INDIAN INSTITUTE OF TECHNOLOGY

DATE 23/09/16 | EXPERIMENT No. 6 | SHEET NO. 33

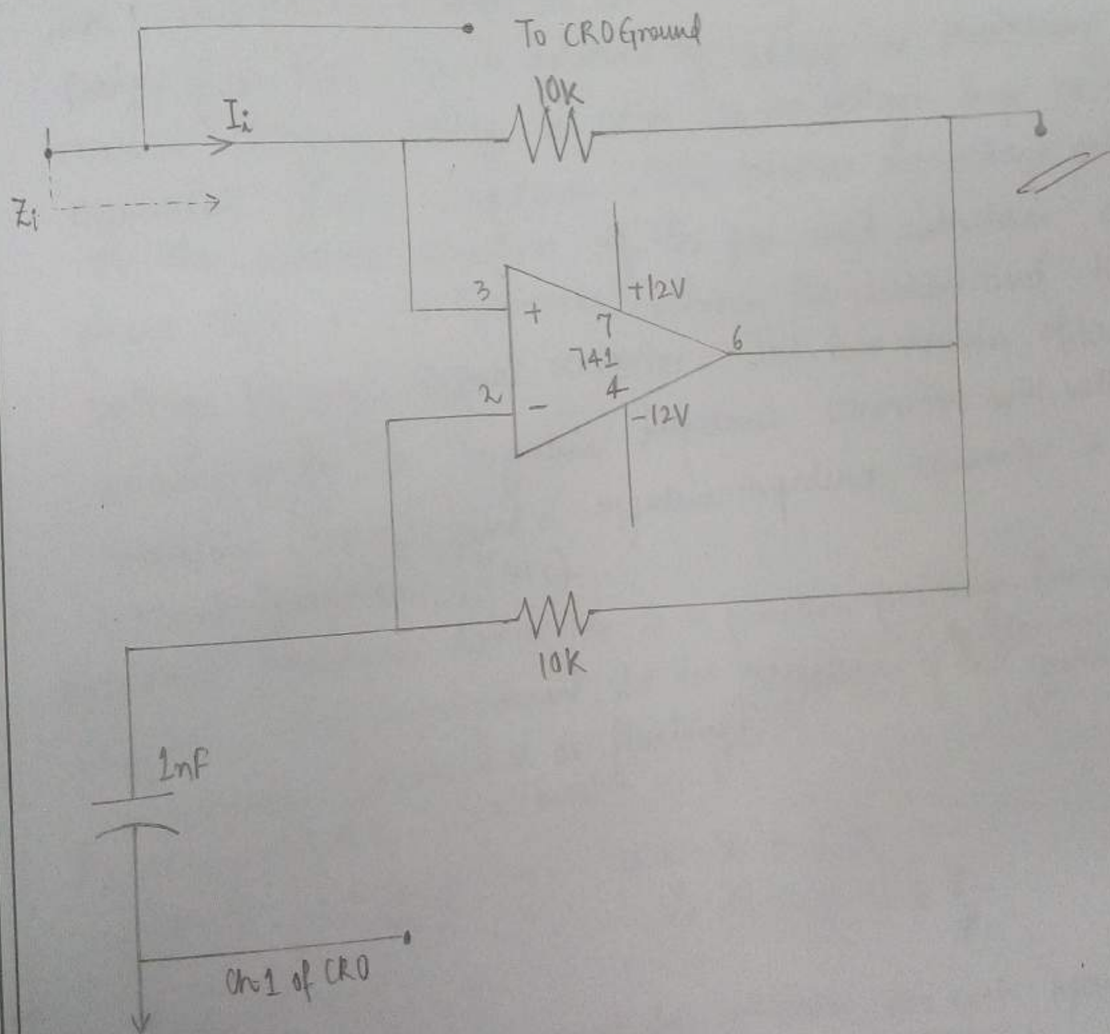
OBJECTIVE:-

Experiment on 1-port Network : Negative Impedance Converter.
To find the frequency response of a simple Negative Impedance Converter.

APPARATUS :-

S.No.	APPARATUS	QUANTITY	SPECIFICATION
1.	Cathode Ray Oscilloscope (CRO)	1	-
2.	Function generator	1	-
3.	Supply Source	1	+12V
4.	Resistor	3	10KΩ
5.	Capacitor	1	1nF
6.	Bread Board	1	-
7.	Op-Amp (Operational Amplifier)	1	IC-741

CIRCUIT DIAGRAM:-



THEORY :-

The negative impedence converter (NIC) is a one-port op-amp circuit acting as a negative load which injects energy into circuits in contrast to an ordinary load that consumes energy from them. This is achieved by adding or subtracting excessive varying voltage in series to the voltage drop across an equivalent positive impedence. This reserves the voltage polarity or the current direction of the port and introduces a phase shift or 180° (inversion) between the current and the voltage for any signal converter. The two versions obtained are accordingly a negative impedence converter with voltage inversion (VNIC) and a negative impedence converter with current inversion (INIC).

Negative impedance conversion is a function yielding (normally) impedence that is propotional to the negative of the given grounded impedence (grounded or floating).

