INTRODUCTION TO ELECTRONICS LAB

FAMILIARIZATION WITH SIGNAL GENERATOR, OSCILLOSCOPE AND STUDIES ON RC, CR AND RL CIRCUITS

NAME: NAKUL AGGARWAL

ROLL NO.: 19CS10044

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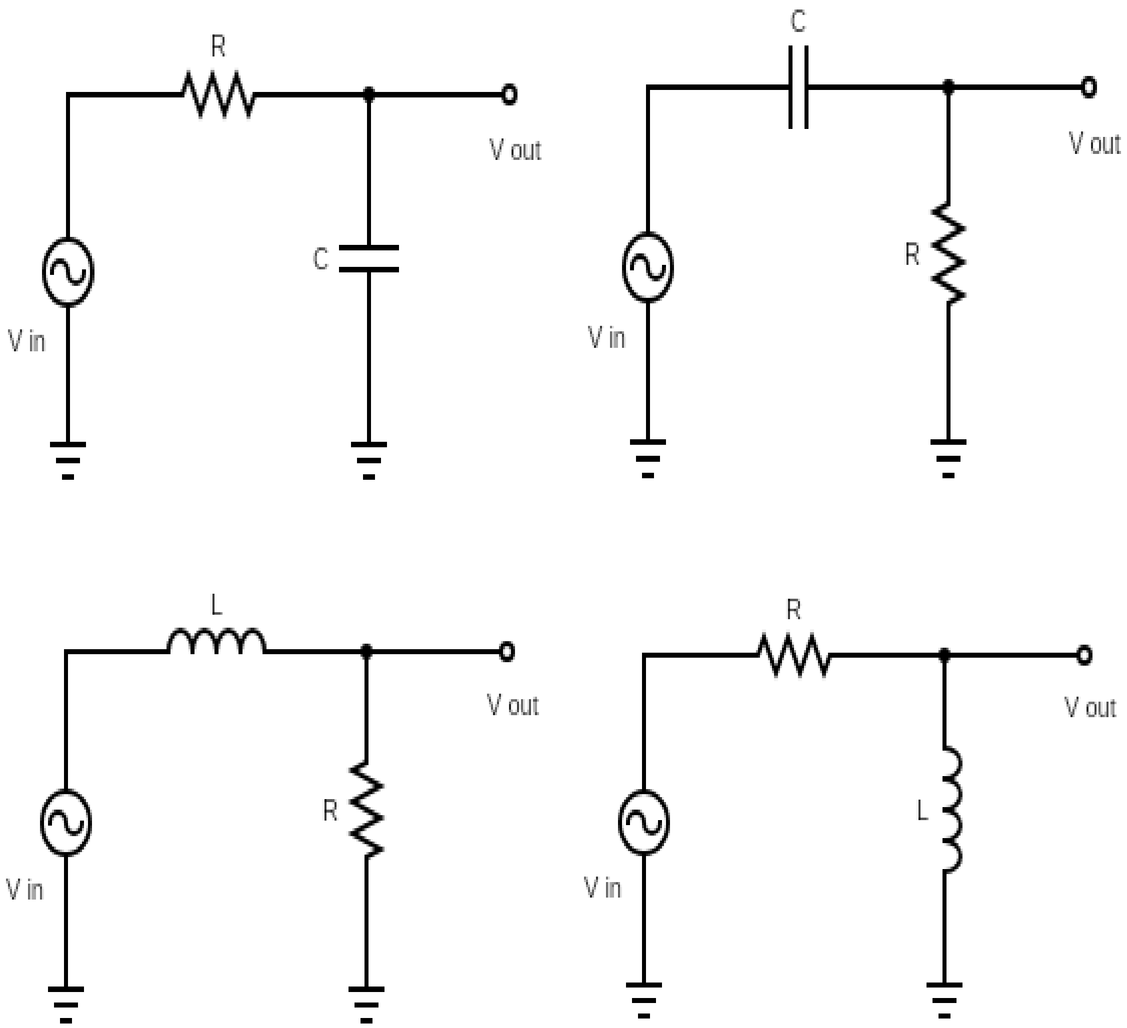
INDIAN INSTITUTE OF TECHNOLOGY KHARAGPUR

EXPERIMENT O2

FAMILIARISATION WITH SIGNAL GENERATOR, OSCILLOSCOPE AND STUDIES ON RC, CR, AND RL CIRCUITS

AIM: To study RC, CR, RL and LR circuits and identify them as low or high pass filters and practically determine their cut-off frequencies. To use some of these circuits as differentiator and integrator for appropriate values of the components and tracing the output for pulse signals like square waveforms.

