Ext. No. 2

Date: 06/06/22

RC DIFFERENTIATING AND INTEGRATING CIRCUITS

AIM :

(1) To design and setup RC differentiating and integrating circuits and to study its response to square wave and sine wave input
(2) To design and setup RC high pass and low pass filter and to plot frequency response curve.

COMPONENTS REQUIRED:

Capacitor, resistor, signal generator, breadboard and CRO

THEORY:

RC Integrator: Constituted by a resistance in series and a capacitor in parallel with the output. An integrator as its name suggests, does the mathematical operation of integration on the input signal. The time constant RC of the circuit is very large compared to the time period of input signal. Under the condition voltage drop across C is very small in comparison to drop across R.

The current is V_i/R since almost all V_i appear across R

so, the output voltage across C is

$$V_o = \frac{1}{RC}\int V_i\,dt$$

The output is proportional to the integral of the input. Voltage drop across C increases as time passes. For the satisfactory integration it is necessary that $RC \geq 16T$, where T is the period of input wave.

RC Differentiator: Constituted with a capacitor connected in series and a resistor connected in parallel to the output. The time constant RC of the circuit is very small in comparison with the time period of the input signal. The voltage drop across R is very small in comparison with the voltage across C.

The current through the capacitor is $I = C\frac{dv}{dt}$. Hence the output is proportional to the derivative of the input.

The output voltage

$$V_o = I \times R = RC\frac{dv}{dt}$$

Consider a sinusoidal signal $V\sin\omega t$ is fed to the input of the differentiator. Its output will be $VRC\omega\cos\omega t$.

Differentiated output is proportional to the rate of change of input. When the input rises to maximum value instantaneously, differentiated output follows it because the sudden change of voltage at one side of capacitor is transferred to the other side of capacitor. Since the rate of change of voltage is positive, differentiated output is also positive. When input remains maximum for a period of time, the rate of change of voltage is zero. So the output falls to zero. During this time input acts like a dc voltage and capacitor offer high impedance to it. So the charges in capacitor drains to earth through the resistance.

When input falls to zero, rate of change of input voltage is negative. Then the output also goes to negative. For perfect differentiation it should satisfy the criterion $RC < 0.0016\,T$ where $T = 1/f$ and f is frequency of input signal. The peak of the output of the differentiator get doubled when the square wave is fed to the input instead of pulses.

RC Low Pass Filter : Filters are the networks designed to pass only certain desired frequency bands. It can be broadly classified as passive or active filters according to the devices used to implement them. Filters can also be classified according to the frequency it passes, such as low pass, high pass, band pass and band reject filters.

A passive low passes filter passes low frequency readily and attenuates high frequencies. Since the reactance of the capacitor C decreases with increase in frequency, at high frequencies the capacitor act as a virtual short and output falls to zero. For a sinusoidal input V_1, the output signal V_0 decreases with increase in frequency. The magnitude of the ratio of output voltage to input voltage of the circuit is given by

$$A = \frac{1}{\sqrt{1 + (f/f_H)^2}}$$

where f_H is the higher cut-off frequency given by the expression

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

f = input signal frequency

At the frequency $f = f_H$, $A = 1/\sqrt{2}$ when expressed in dB, $20\log(1/\sqrt{2}) = -3$. Since gain falls by 3dB at f_H, It is called upper 3-dB frequency.

RC High Pass Filter : A high pass filter can be made from the low pass filter by interchanging the resistor and capacitor. Since the resistance of capacitor decreases with increase in frequency, the high frequency components in the input signal appear at the output with less attenuation than the low frequency components. In other words lower frequencies are attenuated by the circuit. At high frequencies the capacitor act almost as short circuit and input appears at the output

The magnitude of ratio of output voltage to input voltage of the circuit is given by

$$A = \frac{1}{\sqrt{1+(f_L/f)^2}}$$

f_L is the lower cut off frequency given by the expression

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

and f is the input signal frequency

Substituting $f = f_L$

$$A = \frac{1}{\sqrt{2}} = 0.707$$

When input frequency becomes f_L output becomes 70.7 % of its maximum level. A 29.3 % reduction in voltage corresponds to gain reduction of 3 dB in dB scale. f_L is called half power frequency, resonant frequency or 3dB frequency.

