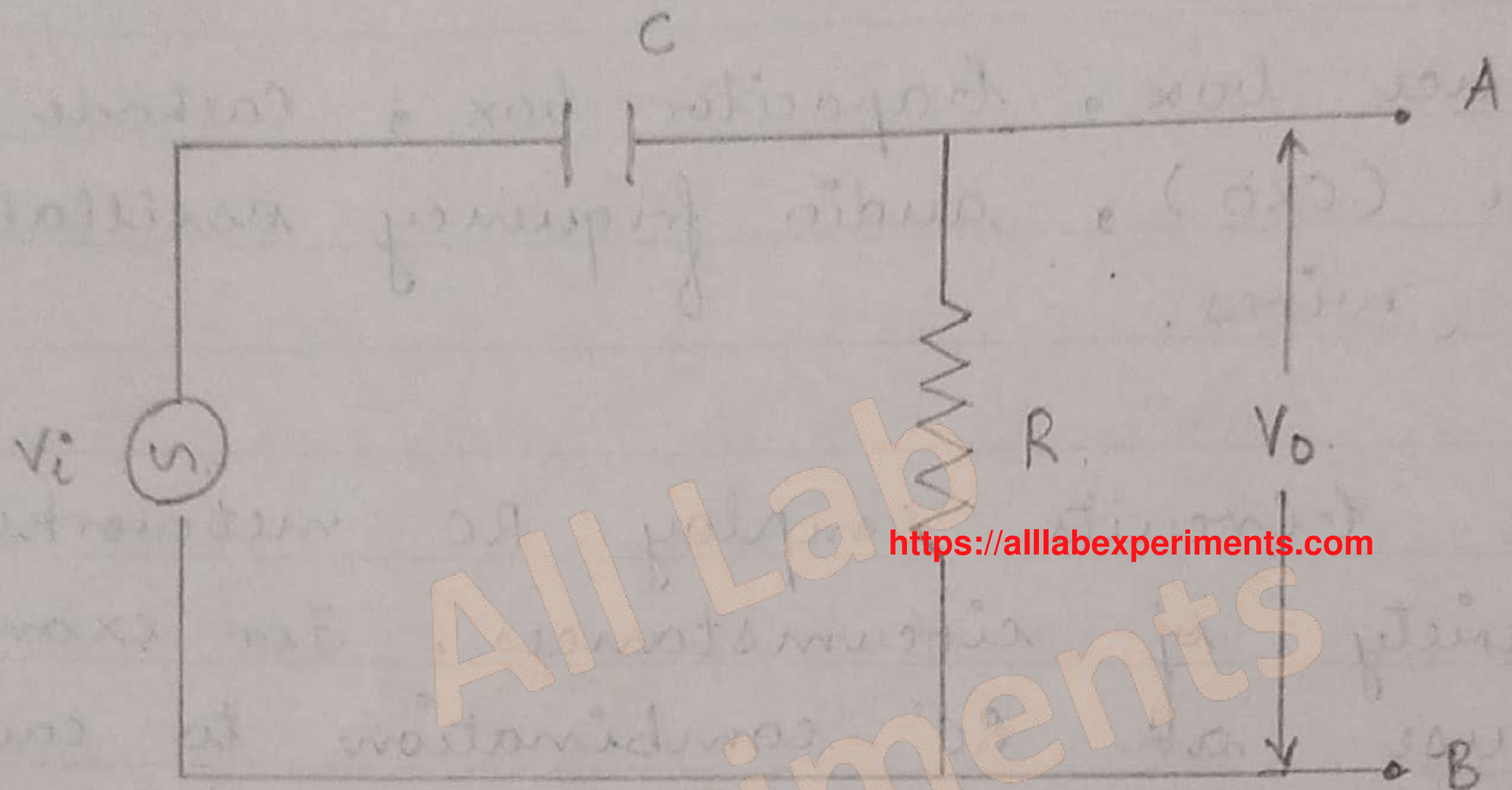
AIM → Study of Low pass and High pass RC filters.