CIRCUIT DIAGRAM:



THEORY AND DISCUSSION:

A filter is a circuit that allows to pass a specified range of frequency components, while blocking the rest according to the frequency range of signals. The most commonly used filter designs are as follows:

The Low Pass Filter- Filter passes low frequencies and blocks high frequencies. It only allows low frequency signals from 0Hz to its cut-off frequency, point to pass while blocking those any higher.

The High Pass Filter- Filter passes high frequencies and blocks low frequencies. It only allows high frequency signals from its cut-off frequency, point and higher to infinity to pass through while blocking those any lower.

R-C NETWORK-

$$V_{out} = V_{in} * \frac{|X_C|}{\sqrt{R^2 + |X_C|^2}}$$

$$X_C = -j\frac{1}{\omega C}$$

$$V_{out} = V_{in} * \frac{1/\omega C}{\sqrt{R^2 + 1/(\omega C)^2}}$$

$$V_{out} = V_{in} * \frac{1}{\sqrt{(2\pi f RC)^2 + 1}}$$

C-R NETWORK-

$$V_{out} = V_{in} * \frac{R}{\sqrt{R^2 + |X_C|^2}}$$

$$X_C = -j\frac{1}{\omega C}$$

$$V_{out} = V_{in} * \frac{R}{\sqrt{R^2 + 1/(\omega C)^2}}$$

$$V_{out} = V_{in} * \frac{2\pi fRC}{\sqrt{(2\pi fRC)^2 + 1}}$$

L-R NETWORK-

$$V_{out} = V_{in} * \frac{R}{\sqrt{R^2 + |X_L|^2}}$$

$$X_C = jL\omega$$

$$V_{out} = V_{in} * \frac{R}{\sqrt{R^2 + (L\omega)^2}}$$

$$V_{out} = V_{in} * \frac{R}{\sqrt{R^2 + (2\pi fL)^2}}$$

R-L NETWORK-

$$V_{out} = V_{in} * \frac{|X_L|}{\sqrt{R^2 + |X_L|^2}}$$

$$X_C = jL\omega$$

$$V_{out} = V_{in} * \frac{L\omega}{\sqrt{R^2 + (L\omega)^2}}$$

$$V_{out} = V_{in} * \frac{2\pi fL}{\sqrt{R^2 + (2\pi fL)^2}}$$

PROCEDURE:

FREQUENCY RESPONSE OF AN R-C NETWORK –

- A resistor and a capacitor were connected in series with an AC voltage source of peak voltage 600mV as shown in the top left circuit diagram.
- The output voltage was taken across the capacitor for some initial frequency of the AC source, say, 20Hz.

- The frequency of the source was gradually increased from 20Hz to 25kHz and the value of the output voltage across the capacitor was noted for every frequency.
- After recording all the readings, the ratio of output voltage and the input voltage, 600mV, was calculated for all the frequencies and recorded in the same table.
- The column made in the last step was searched to find the value closest to 0.707. The corresponding frequency was declared as the practical cut-off frequency for this filter and its value was compared with the theoretical value given by the formula $f_c = 1/2\pi RC$.
- A graph was drawn between the output input voltage ratio and the frequency.

FREQUENCY RESPONSE OF A C-R NETWORK –

- A resistor and a capacitor were connected in series with an AC voltage source of peak voltage 600mV as shown in the top right circuit diagram.
- The output voltage was taken across the resistor for some initial frequency of the AC source, say, 30Hz.
- The frequency of the source was gradually increased from 20Hz to 25kHz and the value of the output voltage across the resistor was noted for every frequency.
- After recording all the readings, the ratio of output voltage and the input voltage, 600mV, was calculated for all the frequencies and recorded in the same table.
- The column made in the last step was searched to find the value closest to 0.707. The corresponding frequency was declared as the practical cut-off frequency for this filter and its value was compared with the theoretical value given by the formula $f_c = 1/2\pi RC$.
- A graph was drawn between the output input voltage ratio and the frequency.

FREQUENCY RESPONSE OF AN L-R NETWORK –

- A resistor and an inductor were connected in series with an AC voltage source of peak voltage 600mV as shown in the bottom left circuit diagram.
- The output voltage was taken across the resistor for some initial frequency of the AC source, say, 20Hz.