DESIGN :

RC Differentiator :

$RC << 0.0016T$

$T \rightarrow$ Period of input wave

Let $f = 1kHz$, $T = 1ms$

$C = 0.01\mu F$

$R = 150\Omega$

Case 1:

$RC = 0.016T$

$R = 1.6k\Omega$

$C = 0.01\mu F$

Case 2:

$RC = 0.16T$

$C = 0.01\mu F$

$R = 16k\Omega \approx 15k\Omega$ (std)

RC Integrator:

$RC >> 16T$

$f = 1kHz \quad T = 1ms$

$C = 0.1\mu F$

$R = 160k \approx 150k\Omega$ (std)

Case (i)

$RC >> 1.6T$

$C = 0.1\mu$

$R = 16k \approx 15k\Omega$ (std)

Case (ii)

$RC >> 160T$

$C = 0.1\mu F$

$R = 1.5M\Omega$

RC High Pass filter:

Cut-off frequency, $f_c = \frac{1}{2\pi RC}$

Let $f_c = 10kHz$

$C = 0.01\mu F$

$R = 1.5k\Omega$

RC Low Pass filter:

Cut-off frequency, $f_c = \frac{1}{2\pi RC}$

$f_c = 10kHz$

$C = 0.01\mu F$

$R = 1.5k\Omega$

PROCEDURE:

RC Integrator and Differentiator:

1. Switch on the function generator and set it at 10 VPP, 1kHz square wave

2. Note down the output waveforms for the following conditions
(i) RC = T (ii) RC << T and (iii) RC >> T
3. Repeat the above setep for 5V 1kHz pulse wave

RC High Pass and Low Pass filter
1. Wire up the circuit and set the input sine wave voltage at 5V peak to peak and observe the input and output on two channels of CRO
2. Vary the input frequency from 10Hz to 1MHz or more and note down the output voltage in the table.
3. Plot the graph on semilog graph sheet with f on x axis and gain in dB along Y axis
4. Mark a point on graph at 3dB less than the maximum gain. Extend the point to X axis and mark the upper 3dB frequency.

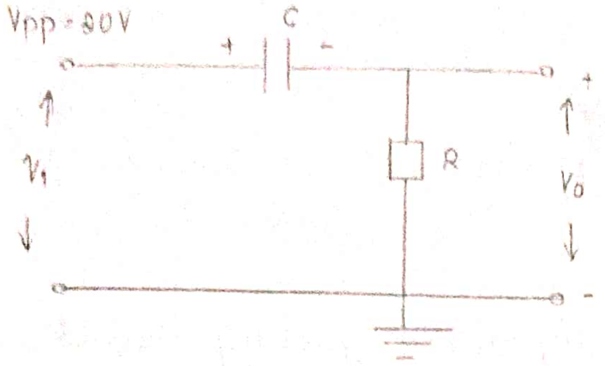
RESULT:

Cut-off frequency of Low Pass filter = 10kHz
Cut-off frequency of High Pass filter = 10.5kHz

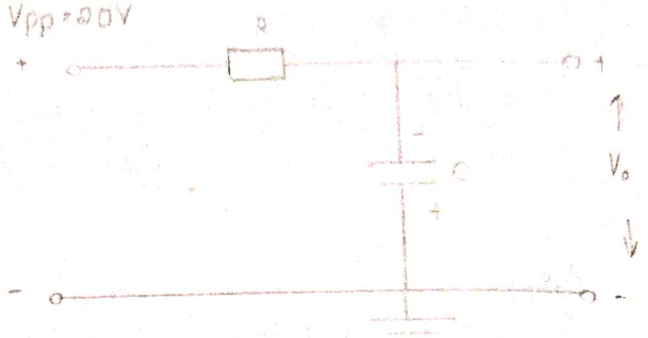
Designed and setup RC differentiating and integrating circuit and studied its response to square wave and sine wave inputs.
Designed and setup RC High Pass and Low Pass filters and plotted its frequency response curve.