APPARATUS → Resistance box, Capacitor box, Cathode ray Oscilloscope (CRO), audio frequency oscillator, connecting wires.

THEORY → Electronic Circuits employ RC networks in a wide variety of circumstances. For example, if we use an RC combination to couple two stages of an amplifier. This circuit can be used as a Low pass or High pass filter. The series combination of a resistance and a capacitor can differentiate or integrate a wave form. In addition, resistor and capacitor are inherent parts of all circuits and devices. Hence, it is desirable to have a thorough knowledge of characteristics of these circuits.

HIGH PASS FILTER - The method of high pass filter is that in which output is taken across the resistance (R) as shown in the figure. It passes the high frequency and



HIGH PASS FILTER.

alternates the low frequency.

As we know,

$$V_{in} = I\,(X_c + R.) \qquad \text{—— } 1.$$

where, V_{in} = input voltage

X_c = impedence across the capacitor.

Putting the value of $X_c = \frac{1}{j\omega C}$ in Eq^n 1.

$$V_{in} = I\left(\frac{1}{j\omega C} + R.\right).$$

$$= I\left(\frac{1 + jR\omega C.}{j\omega C.}\right)$$

OR

$$I = \frac{V_{in}\,(j\omega C)}{1 + jR\omega C.}$$

Voltage drop across resistance is $V_o = IR.$

$$\therefore, \quad V_o = \frac{V_{in}\;R(j\omega C)}{1 + jR\omega C.}$$

$$= \frac{V_{in}\;Rj\omega C}{Rj\omega C.\left(1 + \frac{1}{Rj\omega C.}\right)} = \frac{V_{in}}{1 + \frac{1}{Rj\omega C.}}$$

$$V_0 = \frac{V_{in}}{1 + \frac{1}{j 2\pi f RC}}$$

$$= \frac{V_{in}}{1 - j f_0/f}$$

$$\theta = \tan^{-1}(f_0/f)$$

where f_0 = cut off frequency.