- The frequency of the source was gradually increased from 20Hz to 25kHz and the value of the output voltage across the resistor was noted for every frequency.
- After recording all the readings, the ratio of output voltage and the input voltage, 600mV, was calculated for all the frequencies and recorded in the same table.
- The column made in the last step was searched to find the value closest to 0.707. The corresponding frequency was declared as the practical cut-off frequency for this filter and its value was compared with the theoretical value given by the formula $f_c = R/2\pi L$.
- A graph was drawn between the output input voltage ratio and the frequency.

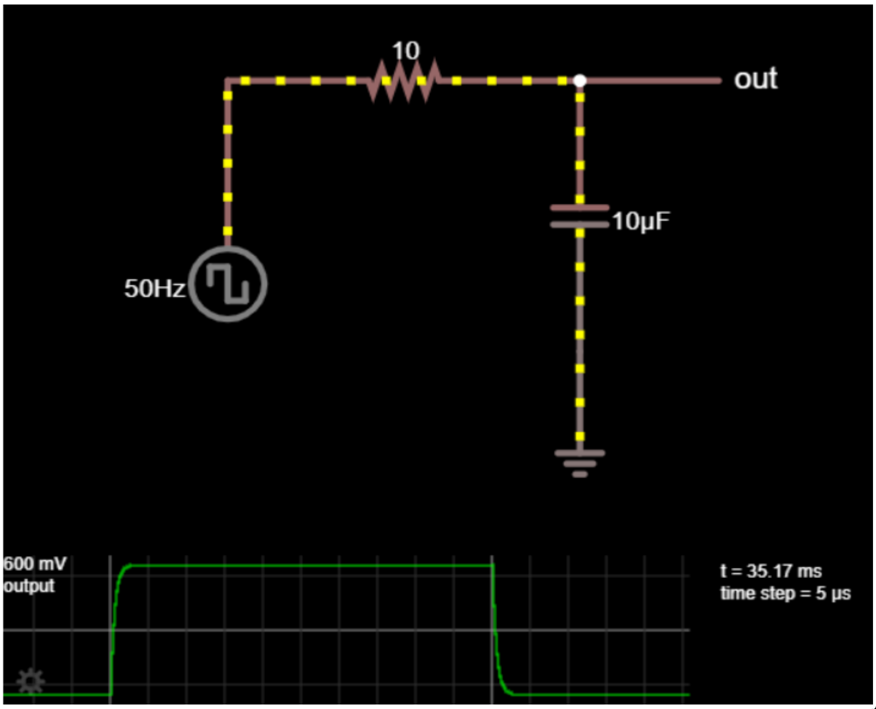
FREQUENCY RESPONSE OF AN R-L NETWORK –

- A resistor and an inductor were connected in series with an AC voltage source of peak voltage 600mV as shown in the bottom right circuit diagram.
- The output voltage was taken across the inductor for some initial frequency of the AC source, say, 20Hz.
- The frequency of the source was gradually increased from 20Hz to 25kHz and the value of the output voltage across the inductor was noted for every frequency.
- After recording all the readings, the ratio of output voltage and the input voltage, 600mV, was calculated for all the frequencies and recorded in the same table.
- The column made in the last step was searched to find the value closest to 0.707. The corresponding frequency was declared as the practical cut-off frequency for this filter and its value was compared with the theoretical value given by the formula $f_c = R/2\pi L$.
- A graph was drawn between the output input voltage ratio and the frequency.