27/7/22

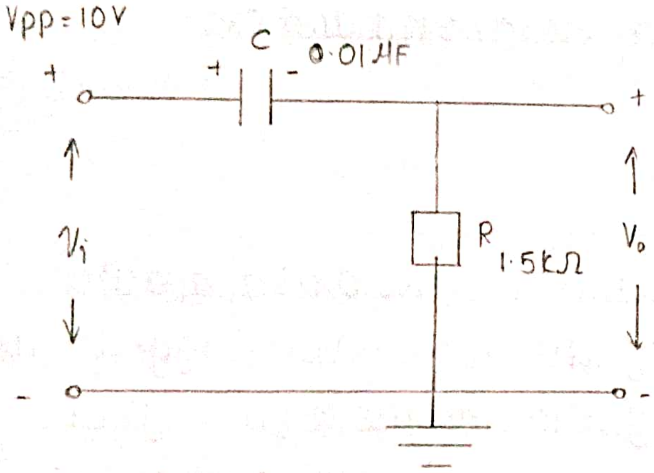
CIRCUIT DIAGRAMS :



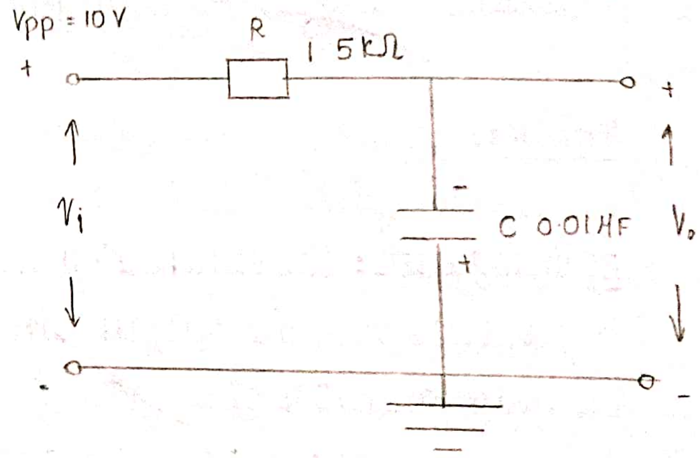
RC differentiator



RC Integrator

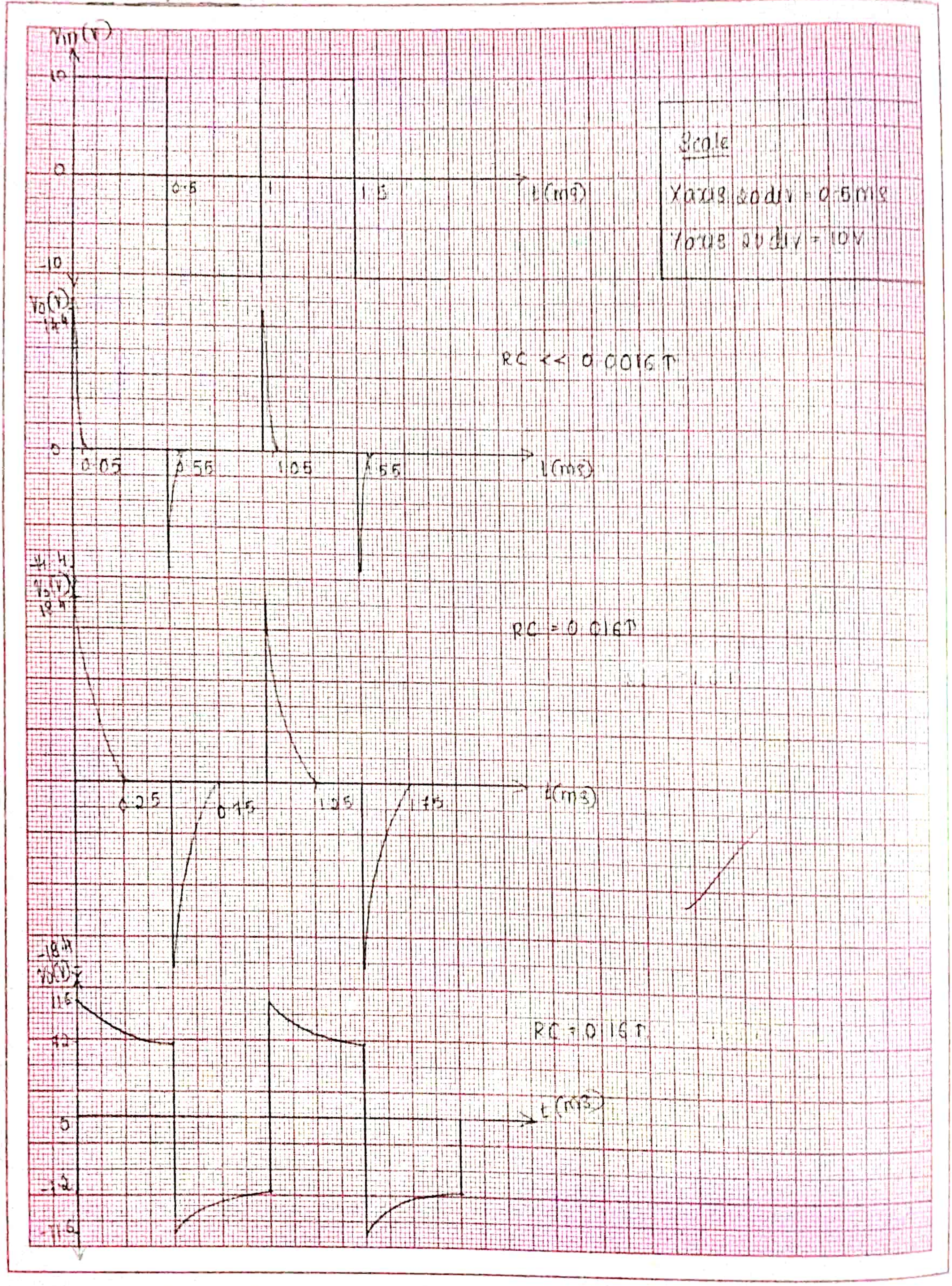


