DISCIPLINE OF ASTRONOMY, ASTROPHYSICS & SPACE ENGINEERING, IIT INDORE

RF Lab

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1 OBJECTIVES

1. Explain RC Voltage Dividers
2. Explain RC Circuit as a Low Pass Filter
3. Explain RC Circuit as a High Pass Filter

2 THEORY

2.1 RC CIRCUIT AS FILTERS

A filter is a circuit that allows to pass a specified range of frequency components, while blocking or "attenuating" 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, (f_C) 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, (f_C) point and higher to infinity to pass through while blocking those any lower.

The Band Pass Filter - Filter passes only a relatively narrow range of frequencies. It allows signals falling within a certain frequency band setup between two points to pass through while blocking both the lower and higher frequencies either side of this frequency band.

Filters can also be classified according to the types of components that are used to implement the circuit. Passive filters are made up of passive components such as resistors, capacitors and inductors and have no amplifying elements (transistors, op-amps, etc) so have no signal gain, therefore their output level is always less than the input.

2.2 RC VOLTAGE DIVIDERS

Let us consider RC circuits as voltage dividers to understand how they would perform as 'filters'.

Note that

$$V_{out} = (\frac{Z_2}{Z_1 + Z_2}) * V_{in}$$

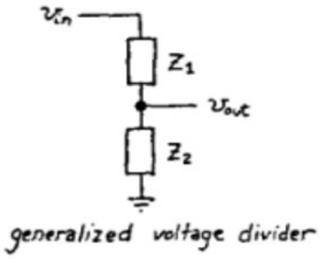


Figure:1

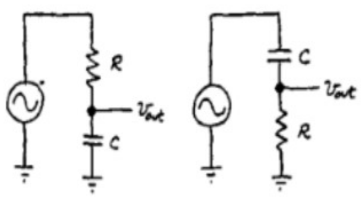


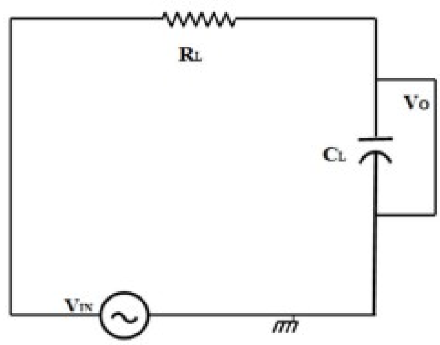
Figure:2

In this case – since Z_1 or Z_2 (impedance) is dependent upon frequency, the output is dependent upon the frequency of the input waveform.

2.3 RC as Low Pass filter

A simple passive RC Low Pass Filter (LPF) can be easily made by connecting together in series a single Resistor (R_L) with a single Capacitor (C_L) as shown in the figure.

In this type of filter arrangement the input signal ($V_I N$) is applied to the series combination (both the Resistor and Capacitor together) but the output signal (V_O) is taken across the Capacitor only. The reactance of a Capacitor varies inversely with frequency, while the value of the Resistor remains constant as the frequency changes.



- $Z_1 = R_L$
- $Z_2 = \frac{1}{jwC_L}$
- $\frac{V_o}{V_{IN}} = \frac{Z_2}{Z_1+Z_2} = \frac{1}{1+jwR_LC_L}$

At low frequencies the capacitive reactance, (X_C) of the Capacitor will be very large compared to the resistive value of the Resistor R. Voltage across the Capacitor (V_C) will be much larger than the voltage drop developed across the Resistor (V_R).

At high frequencies the reverse is true with V_C being small and V_R being large due to the change in the capacitive reactance value.

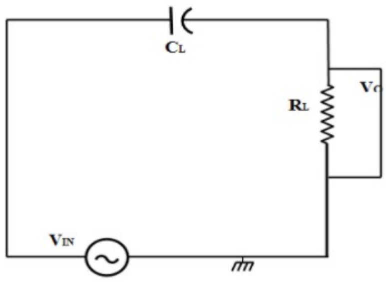
Thus, low frequencies are passed and high frequencies are blocked.