PULSE RESPONSE –

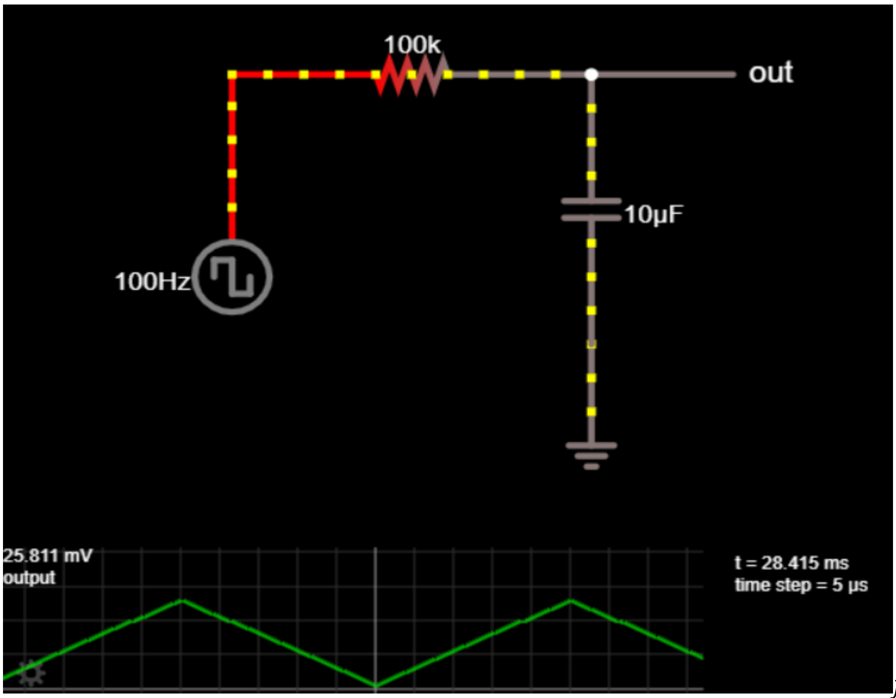
- An RC network was made as in the top left circuit diagram. Instead of a sinusoidal AC signal, a square waveform was applied and the output waveform was simulated.

- In the first case the values of R and C were chosen such that the product RC << T.



from Falstad

- In the second case the values of R and C were chosen such that the product RC >> T.



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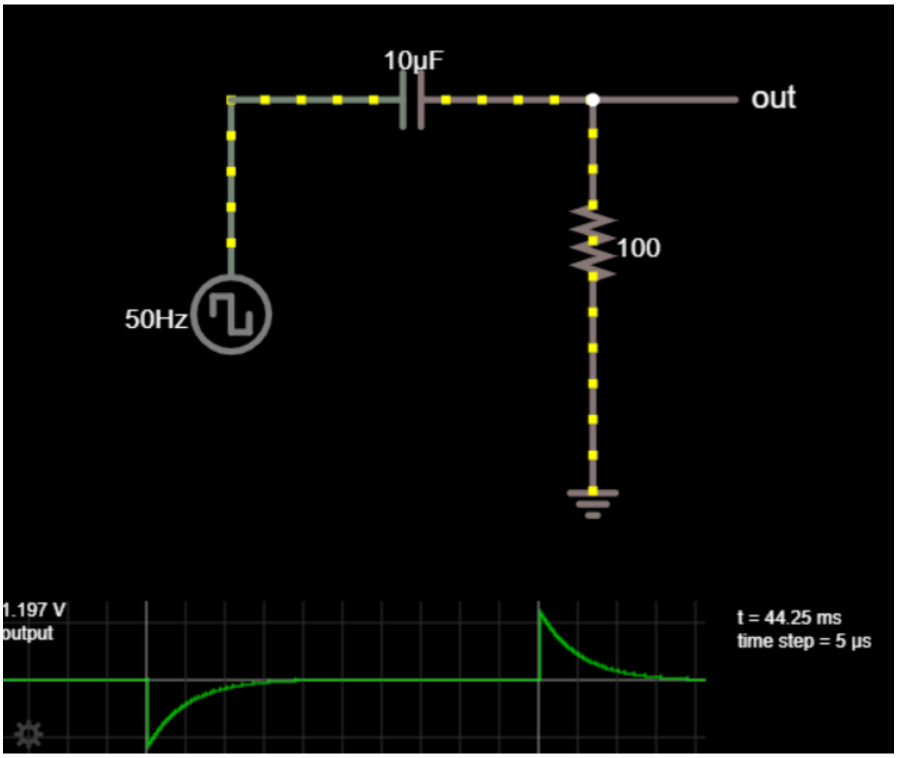
- Now a CR network was made as in the top right circuit diagram. Again, instead of a sinusoidal AC signal, a square waveform was applied and the output waveform was simulated.
- Here the values of R and C were chosen such that the product RC << T.