Assuming ideal equations:-

$V_0 = V_1\left[1 + \frac{Z_1}{Z_2}\right]$

$V_{i2} - V_0 = I_1 I_2$

$\therefore Z_1 = \frac{V_i}{I_i} = -Z\frac{Z_2}{Z_1}$

If $Z_2 = Z_1$, $Z_1 = -Z$

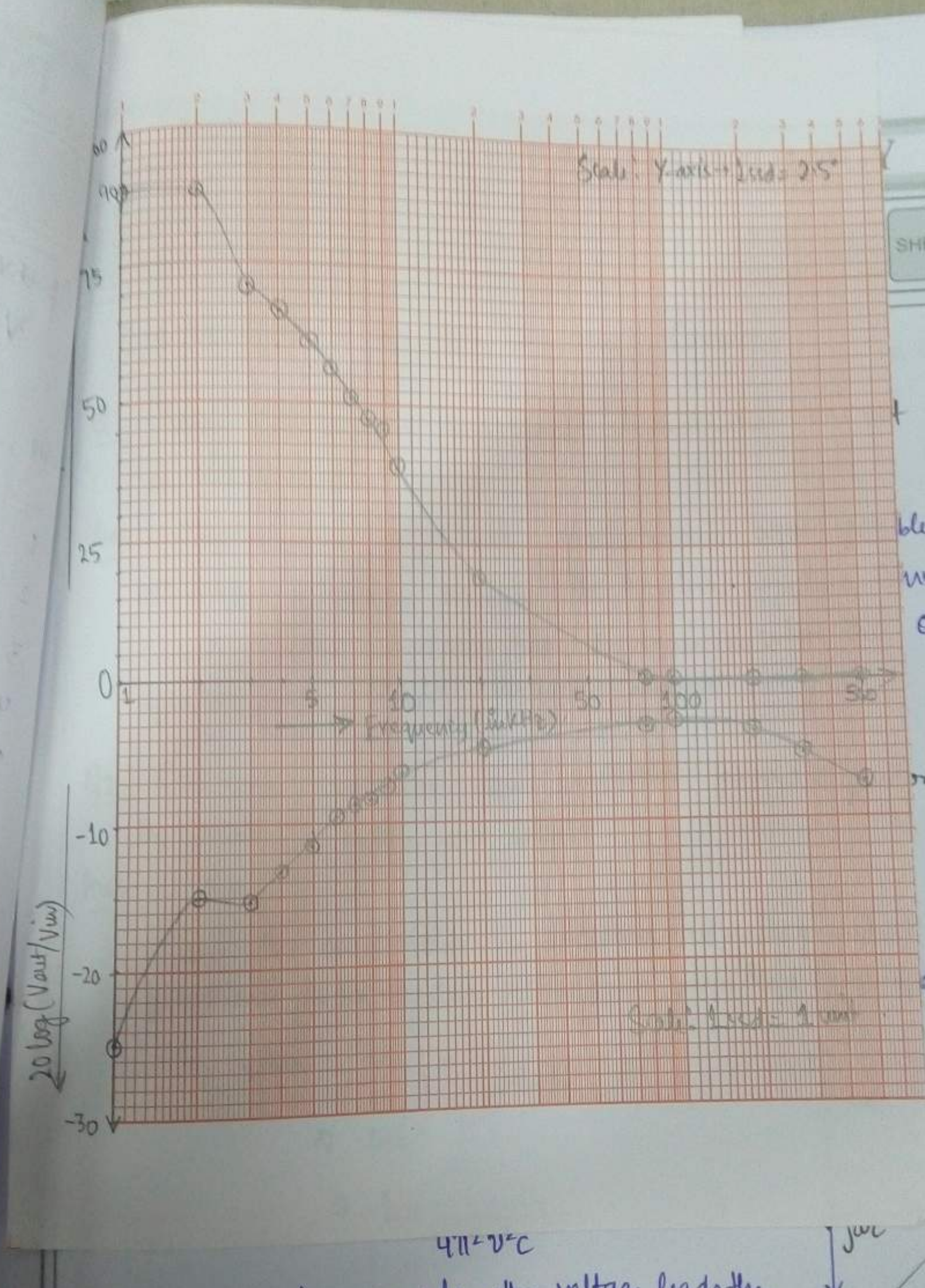
For proper inversion there must be a path for each opamp input which requires:- A more negative than positive feedback

$Z/Z_1 > Z_s/Z_2$, where Z_s is the source impedence.

OBSERVATION TABLE:-

V_{input} = 1V (pp)   Capacitance = 1nF.

S.No.	Frequency (in KHz)	V_{out} (in volts)	V_{out}/V_{in}	$20\log(V_{out}/V_{in})$	Phase (in degrees)
1	1	0.060	0.060	-24.44	87.9°
2	2	0.112	0.112	-15.02	88.5°
3	3	0.170	0.170	-15.39	70.3°
4	4	0.220	0.220	-13.15	65.4°
5	5	0.270	0.270	-11.37	62.7°
6	6	0.320	0.320	-9.90	57.5°
7	7	0.360	0.360	-8.87	51.1°
8	8	0.380	0.380	-8.40	47.5°
9	9	0.420	0.420	-7.54	45.6°
10	10	0.480	0.480	-6.38	38.7°
11	20	0.600	0.600	-4.44	19.5°
12	80	0.700	0.700	-3.09	0.01°
13	100	0.720	0.720	-2.85	0.006°
14	200	0.660	0.660	-3.61	0.008°
15	300	0.560	0.560	-5.04	0.008°
16	500	0.440	0.440	-7.13	0.02°



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→ I

$j\omega L$

$4\pi^2 \nu^2 C$

where ν is the frequency when the voltage leads the current by 90°, then we get an inductance (L), whose value is given by

$$\boxed{L = \frac{1}{4\pi^2 \nu^2 C}}$$

DISCUSSION: Negative Impedence Converter.

Q1. Why the negative impedence characteristics are not possible in all frequency range?

Ans – The negative impedence characteristics aren't possible for all frequency ranges because the Negative Impedence Converter (NIC) circuit inverts impedences only at frequencies where the op-amp open loop gain can be considered infinite.

Q2. Can you synthesize an inductor from a capacitor using the circuit? Justify your answer.

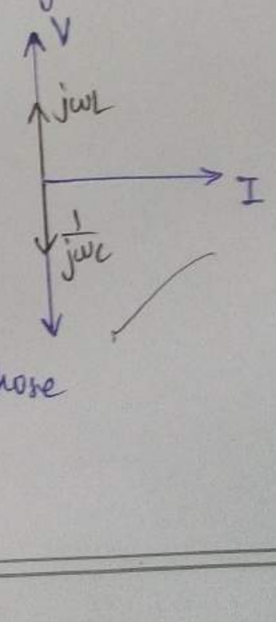
Ans.– Yes.

Since the circuit yields an impedence (normally grounded) that is proportional to the negative of the given impedence (grounded or floating).

So, when $|j\omega L| = \left|\frac{1}{j\omega C}\right|$

$$\Rightarrow \omega L = \frac{1}{\omega C}$$

$$\Rightarrow L = \frac{1}{4\pi^2 \nu^2 C}$$



where ν is the frequency when the voltage leads the current by 90°, then we get an inductance (L), whose value is given by $\boxed{L = \frac{1}{4\pi^2 \nu^2 C}}$

Q3 What could be the reasons for distortion of in the output voltage?

Ans: The distortion of the output voltage signal is due to the opamp nonlinearity in the Negative Impedance Converter (NIC) circuit.

Q3. What could be the reasons for distortion of in the output voltage?

Ans: The distortion of the output voltage signal is due to the op-amp non-linearity in the Negative Impedance Converter (NIC) circuit.

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Q3. What could be the reasons for distortion of in the output voltage?

Ans. The distortion of the output voltage signal is due to the opamp non-linearity in the Negative Impedance Converter (NIC) circuit.

