EXPERIMENT-2,3

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Problem 1(a,b):

Aim:

To design a single stage low pass filter with a cutoff frequency of f_c = 64㎑

Material Required:

Breadboard, Resistor(2.5kΩ), capacitor(1nF), multimeter, Oscilloscope

Theory:

A low pass filter is a circuit that attenuates all the signal above a certain frequency leveland lets the frequency below that level pass through it.

The cutoff frequency is

$$f = \frac{1}{2\pi RC}\,\mathrm{Hz}$$

When the voltage source of frequency *w* is applied as an input. The impedance of the capacitor is

$$X_c = \frac{1}{jwc}$$

From the above equation, we can say that the impedance of the capacitor decreases as the frequency *w* increases of the input voltage.

The gain of the circuit is

$$gain = 20log(\frac{V_{out}}{V_{in}})$$

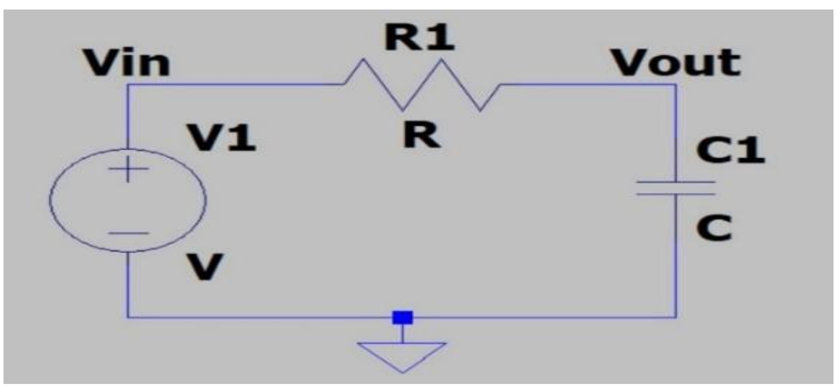
$$V_{out} = V_{in}\frac{R}{(R+\frac{1}{jwc})}$$

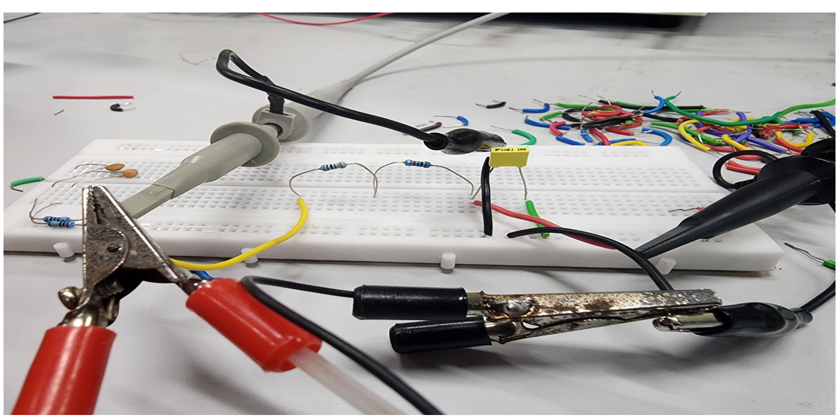
The phase is given by,

$$Phase = tan^{-1}(\frac{1}{wRC})$$

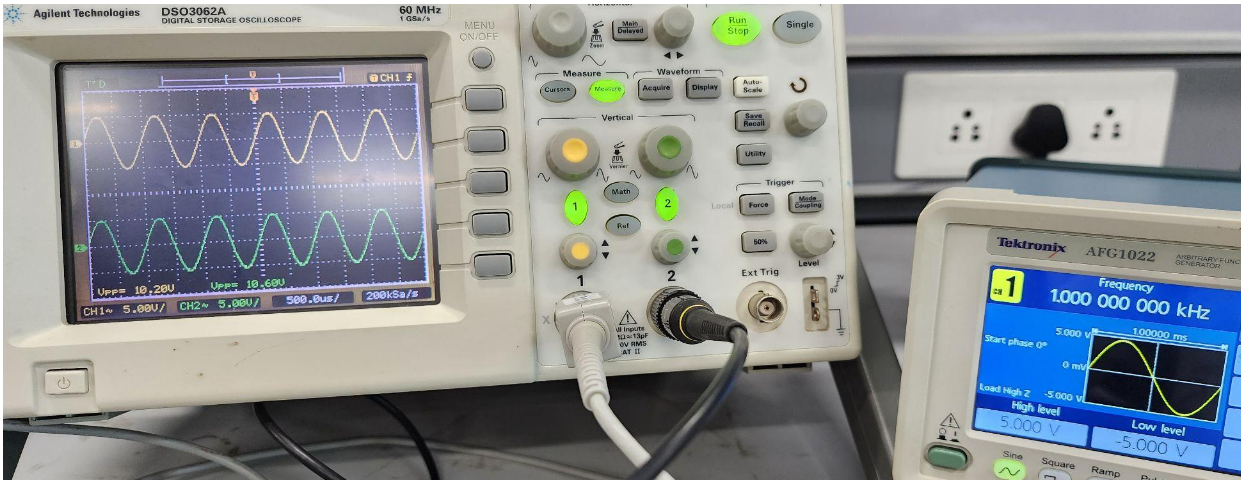
Procedure:

1. We connect the RC circuit in series,giving input from the resistor and taking output from capacitor.
2. Taking R=2.5k and C=1nF
3. We record the gain and phase difference from 10hz and 1.28Mhz



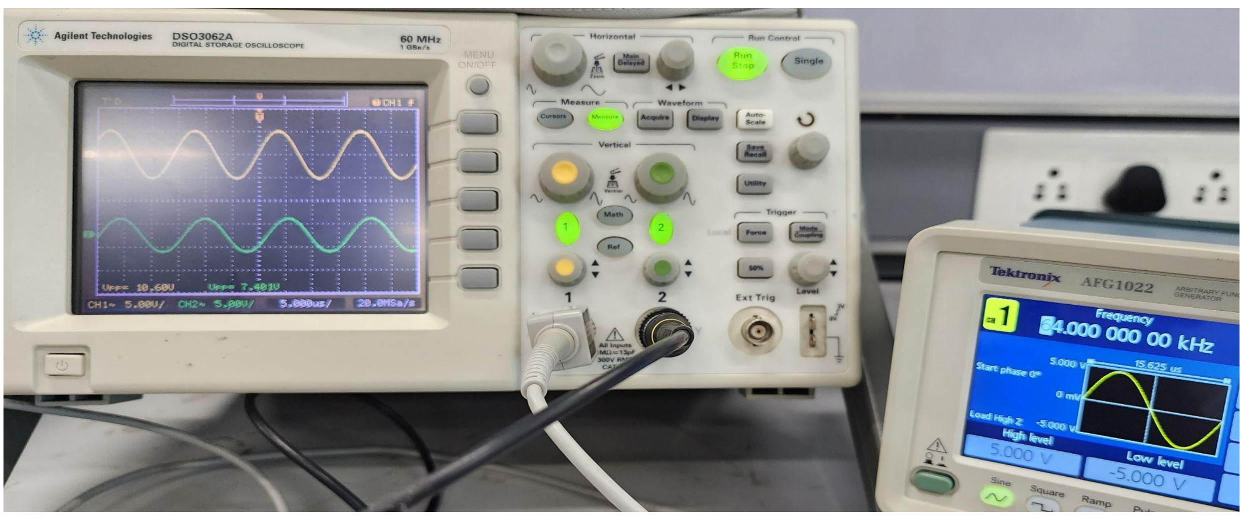


Observations:



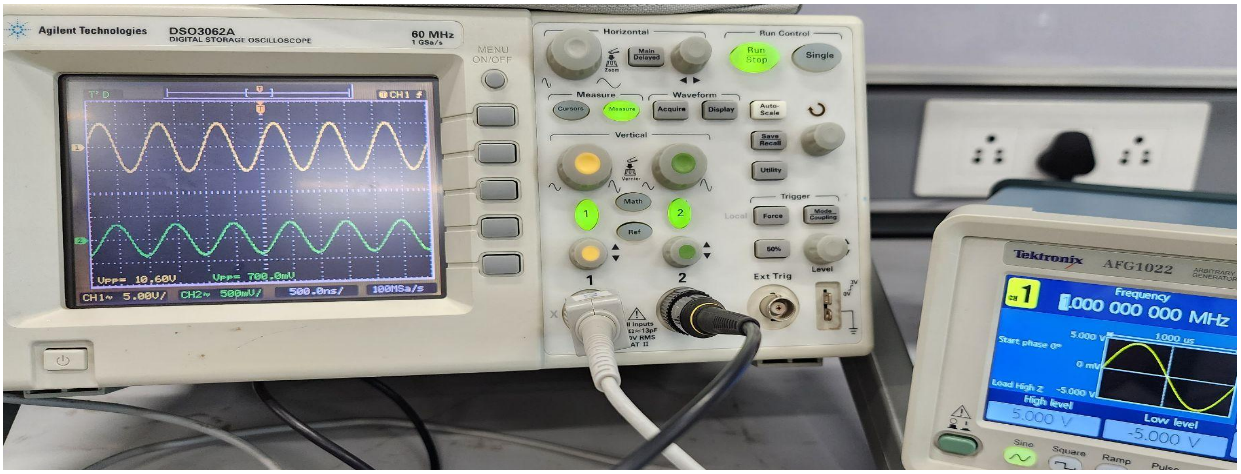
For lower frequency, we observe that

- Experimental gain = 0 and LTspice gain ≅ 0
- Experimental phase diff. = -0.36 and LTspice = -9.0E-03



For cutoff frequency, we observe that

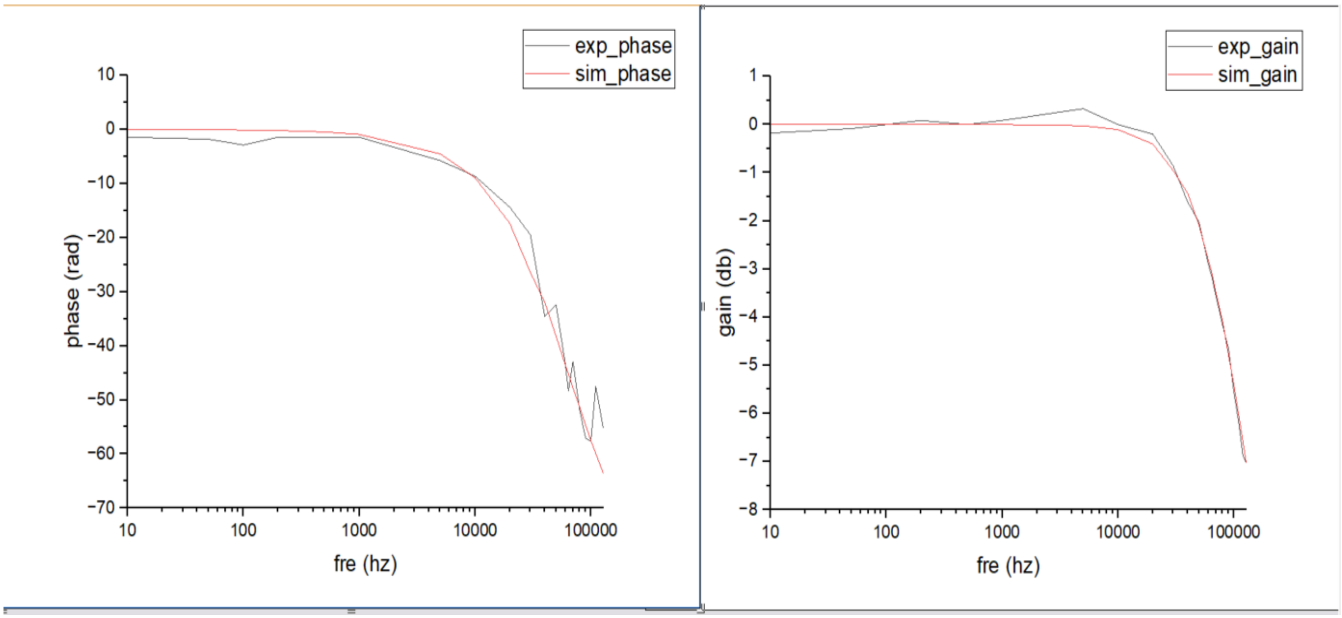
- Experimental gain = -3.12 and LTspice gain = -48.32
- Experimental phase diff. = -3.04 and LTspice = -45.15



For higher frequency, we observe that

- Experimental gain = -26.6 and LTspice gain =-82.94
- Experimental phase diff. = -26.07 and LTspice = -87.15