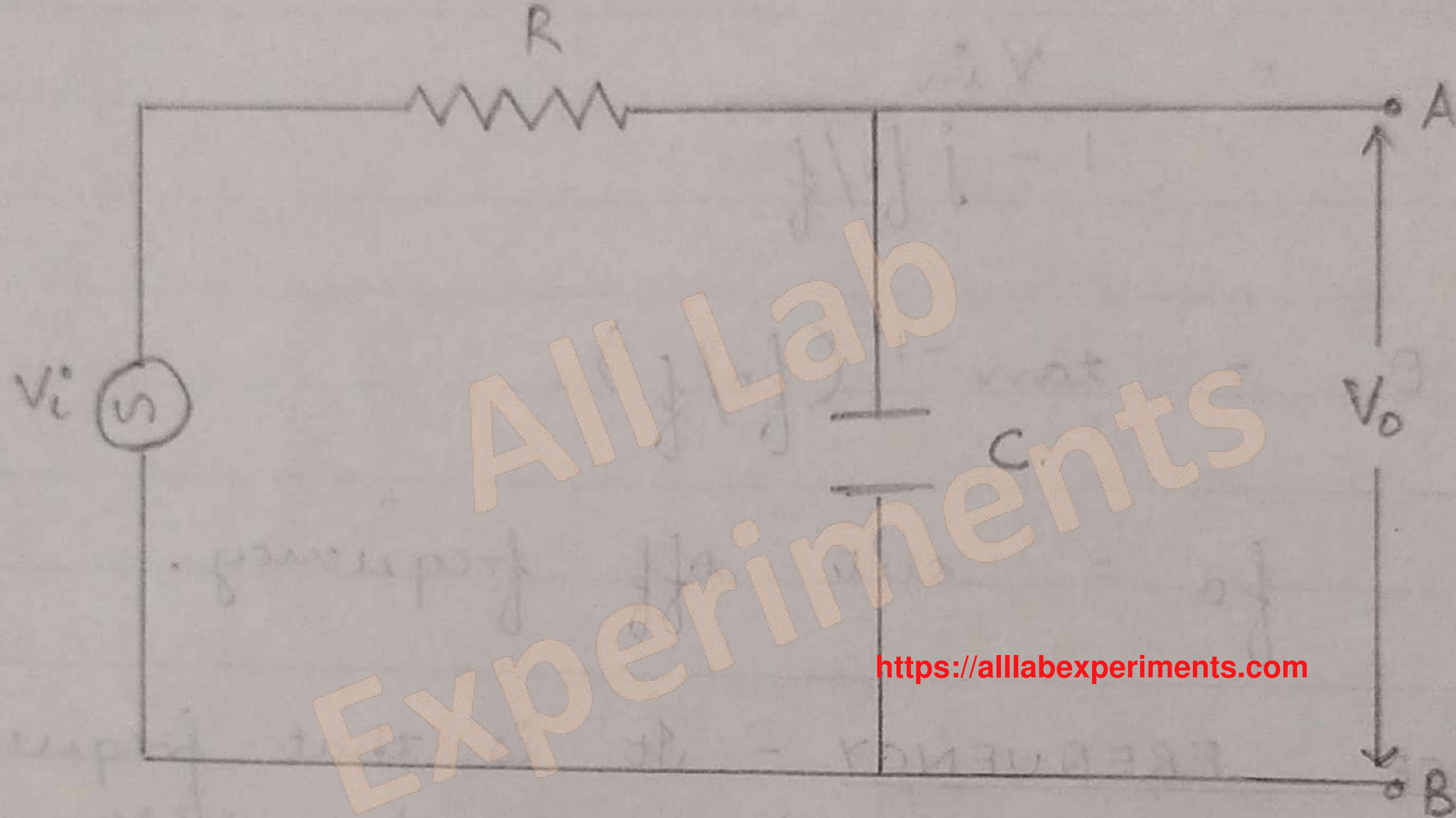
CUT OFF FREQUENCY - It is that frequency at which the gain is fall to $\frac{1}{\sqrt{2}}$ of its initial value.

$$\frac{V_0}{V_{in}} = \frac{1}{[1 + (f_0/f)^2]^{1/2}}$$

Special case.

1. If $f < f_0$, $f_0/f > 1$, so $\left|\frac{V_0}{V_{in}}\right| < 1$.

2. If $f = f_0$, $\left|\frac{V}{V_{in}}\right| = \frac{1}{\sqrt{2}}$



LOW PASS FILTER.

3. If $f > f_0$, $\left|\frac{V_0}{V_{in}}\right| \approx 1$

Cut off frequency of high pass filter is

$f_0' = \frac{1}{2\pi RC} = $ 1500 Hz (theoritically)

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f_0 (practically) = 600 Hz (practically)

LOW PASS FILTER. - The network acts as a low pass filter if output is taken across capacitor as shown in figure. It passes the low frequency and alternates the high frequency.

As we know,

$$V_{in} = I(X_C + R)$$

$$= I\left(\frac{1}{j\omega C} + R\right) = I\left(\frac{1 + jR\omega C}{j\omega C}\right)$$

$$\therefore I = \frac{V_{in}\, j\omega C}{1 + jR\omega C}$$

Now voltage drop across capacitor is

$$V_0 = I \times \gamma$$

$$= \frac{V_{in}\, j\omega C}{1 + Rj\omega C} \times \frac{1}{j\omega C} = \frac{V_{in}}{1 + Rj\, 2\pi f C}$$

$$f_o = \frac{1}{2\pi RC} \quad \text{(cut off frequency)}$$

$$\frac{V_o}{V_{in}} = \frac{1}{1 + i f/f_o} \qquad \theta = \tan^{-1}\left(\frac{f}{f_o}\right).$$

$$\left|\frac{V_o}{V_{in}}\right| = \frac{1}{[1 + (f/f_o)^2]^{1/2}}$$

<u>Special case,</u>

1. If $f < f_o$, then f/f_o being very less than one, so $V_o \approx V_{in}$.
2. If $f = f_o$, then $V_o = \frac{V_{in}}{\sqrt{2}}$, called the cut off frequency.
3. If $f > f_o$, then V_o decreases.