OBJECTIVE :-

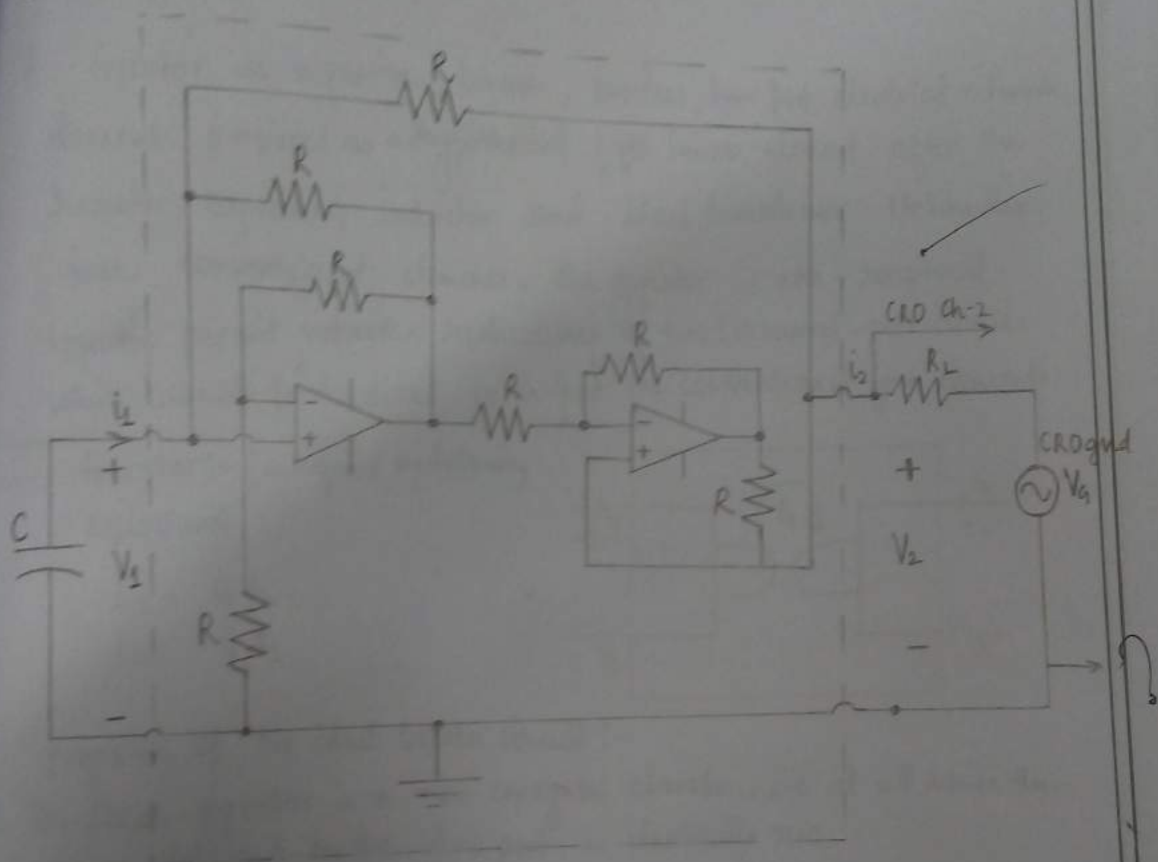
Study of the Gyrator circuit and its application in synthesizing inductors.

→ To find the frequency response of a Gyrator circuit

APPARATUS:-

S.No.	APPARATUS	QUANTITY	SPECIFICATION
1.	Cathode Ray Oscilloscope (CRO)	1	-
2.	Function Generator	1	-
3.	Supply Source	1	12V
4.	Resistors	7	10kΩ
		1	1kΩ
5.	Capacitors	1	10nF
		1	220nF
		1	1μF
6.	Bread Board	1	-
7.	Op-amp (Operational Amplifier)	2	IC-741

CIRCUIT DIAGRAM:-

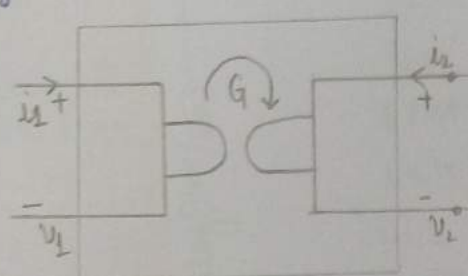


THEORY:-

A Gyrator is a passive, linear, lossless, two port electrical network element proposed as a hypothetical fifth linear element after the resistor, capacitor, inductor and ideal transformer. Unlike the four conventional elements, the gyrator is non-reciprocal. Gyrator permit network realizations of two (or more) -port devices which cannot be realized with just the conventional four elements.

Gyrator:- (is defined by following equations)

$i_1 = G V_2$
$i_2 = -G \cdot V_1$



Properties of the ideal Gyrator circuit :-

1. The ideal gyrator is a non-energetic elemetic, i-e at all times the power delivered to the two port is identically zero.
2. Impedance gyration is given by:-

$$\frac{V_1}{i_1} = -\frac{1}{G^2}\frac{i_2}{V_2} \Rightarrow \frac{V_1}{i_1} = \frac{1}{G^2}\frac{1}{R_L}, \quad \text{where } R_L = \frac{v_2}{-i_2}$$

3. Capacitor to Inductor Mutation property:- If the output port of an ideal gyrator is terminated with a capacitor, the input port behaves like an inductor. Thus, a gyrator is a useful element in the design of inductor less filters.

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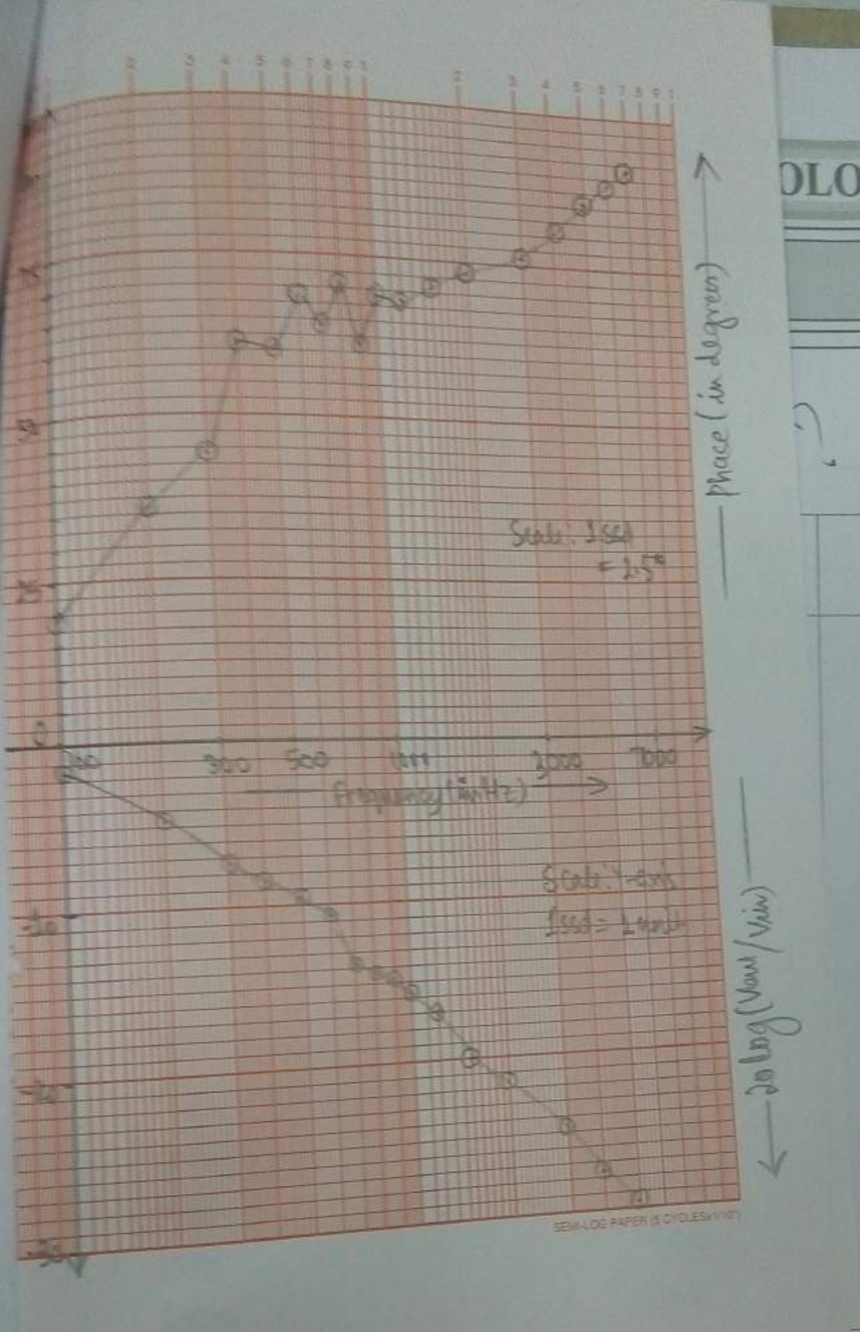