RC High Pass Filter



RC Low Pass Filter

RC DIFFENTIATOR



RC INTEGRATOR

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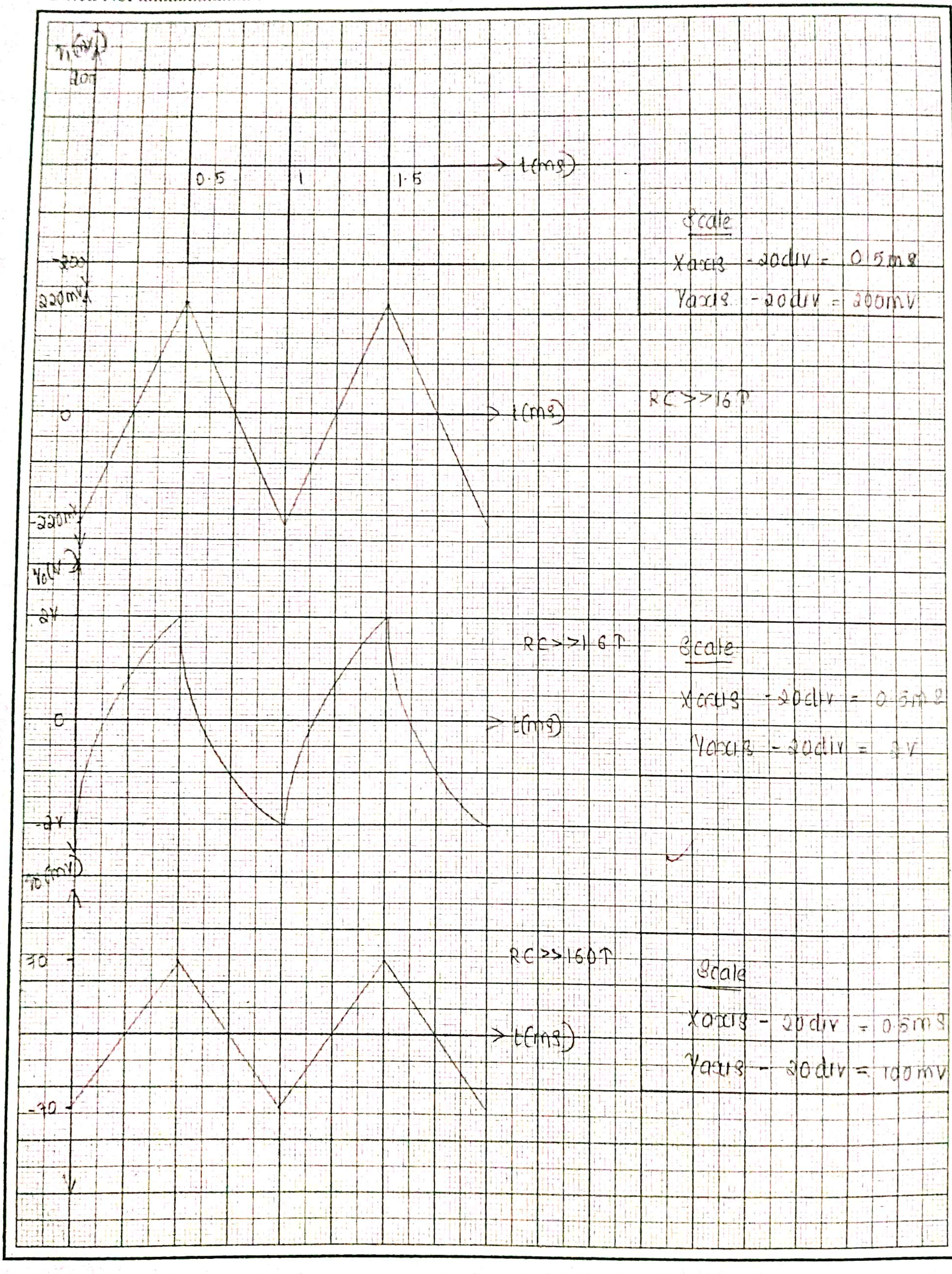