Cut off frequency of a low pass filter

$$f_o' = \frac{1}{2\pi RC} = \quad 2000 \text{ Hz}$$

$$f_o \text{ (practically)} = 1000 \text{ Hz}$$

PROCEDURE → 1. Design a high pass RC filter as shown in Fig 1. With some f_0 choose a resistance for such that its value is small in comparison to the input impedence. The capacitance is used as stated on the capacitor.

2. Keeping the input voltage V_i at a constant value measure the ouput voltage V_0 on a CRO as a func^n of frequency.

3. Evaluate the theoretical response and plot it on the V_0/V_i vs log f graph plotted.

4. Now design a low pass filter by interchanging the positions of resistance and capacitance and repeat the ~~above~~ process.

CALCULATIONS AND OBSERVATIONS →

HIGH PASS FILTER.

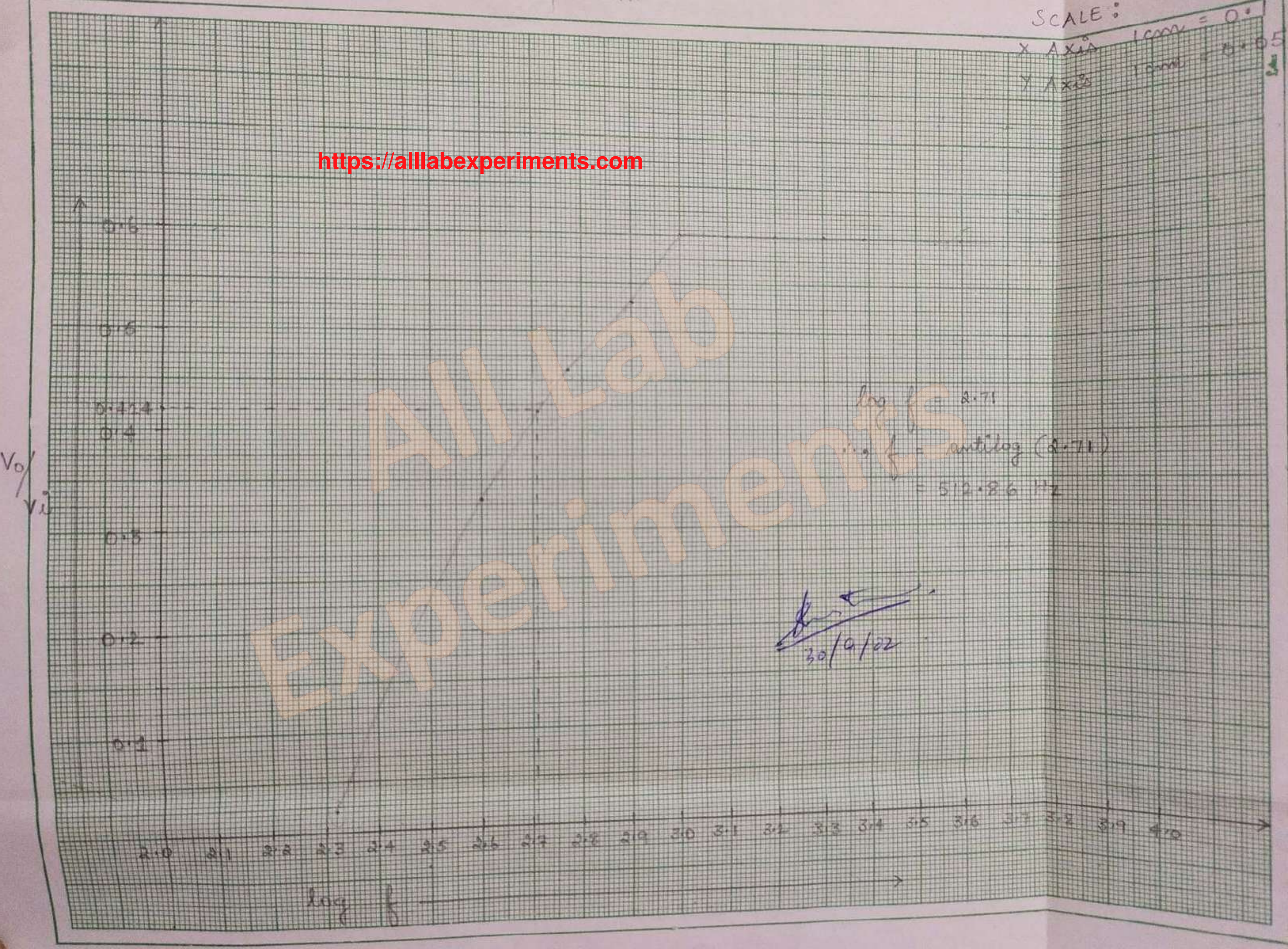
$V_i = 1.5$ V $C = 0.1$ μfd. $f_0 = 1.5$ KHz.