2.4 RC Circuit as a High Pass Filter

A simple passive RC High Pass Filter (HPF) can be easily made by connecting together in series a single Resistor (R_L) with a single Capacitor (C_L) as shown in the figure. The input signal (V_IN) is applied to the series combination (both the Resistor and Capacitor together) but the output signal (V_out) is taken across the Resistor only.

In this circuit, the reactance of the Capacitor is very high at low frequencies so the Capacitor acts like an open circuit and blocks any input signals at (V_IN) until the cut-off frequency point (f_c) is reached.

Above this cut-off frequency point the reactance of the Capacitor has reduced sufficiently as to now act more like a short circuit allowing all of the input signal to pass directly to the output as shown below in the filters response curve.



$$Magnitude = 20log(\frac{R}{Z})$$

$$V_{out} = V_{in}\frac{R}{Z}$$

3 Observations

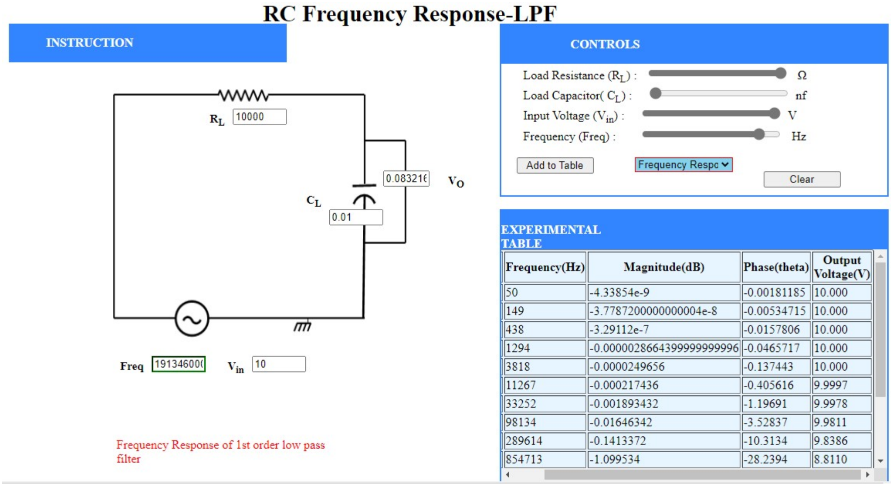
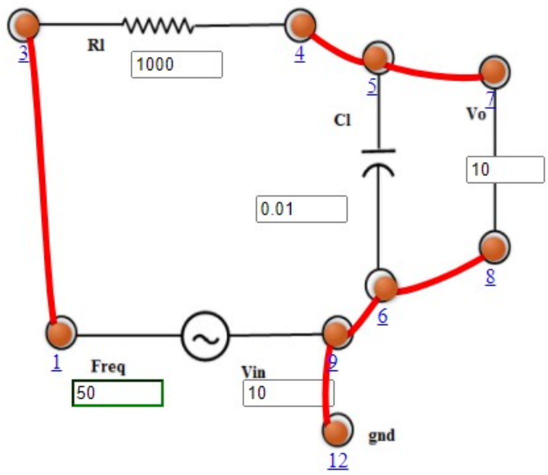
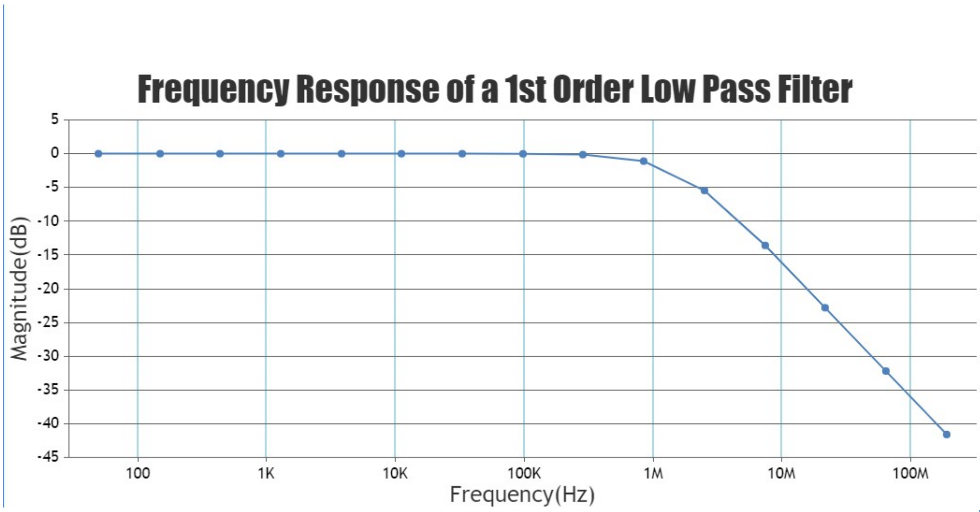
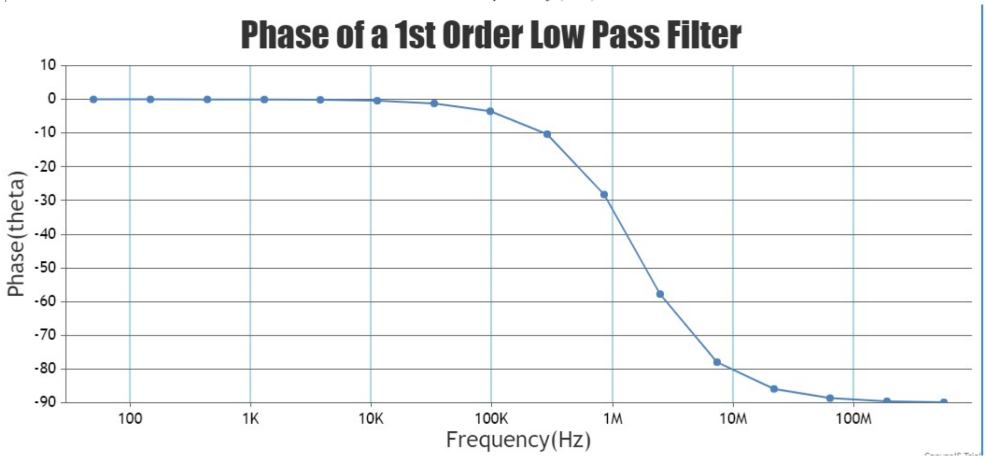