				Phase (in degrees)
				19.07°
				36.860
				44.42°
				62.73°
				61.04°
				68.59°
				64.15°
				71.15°
				62.73°
				69.63°
				68.21°
				71.32°
				76.19°
				80.02°
15.	4000	0.04	-27.9	82.19°
16.	5000	0.032	-29.9	85.23°
17.	6000	0.028	-31.03	88.19°
18.	7000	0.024	-32.3	89.23°

OBSERVATION TABLE:-

$V_{in} = 1V$ p-p

C = 11.39μf. ?

S.No.	Frequency (in Hz)	Vout (in volts)	20log(Vout/Vin)	Phase (in degrees)
1.	100	0.84	-1.51	19.07°
2.	200	0.60	-4.4	36.860
3.	300	0.44	-7.1	44.42°
4.	400	0.36	-8.8	62.73°
5.	500	0.32	-9.9	61.04°
6.	600	0.24	-10.75	68.59°
7.	700	0.20	-14	64.15°
8.	800	0.19	-14.4	71.15°
9.	900	0.18	-14.9	62.73°
10.	1000	0.16	-15.9	69.63°
11.	1200	0.14	-17.0	68.21°
12.	1500	0.10	-20.0	71.32°
13.	2000	0.08	-21.9	76.19°
14.	3000	0.06	-24.4	80.02°
15.	4000	0.04	-27.9	82.19°
16.	5000	0.032	-29.9	85.23°
17.	6000	0.028	-31.03	88.19°
18.	7000	0.024	-32.3	89.23°

V_{in} = 1 V_{p-p} C = 95nF

S.No.	Frequency (in Hz)	Vout (in volts)	20 log (Vout/Vin)	Phase (in degrees)
1.	100	0.18	-16.5	12.6°
2.	200	0.09	-20.9	180°
3.	300	0.06	-24.4	86.4°
4.	400	0.05	-26.0	85.3°
5.	500	0.036	-28.8	90°
6.	600	0.032	-29.8	86.1°
7.	700	0.028	-31.1	75.6°
8.	1000	0.019	-34.5	72.0°
9.	2000	0.010	-40.0	81.3°
10.	3000	0.005	-46.0	78.3°
11.	5000	0.002	-53.9	72.0°

$V_{in} = 1V(pp)$

$C = 1nF$

S.NO.	Frequency (in kHz)	Voutput (in volts)	$20\log(V_{out}/V_{in})$	Phase (in degrees)
1.	1	0.016	-35.92	48.6°
2.	2	0.024	-32.40	56.4°
3.	3	0.034	-29.37	55.4°
4.	4	0.044	-27.13	59.4°
5.	5	0.054	-25.35	58.4°
6.	6	0.060	-24.44	53.1°
7.	7	0.068	-23.35	55.4°
8.	8	0.076	-22.38	47.5°
9.	9	0.080	-21.94	48.6°
10	10	0.088	-21.11	46.6°
11.	20	0.128	-17.86	34.5°
12.	50	0.170	-15.39	20.7°
13.	100	0.220	-19.15	21.3°
14.	500	0.230	-12.77	0

DISCUSSION: GYRATOR CIRCUIT:-

Q1. Why this circuit is named as a Gyrator circuit?

Ans- 'Gyrator' means to oscillate or vary, especially in a repetition pattern. This circuit is named Gyrator because of the following properties shown by the circuit:-

1. It reverses the polarity of the signal travelling in the backward direction (180° phase-shifts the backward travelling signal).
2. If one port of the circuit is terminated with a linear load, then the other part represents an impedance inversely proportional to that of the load.
3. It inverts the current-voltage characteristic of an electrical component or network.
4. In the case of linear elements, the impedence is also inverted.

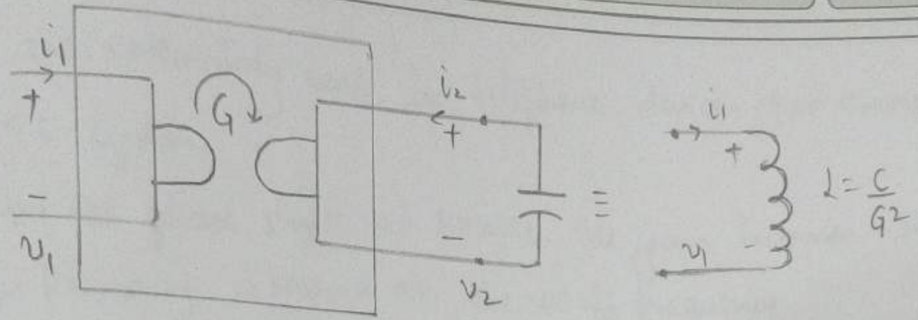
In other words, a gyrator can make a capacitive circuit behave inductively, a series LC circuit behaves like a polarised LC ckt, and so on. Hence, this circuit shows an oscillatory behaviour, So it is named as gyrator circuit.

Q2. Derive the expression:- $L = R^2C$.

Ans- Applying Kirchoff's loop Law:-

$$v_1 = L\frac{di_1}{dt} = \left(\frac{C}{G^2}\right)\frac{di_1}{dt}$$

P.R.E



From the experimental ckt;

~~$v_1 z$~~

$$\begin{bmatrix} i_1 \\ i_2 \end{bmatrix} = \begin{bmatrix} 0 & -1/R \\ 1/R & 0 \end{bmatrix} \begin{bmatrix} v_1 \\ v_2 \end{bmatrix}$$

Gyrator : $G = 1/R$

$L = C/G^2$

$\Rightarrow \boxed{L = CR^2}$

Q3. What is the frequency when there is an exact 90° phase shift? Explain the reason of this behaviour.

Ans – At 50 kHz, the phase shift is around 90°. As the inductive impedence becomes very large at low frequency there is about 90° phase shift.
At low frequency, the capacitor gives a high impedence. When this is inverted, the inductance at low frequencies also become very large.

Gyrators are extensively used in telephone devices that connect to POTS system.

* At the 90° phase shift at [illegible]kHz, the gain becomes -3dB. This frequency is known as the cutoff frequency.

The [illegible]kHz frequency is the lower cutoff point of the gyrator circuit.

Gyrators are extensively used in telephone devices that connect ~~to~~ POTS system

* At the 90° phase shift at 50kHz, the gain becomes -3dB. This frequency is known as the cutoff frequency.

The 50KHz frequency is the lower cutoff point of the gyrator circuit.