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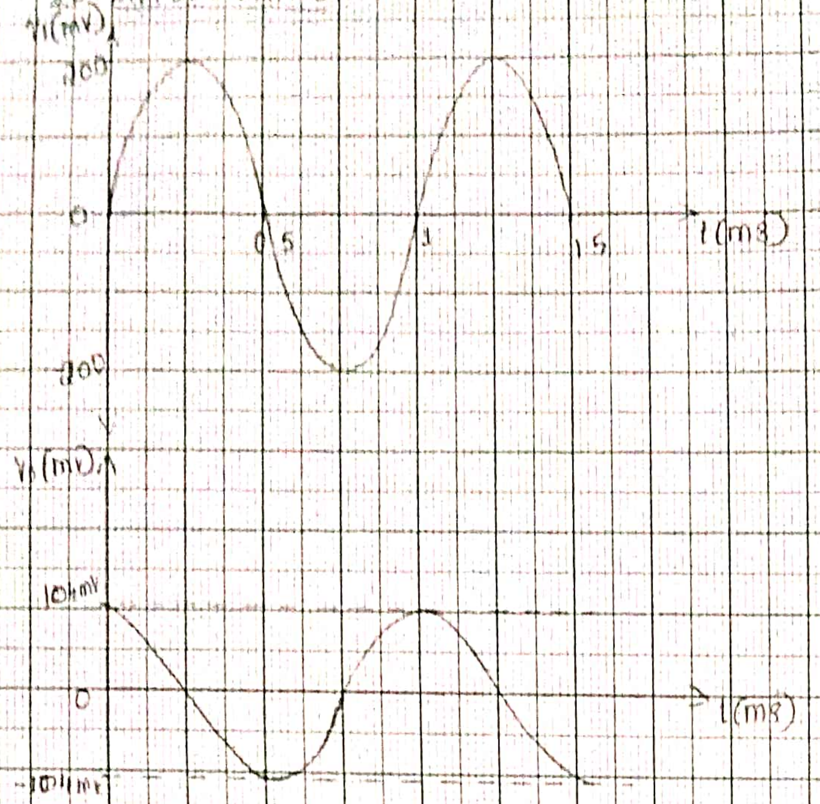
RC DIFFERENTIATOR