	A(X)	B(Y)	C(Y)	D(Y)	E(Y)
Long Name	fre	gain	phase	gain	phase
Units	hz	db	rad	db	rad
Comments		exp_gain	exp_phase	sim_gain	sim_phase
F(x)=					
1	10	-0.1791	-1.44	-1.07E-7	-0.009
2	50	-0.08392	-1.8	-2.69E-6	-0.0451
3	100	0	-2.88	-1.07E-5	-0.09
4	200	0.08312	-1.44	-4.27E-5	-0.18
5	500	0	-1.44	-2.69E-4	-0.451
6	1000	0.08312	-1.44	-0.00107	-0.9
7	5000	0.32781	-5.76	-0.0268	-4.5
8	10000	0	-8.64	-0.106	-8.93
9	20000	-0.20279	-14.4	-0.407	-17.4
10	30000	-0.85979	-19.44	-0.958	-26.4
11	40000	-1.61646	-34.56	-1.43	-32
12	50000	-2.02053	-32.4	-2.09	-38.2
13	60000	-2.88985	-43.2	-2.801	-43.47
14	64000	-3.12148	-48.384	-3.04	-45.15
15	70000	-3.55466	-42.84	-3.48	-47.75
16	80000	-4.16804	-51.84	-4.08	-51.3
17	90000	-4.65828	-57.024	-4.79	-54.64
18	100000	-5.54236	-57.6	-5.4	-57.5
19	110000	-6.18605	-47.52	-6.03	-59.89
20	120000	-6.88129	-51.84	-6.59	-61.97
21	128000	-7.02728	-55.296	-7.03	-63.6

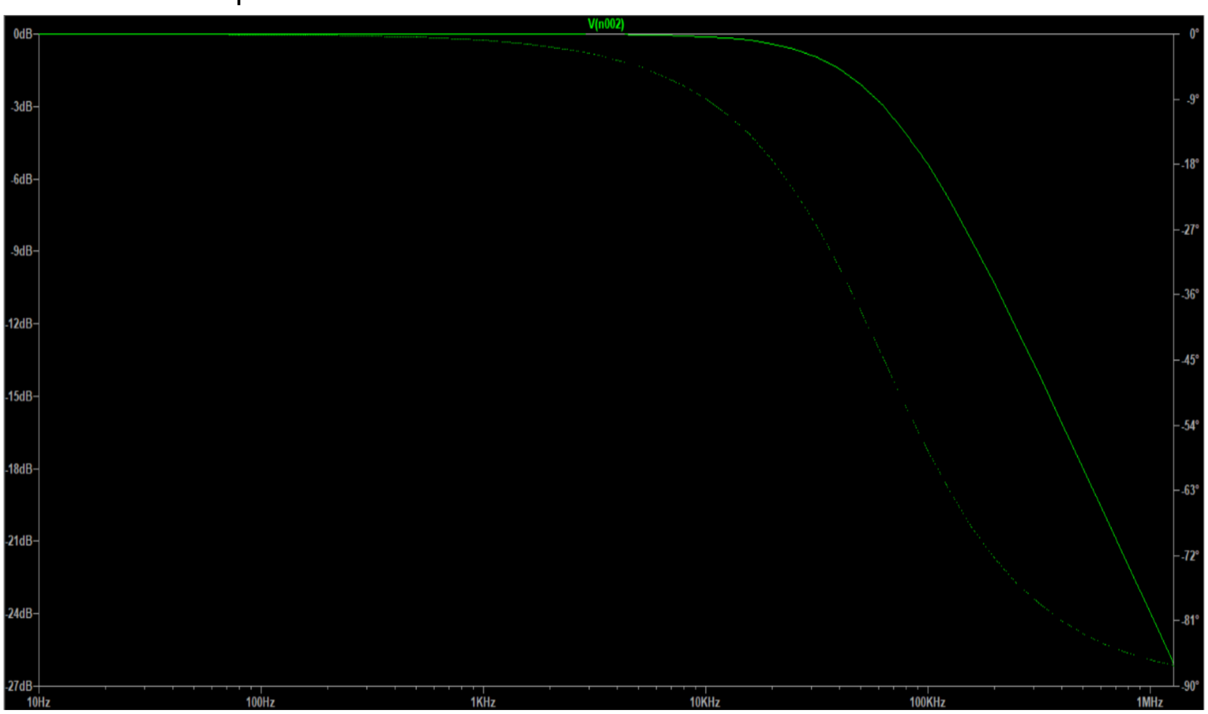


Deviation from Experimental and LTspice model,

The experimentally obtained roll-off slope is: -22.444 - (-5.542) = -16.902dB/decade

Simulation:

Graph derived from LTspice



Experimental Value of R and C are 2.5kΩ and 1nF

Tweaked Value of R and C are 2.4kΩ and 1nF

Problem 1(c):

Aim:

To repeat the same experiment as in 1(a,b) but with a two stage filter for same value of R,C.