07.10.16

(PART-1)

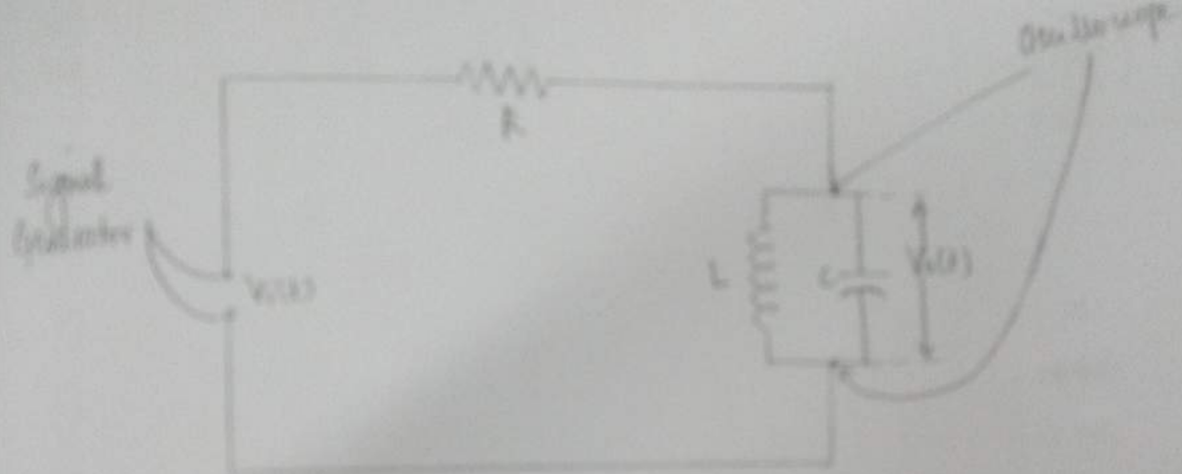
OBJECTIVE:-

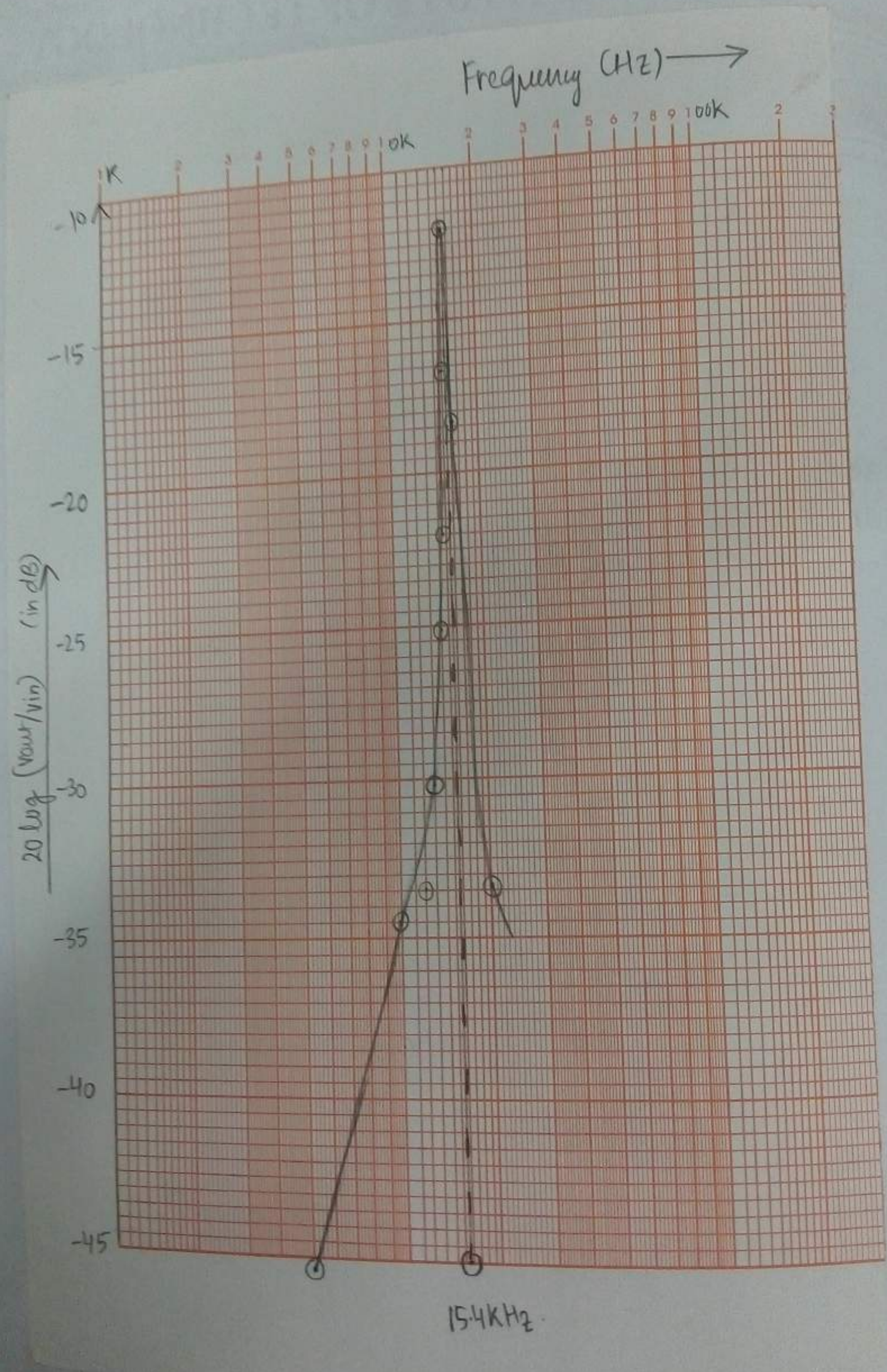
Experimental verification of fourier coefficients of a square wave signal using passive network.

APPARATUS REQUIRED:-

S.No.	APPARATUS NAME	QUANTITY	SPECIFICATIONS
1.	CRO	1	-
2.	Function Generator	1	-
3.	Resistance (Box)	1	-
4.	Inductance (Box)	1	-
5.	Capacitance (Box)	1	-

CIRCUIT DIAGRAM:-





Frequency (Hz)
1K
10K
100K
-10
-15
-20
-25
-30
-35
-40
-45
20 log (vout/vin) (in dB)
15.4KHz