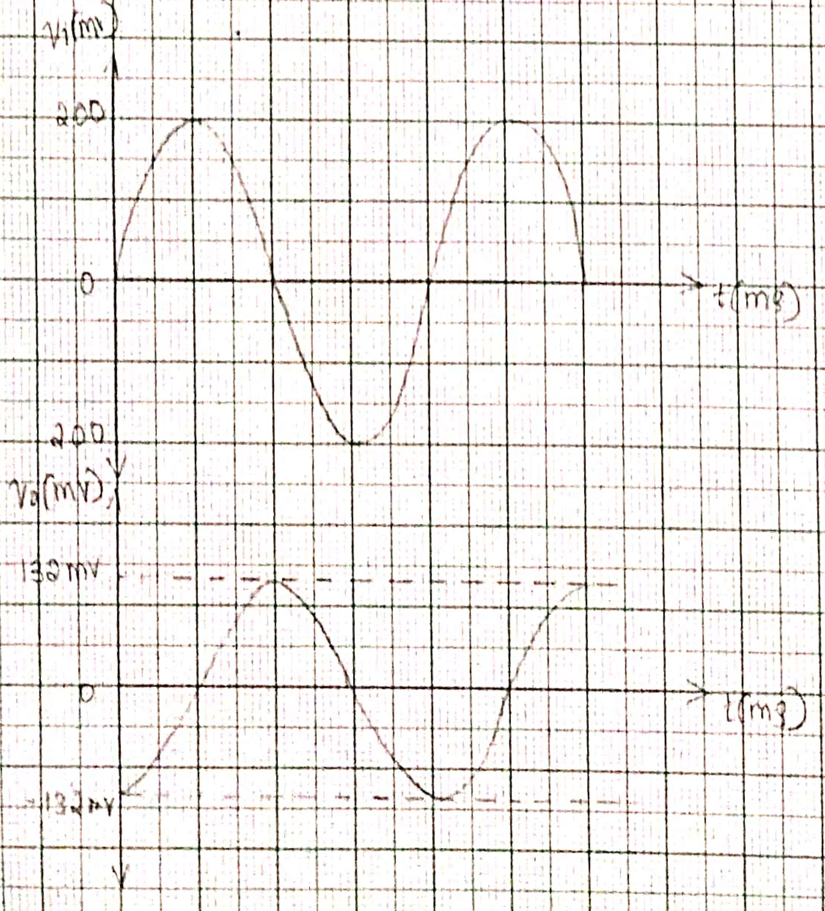


Scale

X axis - 20 div = 0.5 ms

Y axis - 20 div = 200 mV

RC INTEGRATOR

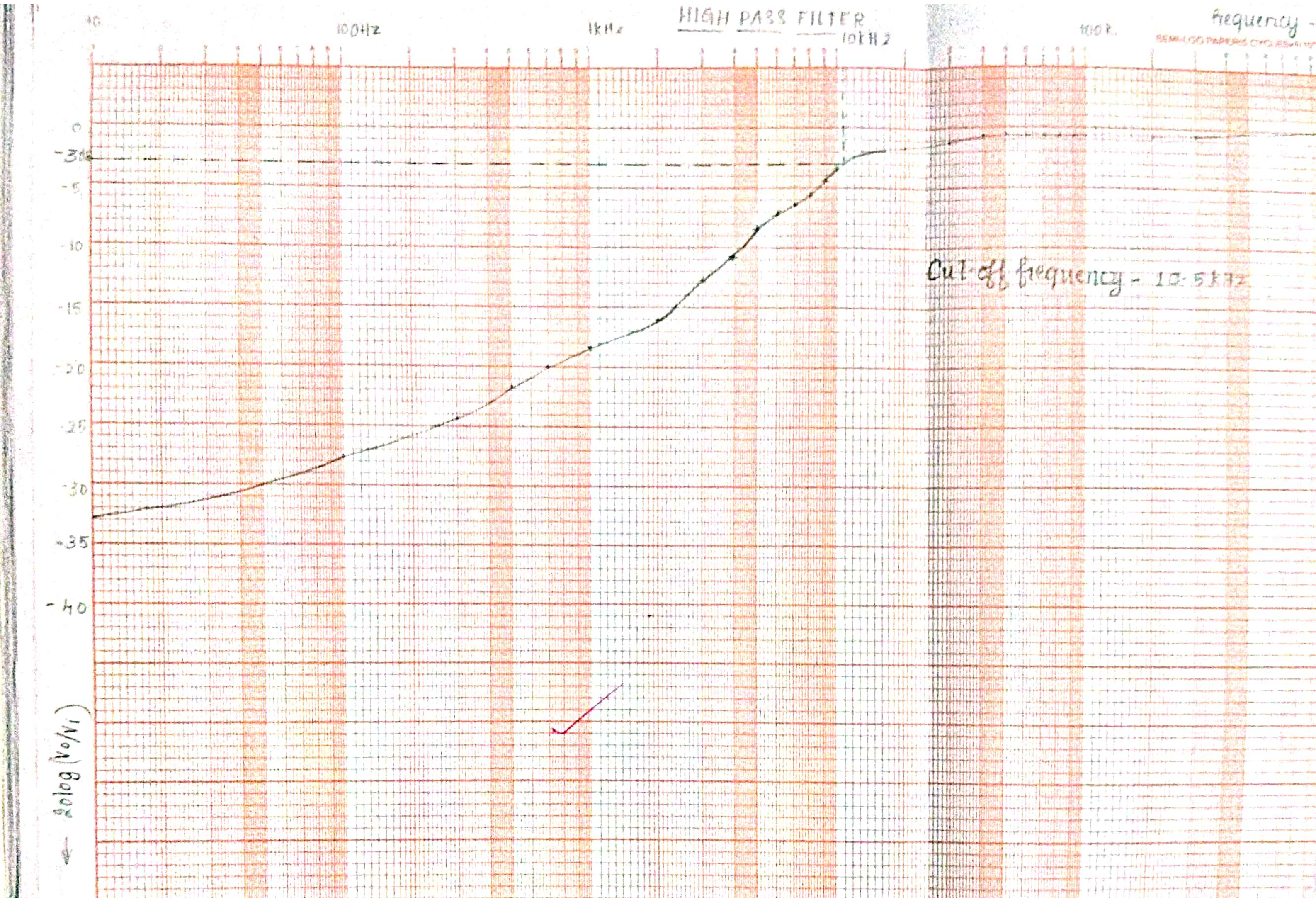


OBSERVATIONS:

RC High Pass filter:

$V_i = 10V$

freq	V_o	V_o/V_i	$20\log(V_o/V_i)$	freq	V_o	V_o/V_i	$20\log(V_o/V_i)$
10Hz	0.2	0.02	-33.97	30kHz	8.8	0.88	-1.110
100Hz	0.4	0.04	-27.95	40kHz	9.6	0.96	-0.354
300Hz	0.6	0.06	-24.43	50kHz	9.6	0.96	-0.354
500Hz	0.8	0.08	-21.93	60kHz	9.6	0.96	-0.354
700Hz	1	0.1	-20	70kHz	9.6	0.96	-0.354
1kHz	1.2	0.12	-18.41	80kHz	9.6	0.96	-0.354
2kHz	1.52	0.152	-16.36	90kHz	9.6	0.96	-0.354
3kHz	2.40	0.240	-12.39	100kHz	9.6	0.96	-0.354
4kHz	2.80	0.280	-11.05	200kHz	9.6	0.96	-0.354
5kHz	4	0.4	-7.95	300kHz	9.6	0.96	-0.354
6kHz	4.40	0.44	-7.13	500kHz	9.8	0.98	-0.175
7kHz	4.80	0.48	-6.37	700kHz	10	1	0
8kHz	5.2	0.52	-5.679	1MHz	10	1	0
9kHz	6	0.6	-4.436				
10kHz	6.8	0.68	-3.34				
20kHz	8	0.8	-1.93				