Table 3.1: Low Pass Filter

Serial_No.	Frequency_Hz	Magnitude_dB	Phase_theta	V_out
1	50	-4.34E-09	-0.00181185	10
2	149	-3.78E-08	-0.00534715	10
3	438	-3.29E-07	-0.0157806	10
4	1294	-2.87E-06	-0.0465717	10
5	3818	-2.50E-05	-0.137443	10
6	11267	-0.000217436	-0.405616	9.9997
7	33252	-0.001893432	-1.19691	9.9978
8	98134	-0.01646342	-3.52837	9.9811
9	289614	-0.1413372	-10.3134	9.8386
10	854713	-1.099534	-28.2394	8.811
11	2522440	-5.45226	-57.766	5.3381
12	7444240	-13.5899	-77.9657	2.0917
13	21969500	-22.8184	-85.898	0.72291
14	64836600	-32.1982	-88.6381	0.24552
15	191346000	-41.5958	-89.5686	0.083216


Rl
1000
3
4
5
7
Cl
Vo
10
0.01
8
6
1
Freq
50
Vin
10
9
gnd
12


Frequency Response of a 1st Order Low Pass Filter
Magnitude(dB)
Frequency(Hz)
100
1K
10K
100K
1M
10M
100M


Phase of a 1st Order Low Pass Filter
Phase(theta)
Frequency(Hz)
100
1K
10K
100K
1M
10M
100M

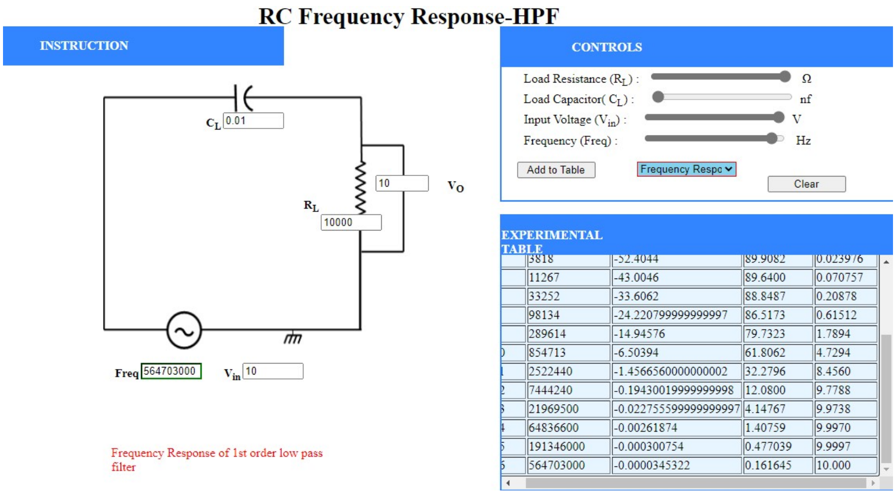
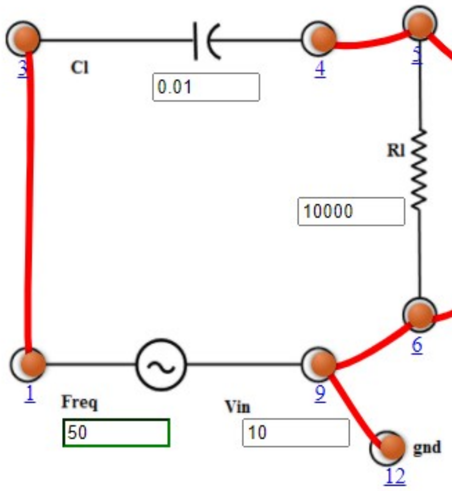
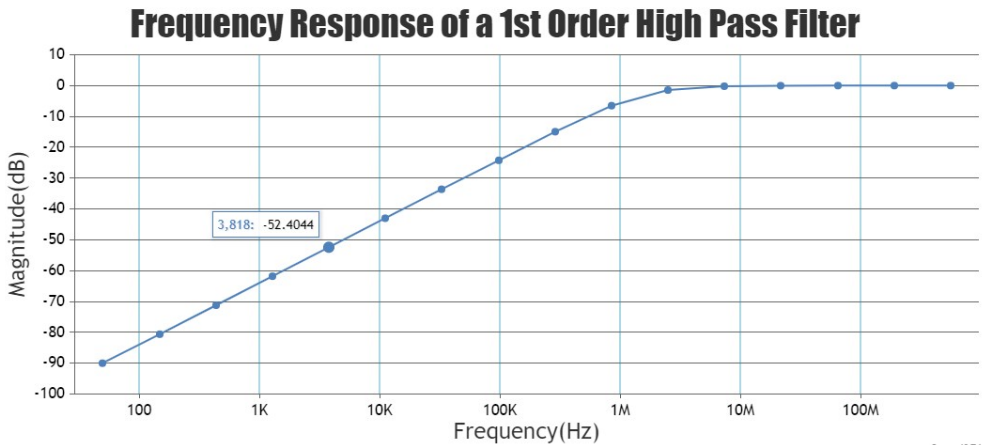