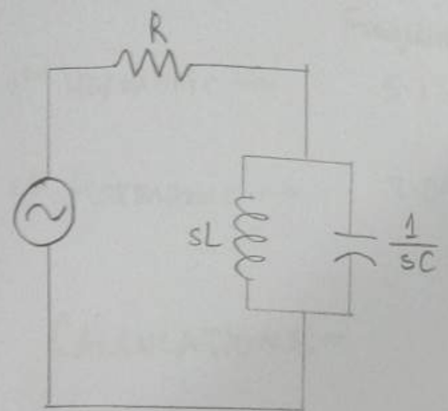
OBSERVATIONS :-

Part I

$V_{in} = 3V_{(p\text{-}p)}$

Sl. No.	Frequency (in Hz)	$V_{out\,(p\text{-}p)}$ (in V)	Gain = $\frac{V_{out}}{V_{in}}$	$20\log\left(\frac{V_{out}}{V_{in}}\right)$ (in dB)
1	100	0	0	-
2	1k	0	0	-
3	5k	15mV	5×10^{-3}	-46.02
4	10k	56mV	0.0187	-34.56
5	12k	64mV	0.021	-33.556
6	13k	92mV	0.0307	-30.266
7	14k	0.16V	0.0533	-25.165
8	14.5k	0.24V	0.080	-21.940
9	15k	0.44V	0.1467	-16.6714
10	15.3k	0.60V	0.200	-13.980
11	15.4k	0.76V	0.2533	-11.927
12	15.5k	0.72V	0.240	-12.396
13	16k	0.36V	0.120	-18.42
14	20k	64mV	0.0213	-33.432

In s domain :



$$I(s) = \frac{V_{in}(s)}{R + \left(sL \parallel \frac{1}{sC}\right)}$$

$$V_{out}(s) = \left(sL \parallel \frac{1}{sC}\right) \left\{ \frac{V_{in}(s)}{R + \left(sL \parallel \frac{1}{sC}\right)} \right\}$$

Transfer function $G(s) = \frac{V_{out}(s)}{V_{in}(s)}$

$$G(s) = \frac{sL \parallel \frac{1}{sC}}{R + sL \parallel \frac{1}{sC}}$$

$$\boxed{G(s) = \frac{s/RC}{s^2 + \left(\frac{1}{RC}\right)s + \frac{1}{LC}}} \rightarrow \text{Band pass filter}$$

*Substituting $s = 2\pi f$, and L C R values, for max value :- $\frac{dG(s)}{ds} = 0$

$\Rightarrow \boxed{f = 15.91 kHz}$

Part II

$R = 100k\Omega$ $V_{in} = 3.2V$

Sl. No.	L (in mH)	C (in nF)	Vout (p-p)	fo (experimental)	fc (theoritical)
1	10	10	2.08	15.42kHz	15.92kHz
2	10	12	1.96	14.1 kHz	14.53kHz
3	12	10	2.16	14.09kHz	14.53kHz

Part II

$V_{in} = 3V$, ~~5kHz~~

	Frequency (in kHz)	V_o (in V)
3rd Harmonic →	5.13 kHz	0.68 V
5th Harmonic →	3.09 kHz.	0.44 V

CALCULATIONS:-

Theoritically for a square wave:

$$\text{Square}(t) = \frac{4}{\pi} \sum_{k=1}^{\infty} \left[\sin(2\pi f_1 t) + \frac{1}{3}\sin(2\pi f_3 t) + \frac{1}{5}\sin(2\pi f_5 t) + \dots \right]$$

f_1 = Fundamental freq.

f_3: 3rd Harmonic

f_5: 5th Harmonic.

Fundamental coefficient (exp.) = 1.08V.

Theoretically, Fundamental → $\frac{4}{\pi} \times 1.5 = 1.7V$ (for $3V_{pp}$)

3rd Harmonic → 0.63V

5th Harmonic → 0.38V.

(PART-2)

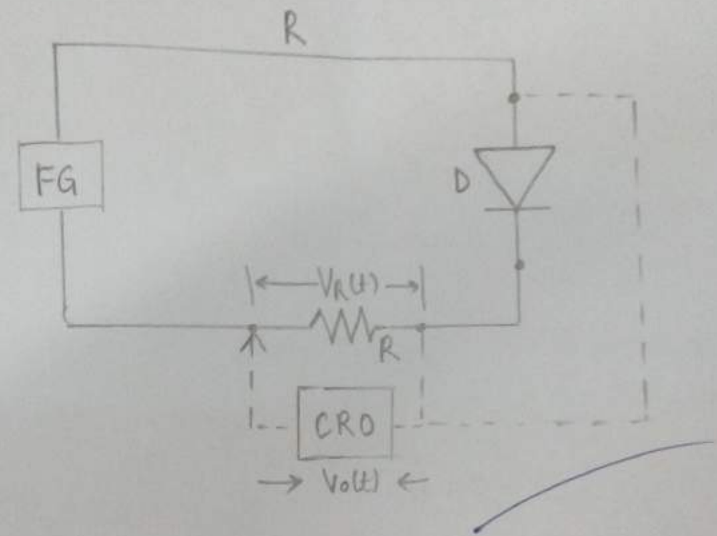
OBJECTIVE:-

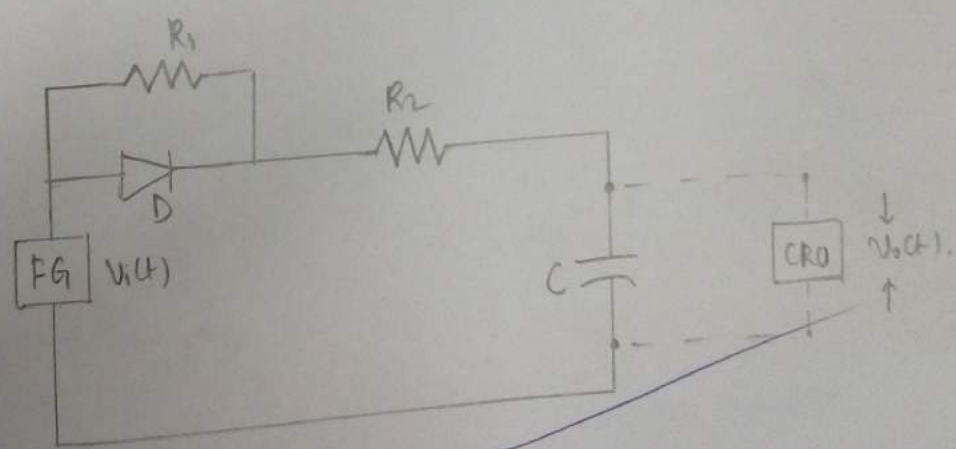
Derivation of V-I characteristic of a diode. Model a non-linear circuit using diode as piecewise linear and then compare its theoritical and experimental transient response.