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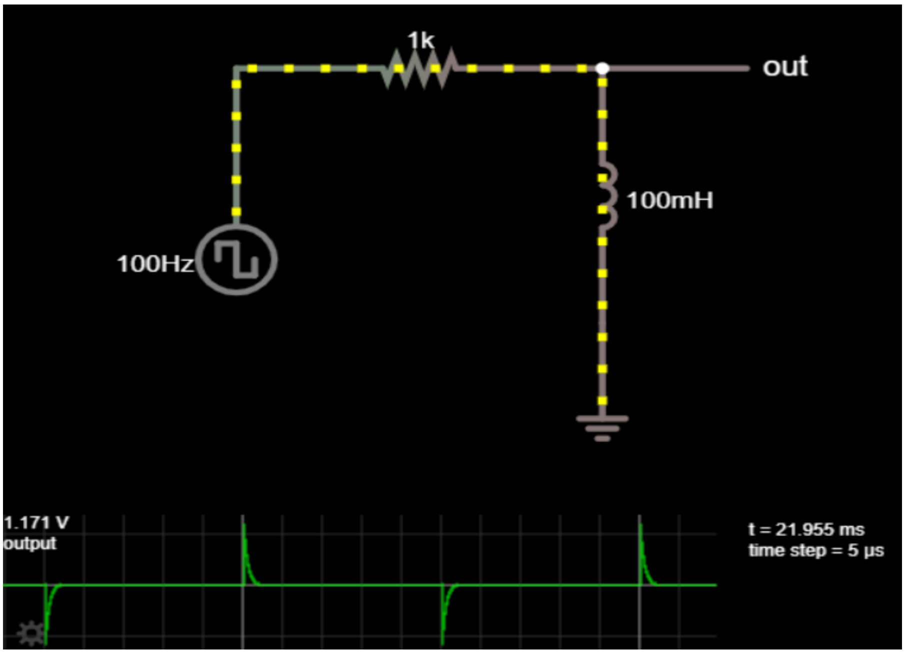
- Now an RL network was made as in the bottom right circuit diagram. Again, instead of a sinusoidal AC signal, a square waveform was applied and the output waveform was simulated.
- Here the values of R and L were chosen such that the ratio L/R << T.



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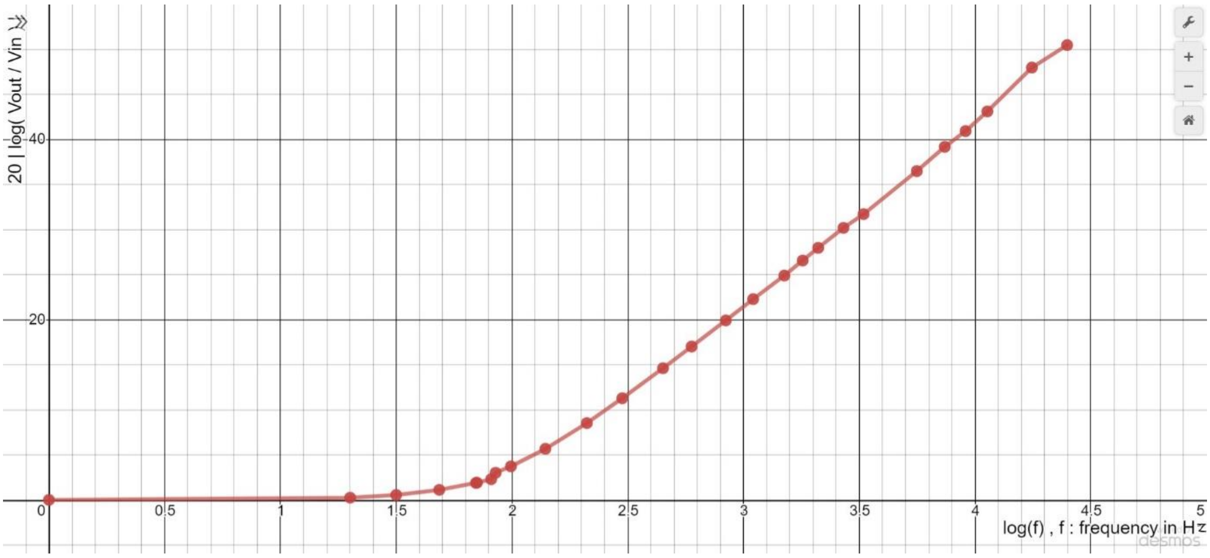
OBSERVATIONS AND PLOTS:

FREQUENCY RESPONSE OF AN R-C NETWORK –

Frequency (in Hz)	V_{out} (in V)	$\frac{V_{out}}{V_{in}}$	$20 \mid \log(V_{out}/V_{in}) \mid$
20.0	584.09	0.973	0.238
31.6	563.59	0.939	0.547
48.5	528.07	0.880	1.110
69.9	483.15	0.805	1.884
70.5	481.95	0.803	1.906
81.3	460.93	0.768	2.293
85.0	424.54	0.707	3.012
98.9	391.37	0.652	3.715
139.5	312.49	0.521	5.663
210.6	224.81	0.375	8.519
299.3	164.11	0.273	11.277
448.9	111.76	0.186	14.610
596.7	84.72	0.141	17.016
838.6	60.58	0.101	19.913
1.1k	46.28	0.077	22.270
1.5k	33.98	0.057	24.882
1.8k	28.33	0.047	26.558
2.1k	24.29	0.040	27.959
2.7k	18.89	0.031	30.173
3.3k	15.46	0.026	31.700
5.6k	9.09	0.015	36.478
7.4k	6.87	0.011	39.172
9.1k	5.57	0.009	40.915
11.3k	4.47	0.007	43.098
14.6k	3.44	0.006	44.437
17.6k	2.83	0.004	47.959
25.0k	1.94	0.003	50.457



from Desmos

R = 187 Ω and C = 10µF

Theoretical cut-off frequency $f_c = 1/2\pi RC$

$f_c = 1 / (2 \times 3.141 \times 187 \times 10 \times 10^{-6}) = 85.12$ Hz

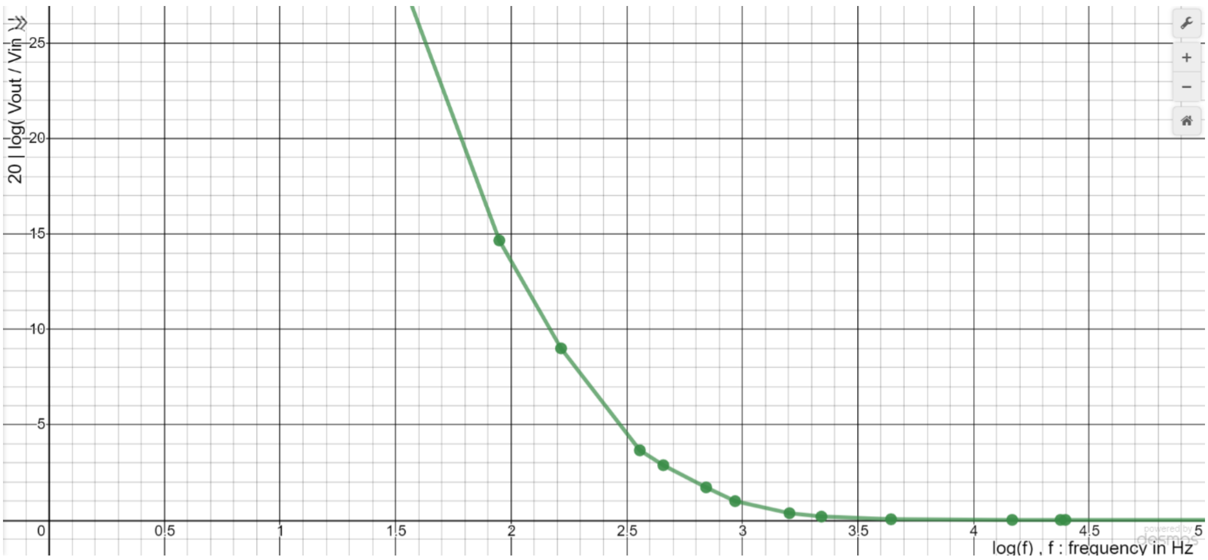
Practical cut-off frequency $f_c = 85.0$ Hz

From the readings and from the plot it is clear that the network acts as a low pass filter.

FREQUENCY RESPONSE OF AN C-R NETWORK –

Frequency (in Hz)	V_{out} (in V)	$\frac{V_{out}}{V_{in}}$	$20 \vert \log(V_{out}/V_{in})$
30.2	19.00	0.032	29.897
88.9	111.18	0.185	14.656
116.6	115.43	0.192	14.334
174.4	207.53	0.346	9.218
164.4	286.59	0.478	6.411
360.4	350.83	0.585	4.657
451.3	401.21	0.669	3.491
455.1	431.01	0.718	2.877
532.3	440.03	0.887	1.041
697.5	492.65	0.821	1.713
931.0	535.43	0.892	0.993
1.6k	575.71	0.959	0.364
2.2k	587.26	0.979	0.184
4.4k	596.76	0.995	0.043