From

$$f_0 = \frac{1}{2\pi RC}$$

$$R = \frac{1}{2\pi f_0 C}$$

HIGH PASS FILTER



$$= \frac{1}{2 \times \frac{22}{7} \times 1500 \times 0.1 \times 10^{-6}} = 1060\ \Omega$$

OBSERVATION TABLE

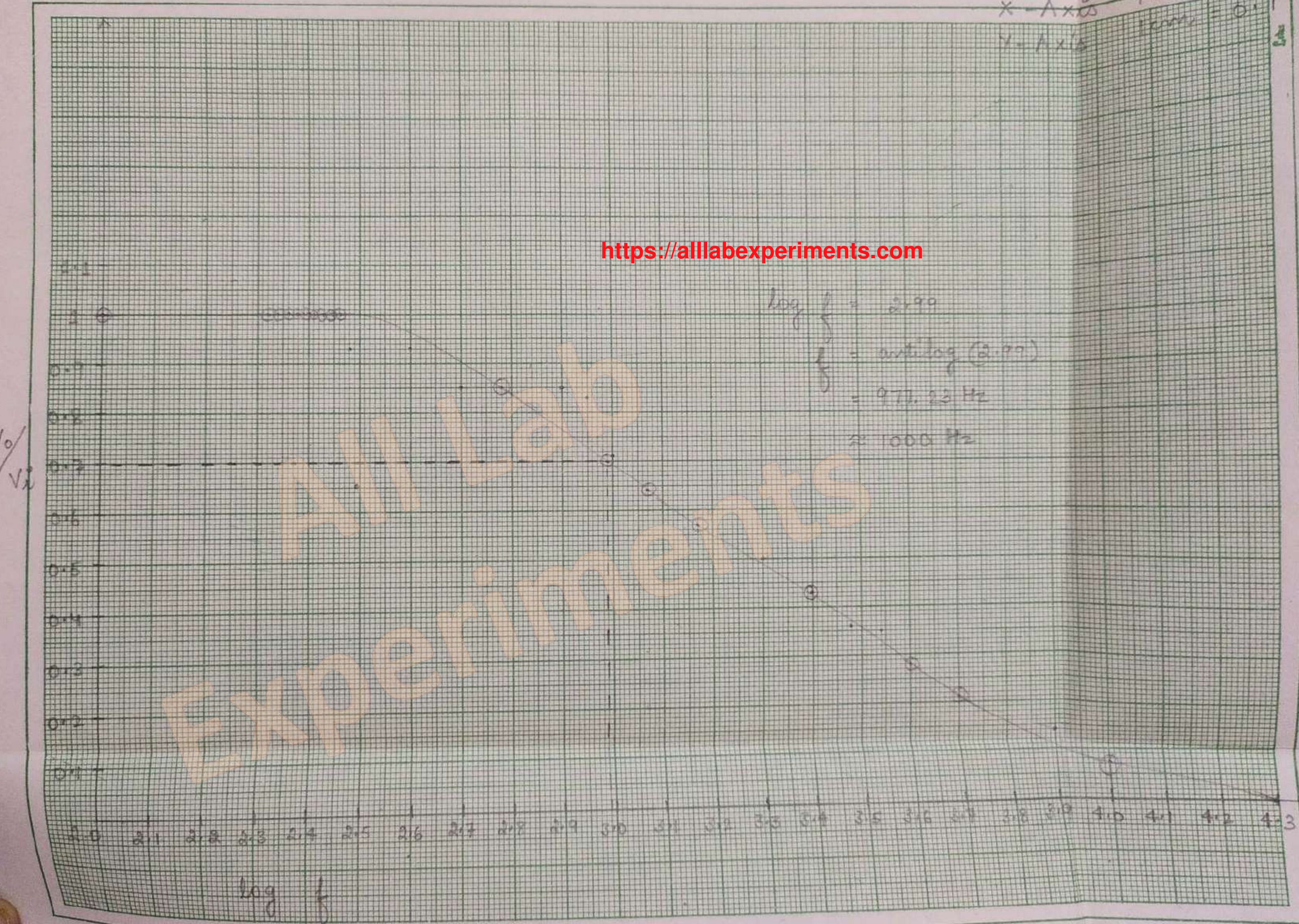
Frequency f (Hz)	log f	Output Voltage V_o (V)	V_o/V_i
210	2.32	0.03	0.02
400	2.60	0.50	0.33
600	2.77	0.70	0.46
800	2.9	0.80	0.53
1000	3.00	0.90	0.60
1200	3.07	0.90	0.60
1400	3.14	0.90	0.60
2000	3.30	0.90	0.60
1600	3.20	0.90	0.60
2500	3.39	0.90	0.60
4000	3.60	0.90	0.60

