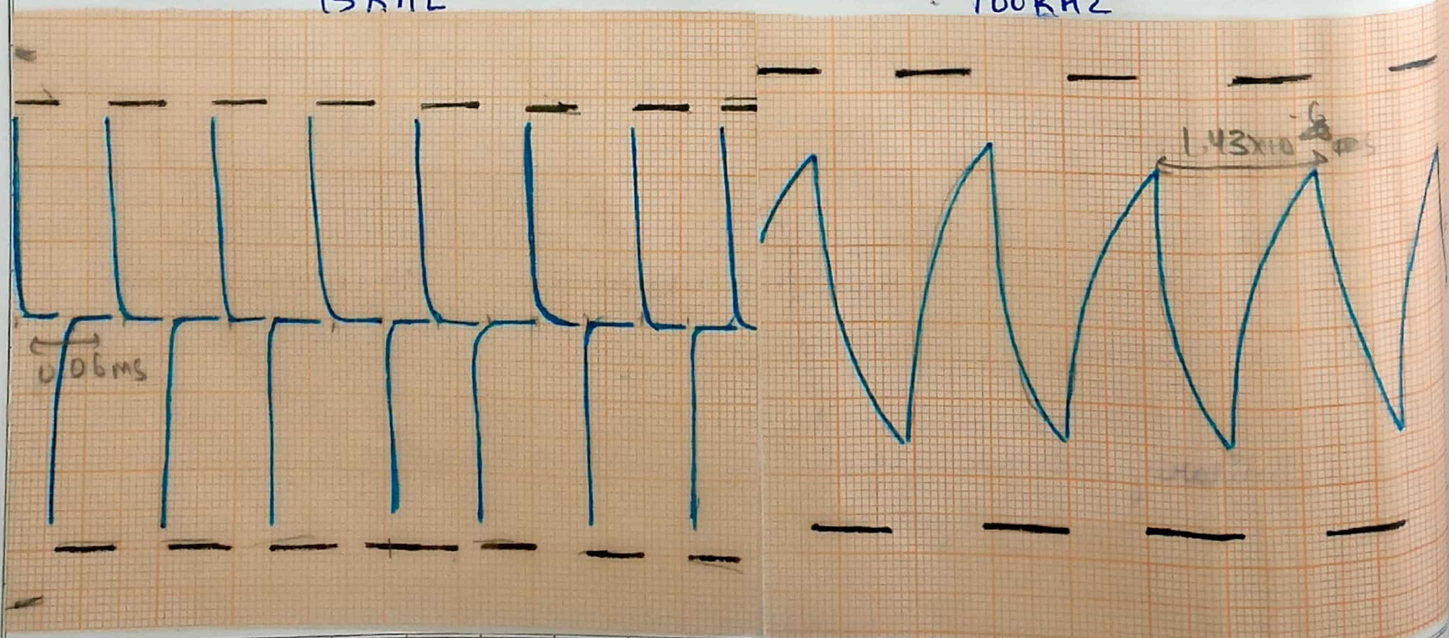
C-R circuit 1.5 KHz $\frac{v}{d} = 0.2\,V$ $\frac{t}{d} = 0.1\,ms$

Vin = 1.2Vpp

(differentiator) (T>>RC)

R-L 15KHz $\frac{t}{d} = 50\,\mu s$ $\frac{v}{d} = 0.2$ $T >> \frac{L}{R}$ differentiator

15KHz 700KHz



circuit :	f_c (Theoritical)	f_c (observed):
R-C circuit	159.15 Hz	170 Hz
C-R circuit (i)	1591.55 Hz	1500 Hz
C-R circuit (ii)	15915.5 Hz	15000 Hz
R-L circuit	108514 Hz.	110 KHz

Date ....

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DISCUSSION :

Swastika Dutta
[16CS10060]

I. In this experiment the Thevenin Model of Voltage Divider for AC supply was verified. The calculated values of Vout using Thevenin Theorem was found to be roughly equal to experimentally calculated values, within limits of experimental error.

For applied frequency of 20KHz, $X_c = 1/2\pi f c$ is in the range of ohms ($\sim .5\Omega$) while the R_L was of order of $K\Omega$. Thus, the impedance offered by capacitor was much less and acted as short circuit, i.e., $V_L << V_{in}$ for cases where C_b is connected.

II. In this experiment, transfer function or frequency gain (Vout/Vin) was obtained for RC and CR circuits. The Vout was analysed at various frequencies to infer whether it is high pass / low pass filter.

A corresponding graph is obtained. The 3dB f_c was deduced, within limits of experimental error.

In R-L circuit, ideally value of Vout should increase, however experimentally it is seen to decline after some time owing to coil winding capacitance, output capacitance, stray wiring, etc., which are in parallel to inductor. Thus the output gets damped after a certain value (LPF character becomes dominant).

Teacher's Signature : ....

Date

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III. In this experiment pulse response of various circuits were obtained; traces of pulse response were obtained and rise time were calculated.

- R-C circuit: Integrator at $T << RC$:

  when capacitance has insufficient time to charge $(V = Q/C)$ and voltage across it is less and hence V_i is almost equal to voltage across resistor. $v = \int \frac{i\,dt}{C}$

- C-R circuit: Differentiator at $T >> RC$:

  Capacitance has sufficient time to acquire charge and V across capacitance is comparable to V_i.

  Here, $v = iR = C\frac{dv}{dt} \cdot R$.

10/10

KBK
8/8/17

Teacher's Signature :

Discussion:-

(By Chelsi Raheja
16CS10013)

1. Voltage divider circuit managed to verify the output voltage obtained with the calculated values within experimental error.
C_0 was applied in circuit but was not involved in calculation as C_0 was of high value and its reactance would be low.
It ~~was~~ ~~used~~ is used to minimize the ripples.

2. In the high range of frequency like 100 kHz, X_C was quite small as compared to R as it was in kΩs. Impedance was quite just resistance, ~~so~~ implying capacitor to act as short circuit

3. Ratio of Vout and Vin was found to be decreasing for R-C circuit and increasing for C-R circuits.

4. It was observed that logarithm of ~~rat~~ Vout/Vin was found to be a straight line after fc for R-C and before fc for C-R circuit.

5. fc value of R-L circuit could ~~&~~ not be reached within the limit of 500 kHz as calculated value was quite large.

6. Defining the case of T<<RC, capacitor has insufficient time to charge up and input voltage equals voltage across resistor. ~~Cir~~ circuit's capacitor act as an integrator at T<<RC.

7. Capacitor charges ~~to~~ almost to input voltage as time ~~appl~~ given is sufficient implying capacitor to work as differentiator

8 Voltage per division was varied from millivolts to volts as ~~change~~ range ~~of~~ frequency was from few Hertz to kilohertz. to maintain accuracy and get ~~g~~. accurate results.

9. Vout observed across R, L ~~circ~~ in R-L circuit was found to be constant at low frequency.

KBP
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