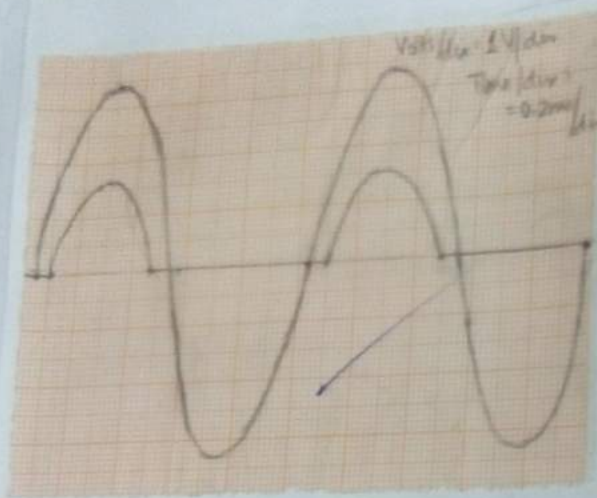
APPARATUS REQUIRED:-

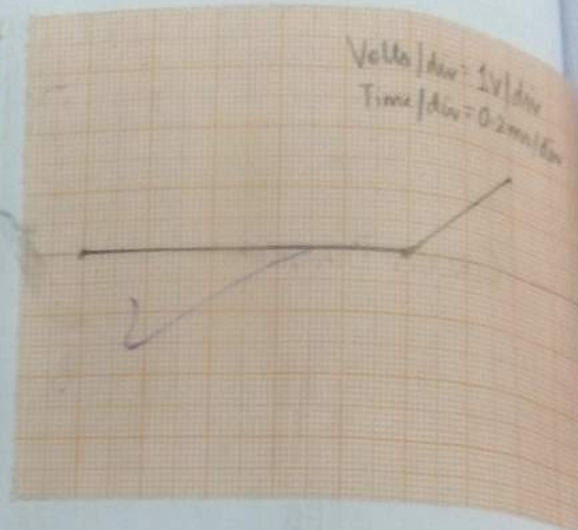
S.No.	APPARATUS NAME	QUANTITY	SPECIFICATIONS
1.	Function Generator	1	-
2.	Diode	1	1N4148, 200mA, 100V
3.	Resistance	1	100Ω
		1	1kΩ
4.	CRO	1	-
5.	Capacitance	1	1μF

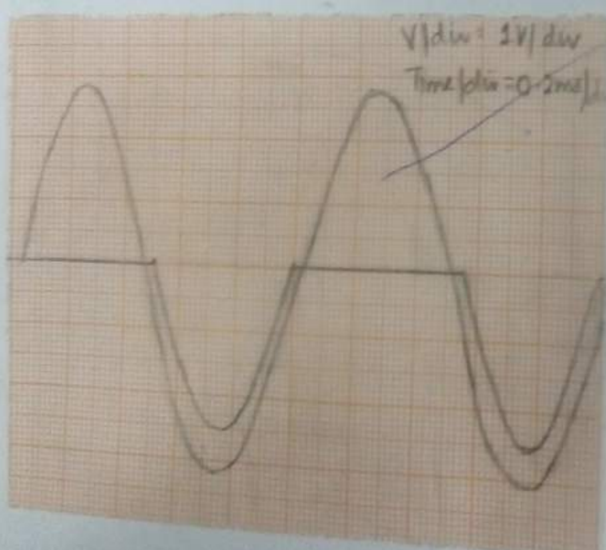
CIRCUIT DIAGRAM:-

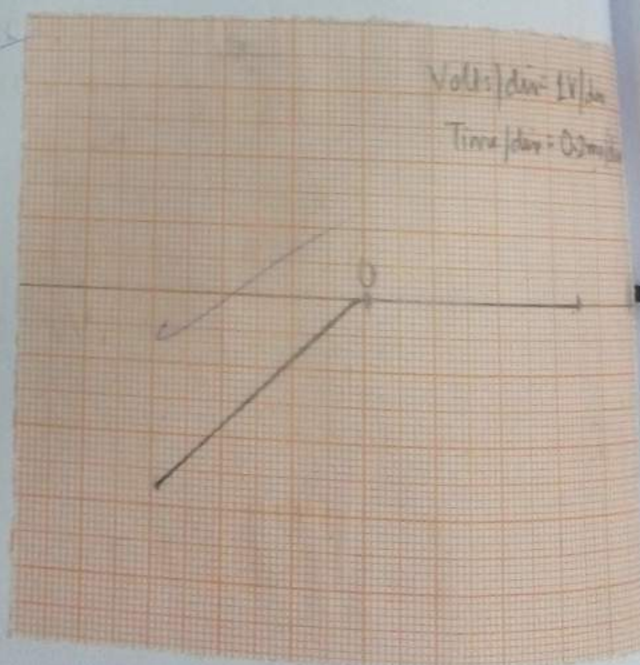





Volts/div = 1V/div
Time/div = 0.2ms/div


Volts/div = 1V/div
Time/div = 0.2ms/div


V/div = 1V/div
Time/div = 0.2ms/div


Volts/div = 1V/div
Time/div = 0.2ms/div
0

OBSERVATIONS:-

Part I

Forward Biased.

$V_{in} = 3.98V$

$V_{out} = 3.60V$

Frequency = 1kHz

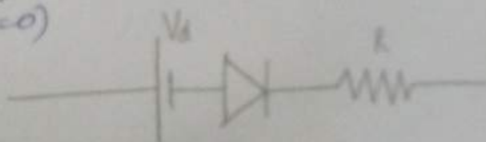
Reverse Biased.

$V_{in} = 3.96V$

$V_{out} = 3.20V$

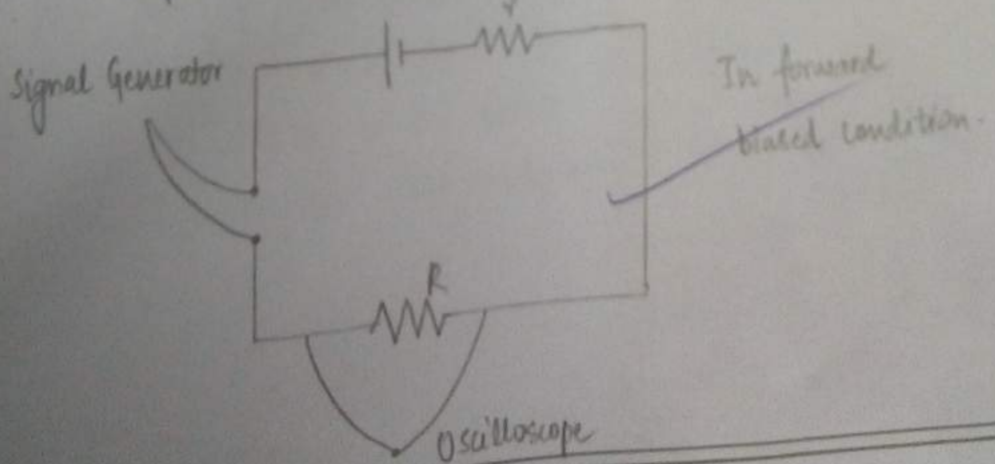
Frequency = 1kHz

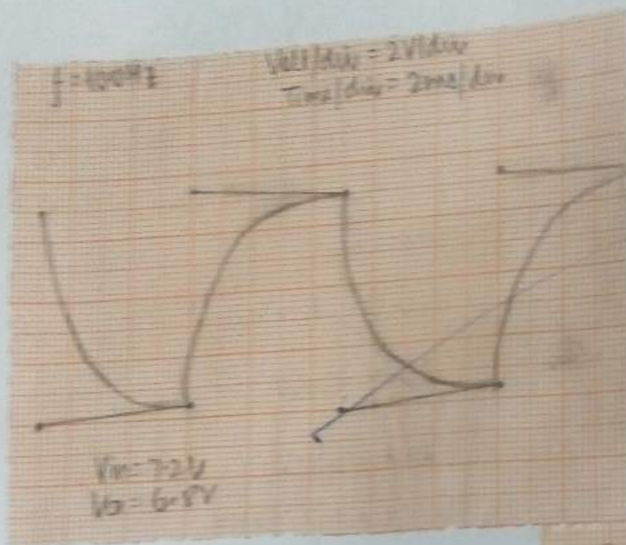
As observed from V-I characteristics, the diode can be replaced by a voltage source with a resistance in series and an ideal diode.
$(V_{\gamma}=0, r_f=0)$