Table 3.2: High Pass Filter

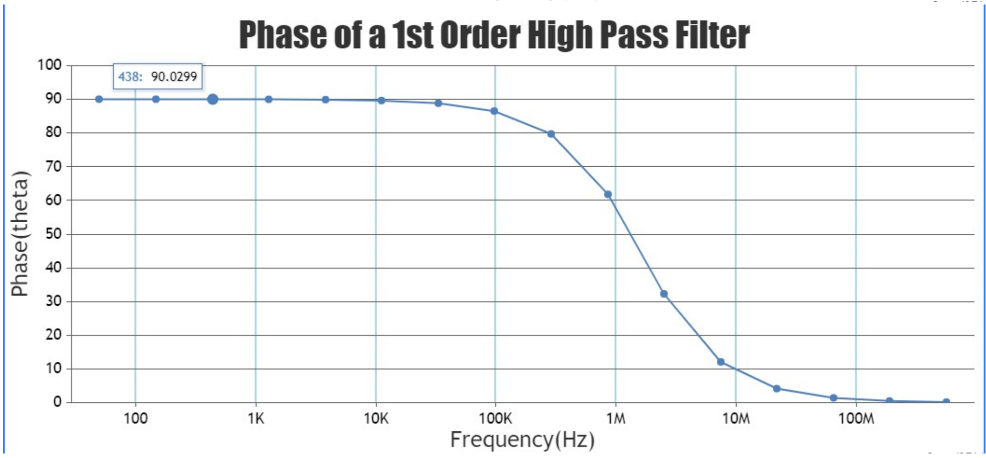
Serial_No.	Frequency_Hz	Magnitude_dB	Phase_theta	V_out
1	50	-9.00E+01	90.0438	0.00031607
2	149	-8.06E+01	90.0403	0.00093278
3	438	-7.12E+01	90.0299	0.0027528
4	1294	-61.8044	89.9991	0.0081242
5	3818	-52.4044	89.9082	0.023976
6	11267	-43.0046	89.64	0.070757
7	33252	-33.6062	88.8487	0.20878
8	98134	-24.2208	86.5173	0.61512
9	289614	-14.94576	79.7323	1.7894
10	854713	-6.50394	61.8062	4.7294
11	2522440	-1.456656	32.2796	8.456
12	7444240	-0.1943002	12.08	9.7788
13	21969500	-0.0227556	4.14767	9.9738
14	64836600	-0.00261874	1.40759	9.997
15	191346000	-0.000300754	0.477039	9.9997
16	564703000	-3.45E-05	0.161645	10



3
Cl
0.01
4
5
7
Rl
Vo
0.0003160
10000
8
6
1
Freq
50
Vin
10
9
gnd
12



Frequency Response of a 1st Order High Pass Filter
Magnitude(dB)
Frequency(Hz)
3,818: -52.4044
100
1K
10K
100K
1M
10M
100M



Phase of a 1st Order High Pass Filter
Phase(theta)
Frequency(Hz)
438: 90.0299
100
1K
10K
100K
1M
10M
100M

4 Conclusions

1. The key difference between high pass and low pass filters is that the high pass filter circuits pass signals of frequencies higher than the cut off frequency while the low pass filters pass signals of the frequencies lower than the cut off frequency.

2. High pass and low pass filters also vary in circuit design. High pass filters consist of a capacitor followed by a resistor in parallel, while a low pass filter's circuit consists of a resistor followed by a capacitor.

3. Low pass filters are used as anti-aliasing filters while high pass filters are used in audio amplifiers for coupling or removing distortions due to low-frequency signals such as noise.

Thus, high pass and low pass filters are passive filters as they use passive components. The gain of the signal can be increased by using amplifiers in the filter circuit, making them active filters.

5 Acknowledgement

The experiment, theory, procedure and simulations are taken from the Virtual Labs – IIT Kanpur `http://www.iitk.ac.in/mimt_lab/vlab/`.