14.7k	599.70	0.999	0.009
23.8k	599.88	0.999	0.009
25k	599.91	0.999	0.009



from Desmos

R = 37Ω and C = 10µF

Theoretical cut-off frequency f_c = $1/2\pi RC$

f_c = 1 / (2 x 3.141 x 37 x 10 x 10^{-6}) = 430.23 Hz

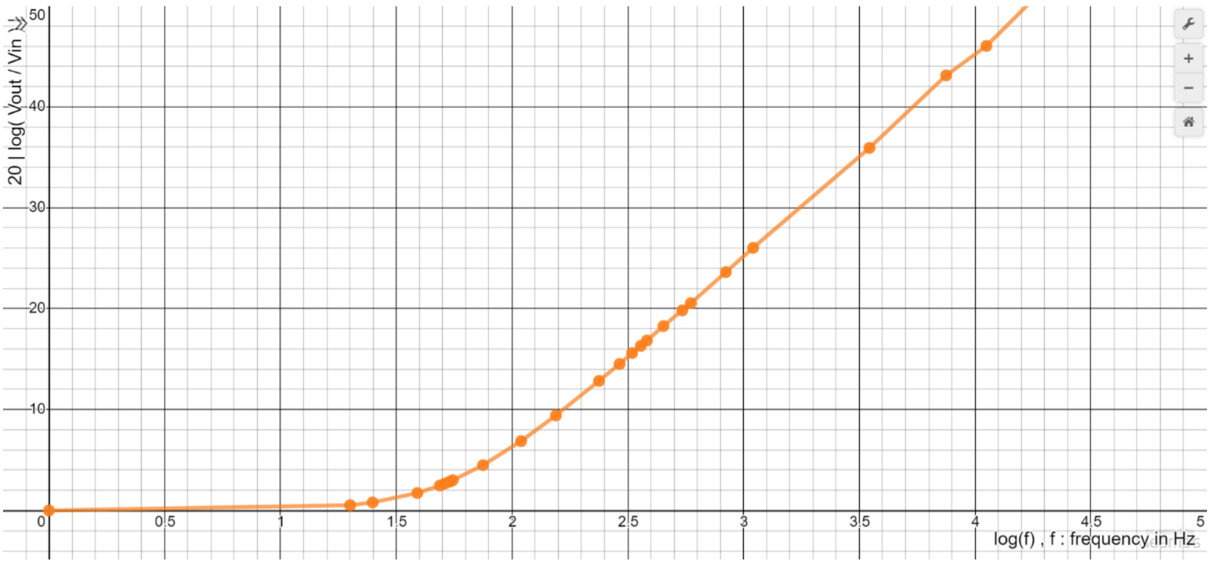
Practical cut-off frequency f_c = 455.1 Hz

From the readings and from the plot it is clear that the network acts as a high pass filter.

FREQUENCY RESPONSE OF AN L-R NETWORK –

Frequency (in Hz)	V_{out} (in V)	$\frac{V_{out}}{V_{in}}$	20 | $\log(V_{out}/V_{in})$
20.0	564.70	0.941	0.528
25.0	547.40	0.912	0.800
39.0	491.51	0.819	1.734
48.8	451.31	0.752	2.476
51.2	441.75	0.736	2.662
53.7	431.96	0.720	2.853
55.5	425.04	0.708	2.999
75.0	357.75	0.596	4.495
109.5	272.05	0.453	6.878
154.8	203.15	0.338	9.422
237.7	136.90	0.228	12.841

291.6	112.58	0.188	14.517
330.1	99.84	0.166	15.598
359.9	91.77	0.153	16.306
382.3	86.51	0.144	16.833
451.0	73.55	0.122	18.273
543.8	61.14	0.102	19.828
591.9	56.22	0.094	20.537
838.6	39.76	0.066	23.609
1.1k	30.34	0.050	26.020
3.5k	9.54	0.016	35.918
7.5k	4.43	0.007	43.098
11.2k	2.95	0.005	46.020
25k	1.27	0.002	53.979