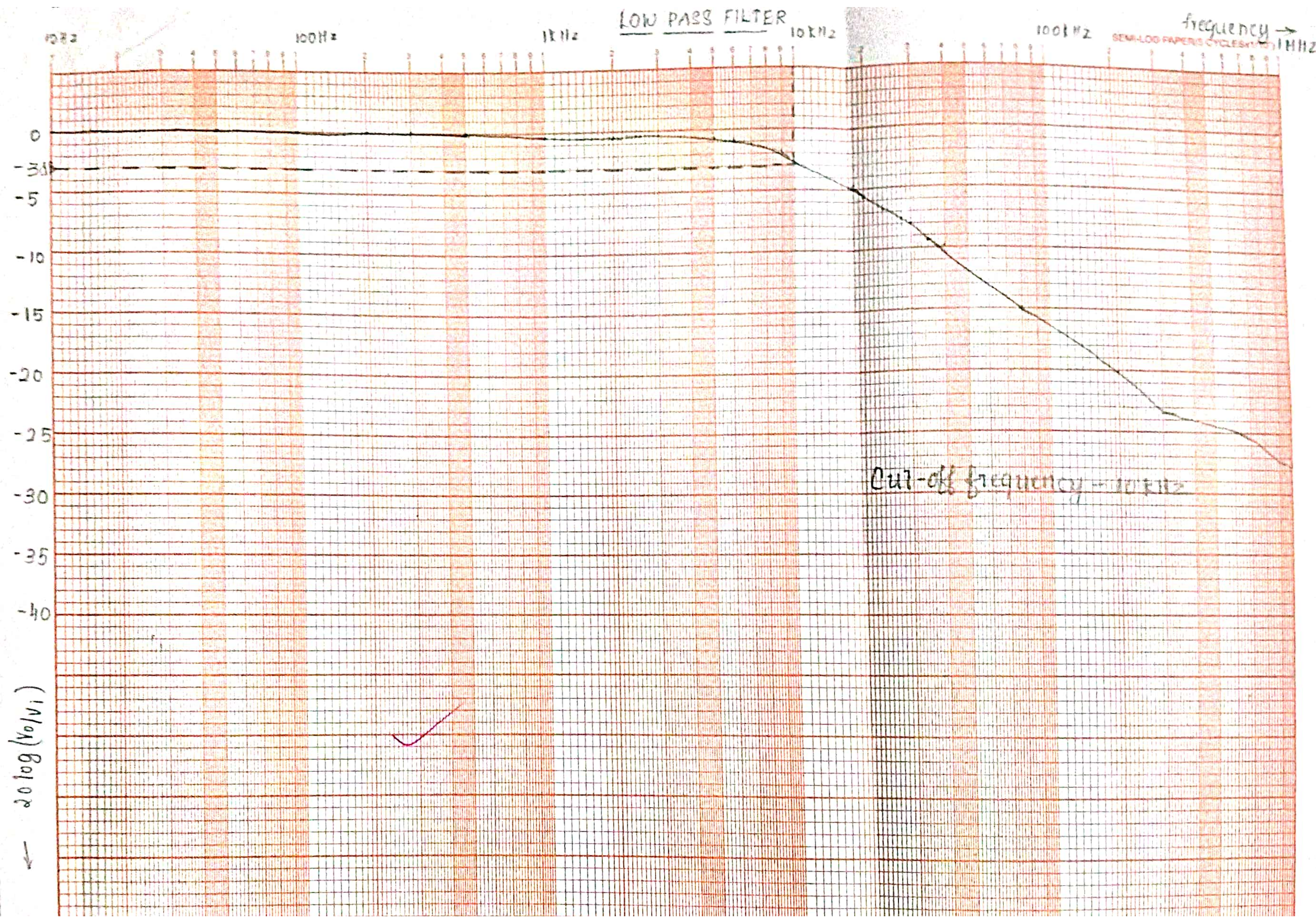

HIGH PASS FILTER
frequency
100Hz
1kHz
10kHz
100k
0
-3dB
-5
-10
-15
-20
-25
-30
-35
-40
20log(Vo/Vi)
Cut-off frequency - 10.5kHz

RC Low Pass filter :

$V_i = 10V$

freq	V_o	V_o/V_i	$20\log(V_o/V_i)$
10 Hz	10	1	0
50 Hz	10	1	0
100 Hz	10	1	0
200 Hz	10	1	0
300 Hz	10	1	0
500 Hz	10	1	0
1k Hz	9.8	0.98	-0.175
2k Hz	9.8	0.98	-0.175
5k Hz	9	0.9	-0.915
k Hz	8.6	0.86	-1.310
1k Hz	8	0.8	-1.93
k Hz	7.4	0.74	-2.615
4k Hz	6.6	0.66	-3.60
8k Hz	5.8	0.58	-4.731
0k Hz	5.4	0.54	-5.352

freq	V_o	V_o/V_i	$20\log(V_o/V_i)$
24k Hz	4.8	0.48	-6.375
28k Hz	4.2	0.42	-7.535
30k Hz	4	0.4	-7.958
35k Hz	3.4	0.34	-9.370
40k Hz	3.2	0.32	-9.897
45k Hz	2.6	0.26	-11.7
50k Hz	2.2	0.22	-13.151
60k Hz	2.2	0.22	-13.151
70k Hz	2.2	0.22	-13.151
80k Hz	1.6	0.16	-15.96
90k Hz	1.6	0.16	-15.91
100k Hz	1.6	0.16	-15.91
200k Hz	1	0.1	-20
300k Hz	0.6	0.06	-24.43
400k Hz	0.6	0.06	-24.43
500k Hz	0.6	0.06	-24.43
1M Hz	0.4	0.04	-27.95
2M Hz	0.2	0.02	-33.97


LOW PASS FILTER
10Hz
100Hz
1KHz
10KHz
100KHz
1MHz
frequency →
SEMI-LOG PAPER 5 CYCLES
0
-3db
-5
-10
-15
-20
-25
-30
-35
-40
20 log (Vo/Vi)
Cut-off frequency = 10KHz