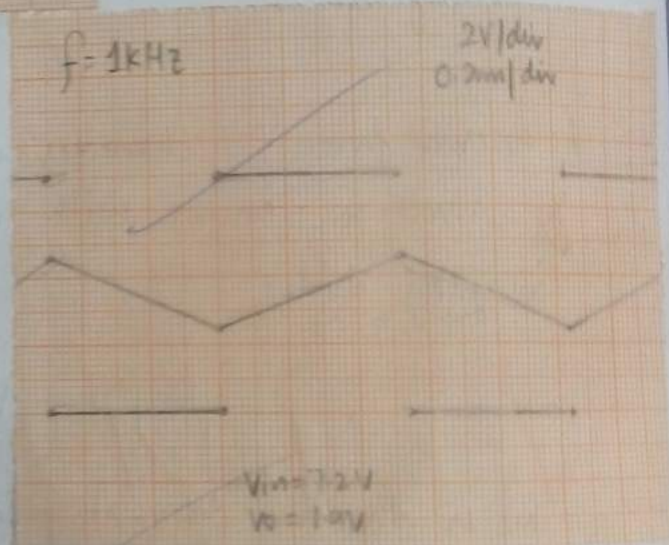


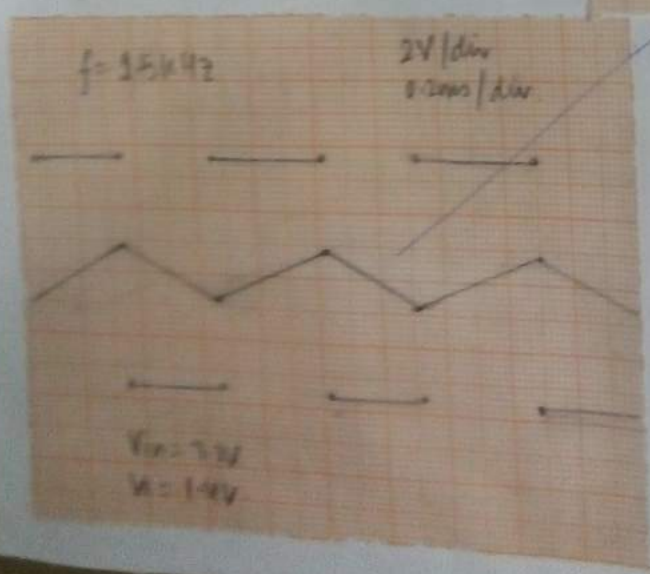
This is the two segment piecewise linear model.

Therefore, the circuit becomes:-




f=100Hz
Volt/div = 2V/div
Time/div = 2ms/div
Vin=7.2V
Vo=6.8V


f=1kHz
2V/div
0.2ms/div
Vin=7.2V


2V/div
0.2ms/div
Vo=1.4V

Part-II

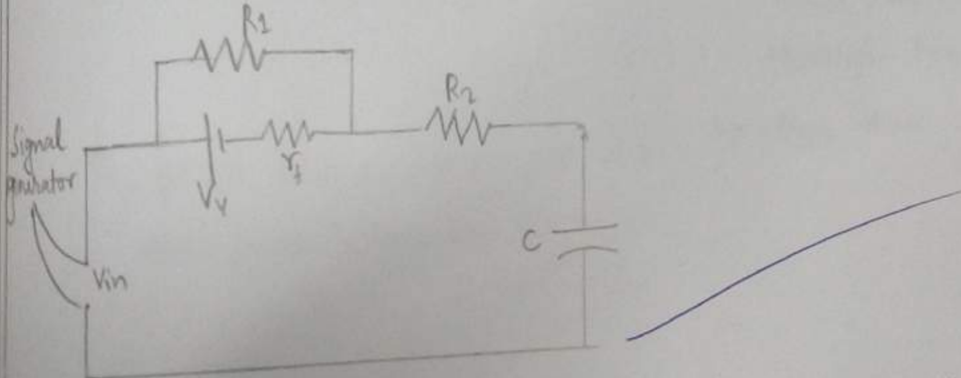
$V_{in} = 7.20V$

Frequency = 100 Hz

$V_{out} = 6.80V$.

Applying piecewise linear model :

(In forward biased condition)



When the capacitor reaches steady state, no current will flow through the circuit.

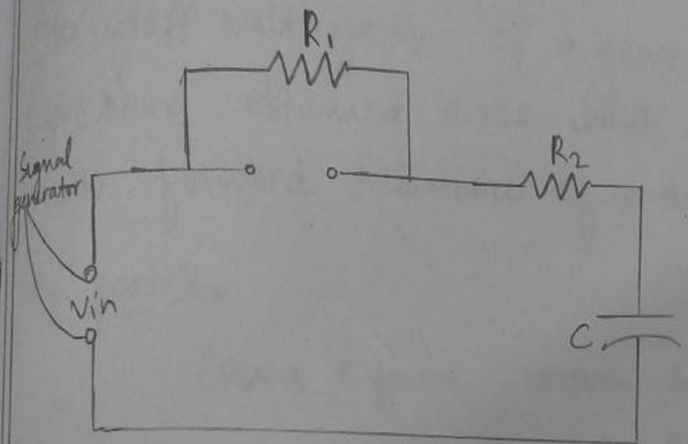
$\Rightarrow$ Voltage across $R_1 = V_\gamma$

voltage across $R_2 = 0$

Voltage across Capacitor (in steady state) $= V - V_\gamma$

$= 6.80V$.

In reverse biased condition:-



The diode is cutoff and the circuit simplifies to a capacitor in series with R_1+R_2. When the capacitor reaches steady state, no current flows through the circuit.

The peak above x-axis is a bit smaller than the peak below x-axis.

DISCUSSION :-

The cutoff voltage V_γ of a general silicon diode is 0.7V. we have obtained 0.76V which is nearly equal. In general the forward resistance of a diode is very low.

In part II,

Given square wave is applied

$$x(t) = \begin{cases} A & 0 \le t \le T/2 \\ -A & T/2 \le t \le T \end{cases}$$

In $0 \le t \le T/2$, a constant DC voltage of A is applied, the circuit consists of a resistance and capacitor in series. Therefore charging of capacitor takes place and we get a transient response.

In $T/2 \le t \le T$, a constant DC voltage of -A V is applied and diode gets into the rev. biased mode because of the negative voltage applied. Hence, this also turns out to be a transient because of the resistor and capacitor.

The time constant in both cases are different as in the first case i.e $0 \le t \le T/2$ the forward resistance r_f acts parallel to R_1, whereas in 2nd case i.e $T/2 < t \le T$ the diode ckt is cut and there is no r_f, only R_1 & R_2 in series.

$$\tau_1 = (R_2 + R_1 \| R_f) C$$

$$\tau_2 = (R_2 + R_1) C.$$

28/10/16