from Desmos

R = 35Ω and L = 100mH

Theoretical cut-off frequency $f_c = R/2\pi L$

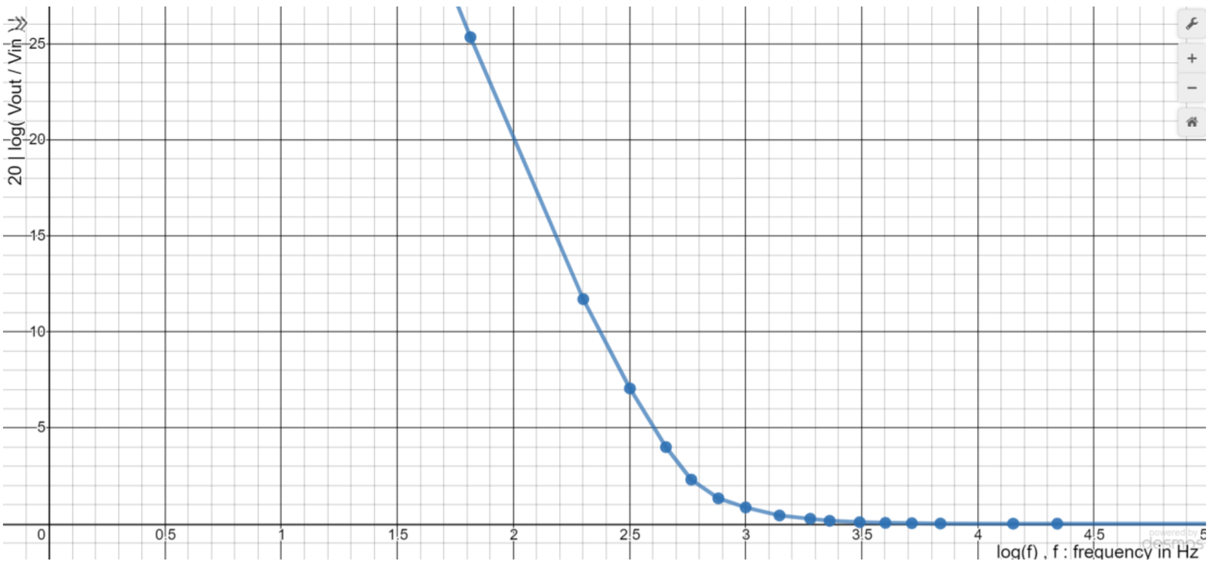
f_c = 35 / (2 x 3.141 x 100 x 10^{-3}) = 55.70 Hz

Practical cut-off frequency f_c = 55.5 Hz

From the readings and from the plot it is clear that the network acts as a low pass filter.

FREQUENCY RESPONSE OF AN R-L NETWORK –

Frequency (in Hz)	V_{out} (in V)	$\frac{V_{out}}{V_{in}}$	20 $\vert \log(V_{out}/V_{in})$
65.3	32.40	0.054	25.352
116.1	121.53	0.202	13.893
199.9	156.14	0.260	11.700
317.4	266.26	0.444	7.052
453.9	415.46	0.692	3.198
583.7	460.22	0.767	2.304
763.4	514.57	0.858	1.330
1k	543.47	0.906	0.857
1.4k	570.57	0.951	0.436
1.9k	582.06	0.970	0.264
2.3k	588.98	0.982	0.158
3.1k	594.01	0.990	0.087
4.0k	596.37	0.994	0.052
5.2k	597.49	0.996	0.035
6.9k	598.75	0.998	0.017
14.2k	599.67	0.999	0.009
22k	599.88	0.999	0.009



from Desmos

R = 187Ω and L = 65.5mH

Theoretical cut-off frequency $f_c = R/2\pi L$

$f_c = 187 / (2 \times 3.141 \times 65.5 \times 10^{-3}) = 454.38$ Hz

Practical cut-off frequency $f_c = 453.9$ Hz

From the readings and from the plot it is clear that the network acts as a high pass filter.

CONCLUSION:

- Resistance and capacitance when connected in series with an AC voltage source with variable frequency, can act as a frequency filter. When output voltage is taken across capacitance, it acts as a low pass filter and when it is taken across resistance, it acts as a high pass filter.
- Resistance and inductance when connected in series with an AC voltage source with variable frequency, can act as a frequency filter. When output voltage is taken across inductance, it acts as a high pass filter and when it is taken across resistance, it acts as a low pass filter.
- RC, CR and RL networks can be used to obtain various output waveforms from some input waveform like square wave. Under appropriate values of the electrical components with respect to the time period of the input waveform, the circuit can act as a differentiator or an integrator.