LOW PASS FILTER.

$V_i = 2.8$ V $f_0 = 2$ KHz $C = 0.1\ \mu fd.$

LOW PASS FILTER.

Scale:
X - Axis 1cm = 0.1
Y - Axis 1cm = 0.1



$$\therefore, \quad R = \frac{1}{2 \times \frac{22}{7} \times 2 \times 10^{3} \times 0.1 \times 10^{-6}} \approx 800\Omega$$

OBSERVATION TABLE

Frequency f (Hz)	log f	Output Voltage V_o (V)	V_o/V_i
100	2	2.8	1
210	2.32	2.8	1
220	2.34	2.8	1
230	2.36	2.8	1
240	2.38	2.8	1
250	2.3979	2.8	1
260	2.41	2.8	1
270	2.43	2.8	1
280	2.447	2.8	1
290	2.46	2.8	1
300	2.477	2.6	.9285
400	2.60	2.6	.9285
500	2.6989	2.4	.8571
600	2.778	2.4	.8571
800	2.90	2.4	.8571
900	2.954	2.2	.7857
1000	3.000	2	.7142

1200	3.079	1.8	0.6428
1500	3.156	1.6	0.5714
2000	3.30	1.4	0.50
2500	3.3979	1.2	0.4285
3000	3.477	1.0	0.3571
3500	3.54	1.0	0.3571
4000	3.60	0.8	0.2857
5000	3.69	0.6	0.2142
8000	3.90	0.4	0.1428
10 K.	4	0.2	0.0714
20 K.	4.30	0	0.00

RESULT → For a high pass filter

$f'_0 = 1500$ Hz (theoretical)

$f'_0 = 600$ Hz (practical)

https://alllabexperiments.com

For a low pass filter

$f'_0 = 2000$ Hz (theoretical)

$f'_0 = 1000$ Hz (practical)

DISCUSSION → We observe that practical value of the cut - off frequency are almost half of the theoretical value, in both the High pass and Low pass RC filters. This may be due to some difference in the theoretical and practical value of the capacitor and the resistor. The other reason may be the difference in the ~~a~~ theoretical and the actual frequency given by the audio oscillator which can lead to considerable differences in the value of cut - off frequency.