Material Required:

Breadboard, Resistor(2.5kΩ), capacitor(1nF), multimeter, Oscilloscope and function generator

Theory:

A double-stage low-pass filter combines two single-stage filters in series. This configuration offers several advantages over a single-stage filter, including enhanced attenuation of high-frequency noise and a steeper roll-off slope.

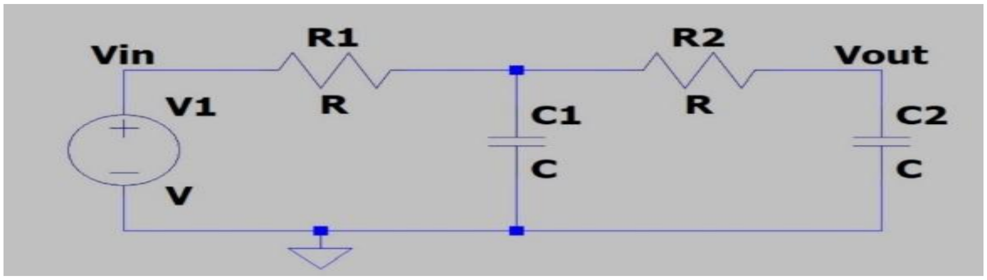
The cutoff of the double-stage filter remains a function of the individual resistor and capacitor values in each stage but is influenced by their combined effect. It is typically calculated as:

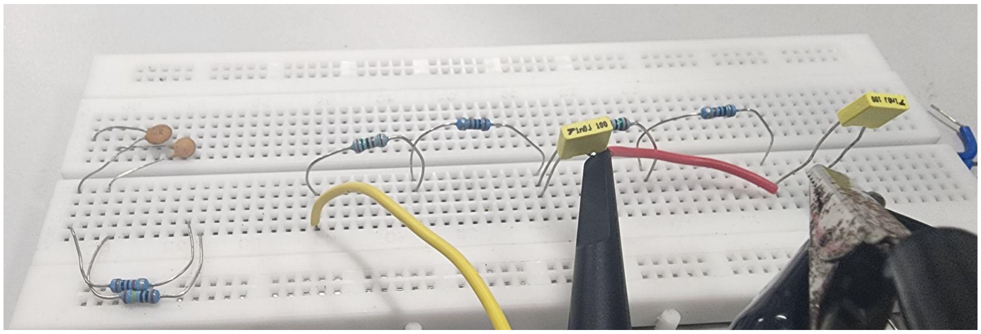
$$fc = \frac{1}{2\pi\sqrt{R_1 C_1 R_2 C_2}}$$

The double-stage filter exhibits a steeper roll-off slope compared to a single-stage filter. The exact roll-off rate depends on the filter order. A double-stage filter has a second-order roll-off.

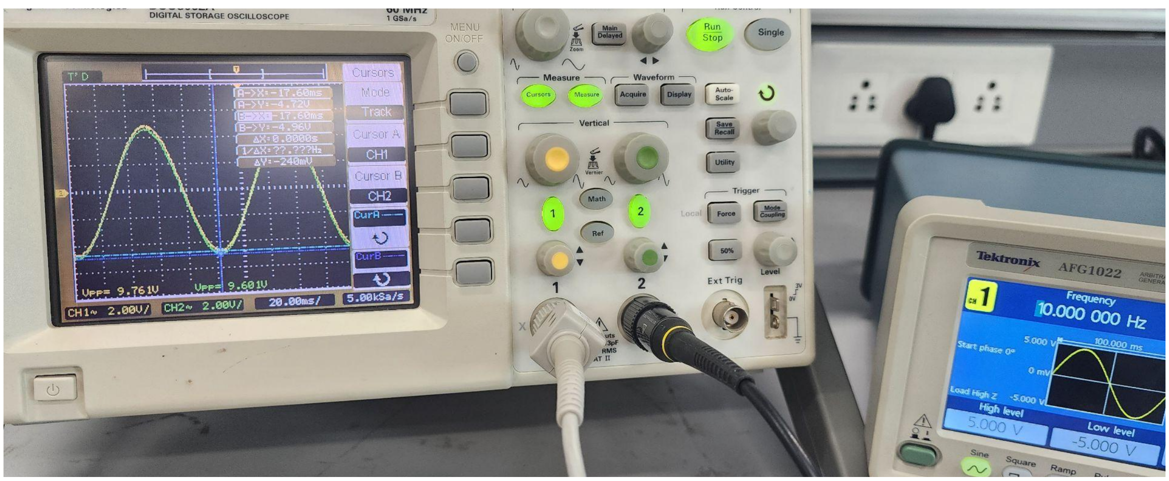
Procedure:

1. We connect two single stage filter in series,giving input from the resistor of first stage and taking output from capacitor of second stage.
2. Taking R=2.5k and C=1n
3. We record the gain and phase difference from 10hz and 1.28Mhz



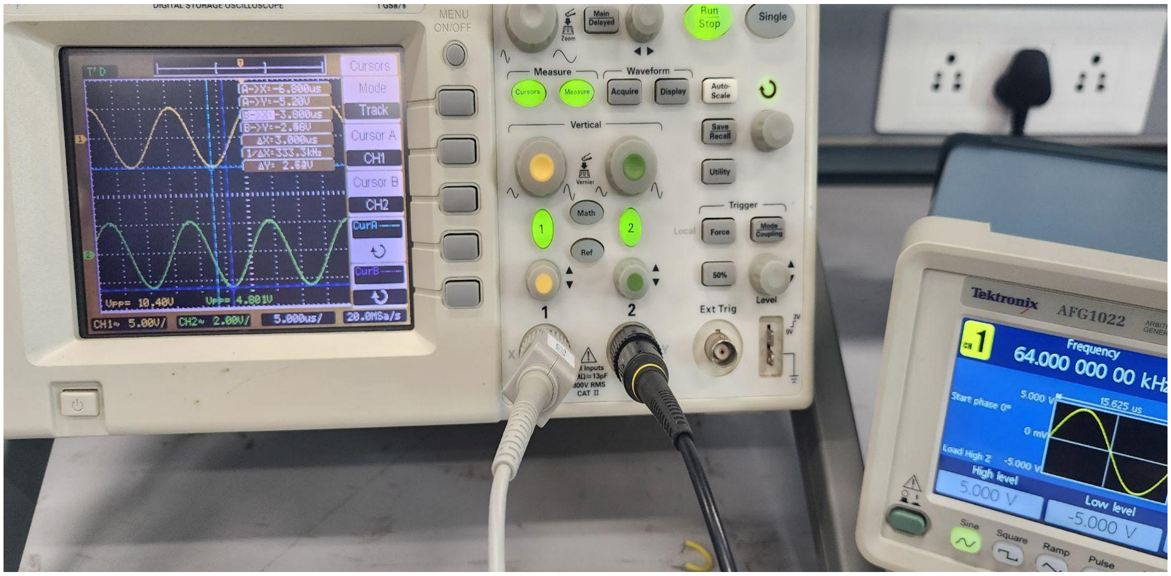


Observations:



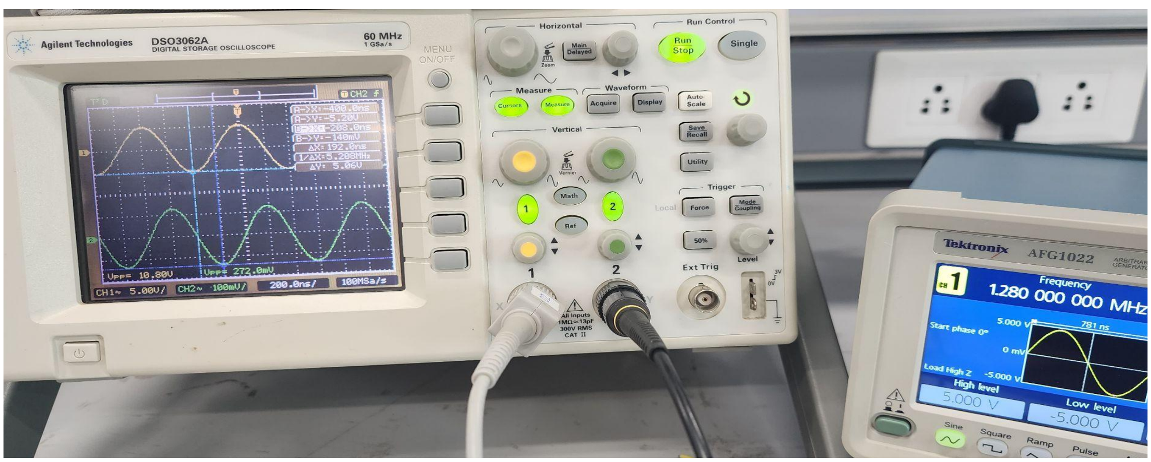
For lower frequency, we observe that

- Experimental gain = 0.3 and LTspice gain = -134.13E-09
- Experimental phase diff. = 0 and LTspice = -2.7E-02



For cutoff frequency, we observe that

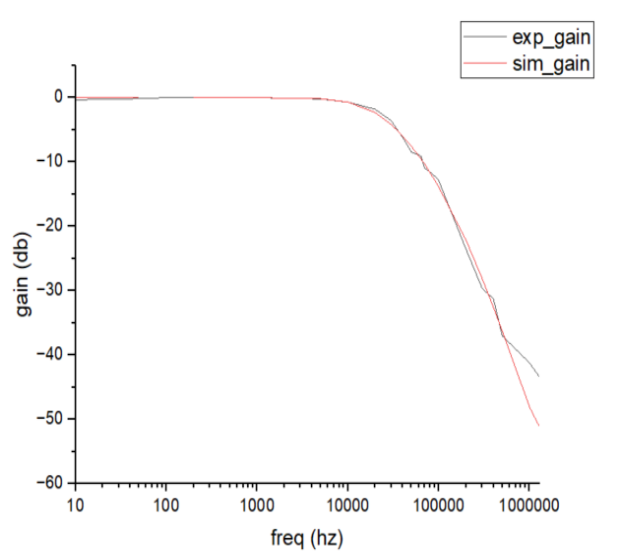
- Experimental gain = -9.18 and LTspice gain = -9.6
- Experimental phase diff. = -94.464 and LTspice = -90.38

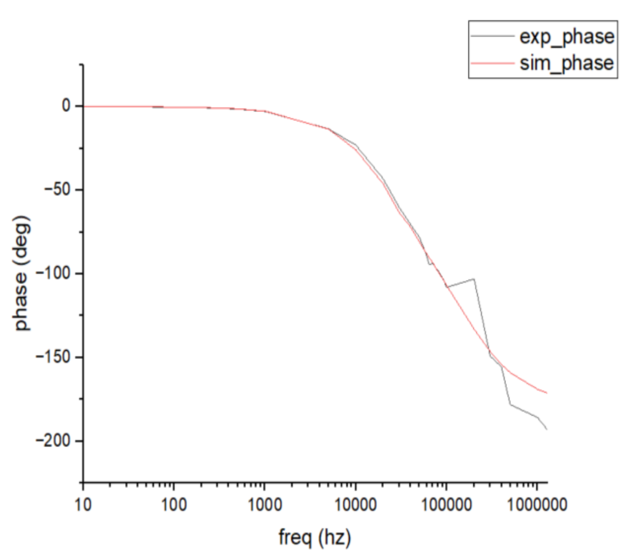


For higher frequency, we observe that

- Experimental gain = -0.272 and LTspice gain = -51.1
- Experimental phase diff. = -193.13 and LTspice = -1.71E+02

	A(X)	B(Y)	C(Y)	D(Y)	E(Y)
Long Name	freq	gain	phase	gain	phase
Units	hz	db	deg	db	deg
Comments		exp_gain	exp_phase	sim_gain	sim_phase
F(x)=					
1	10	-0.35458	-0.02916	0	-0.027
2	50	-0.16866	-0.153	-1.8E-5	-0.135
3	100	0	-0.2988	-74u	-0.27
4	200	0	-0.5832	-2.97E-4	-0.539
5	500	0	-1.44	-0.00186	-1.35
6	1000	0	-2.88	-0.00756	-2.7
7	5000	-0.19808	-13.32	-0.185	-13.4
8	10000	-0.69434	-23.04	-0.696	-25.8
9	20000	-1.81514	-43.2	-2.315	-46.2
10	30000	-3.60292	-60.264	-4.18	-63.2
11	40000	-6.18438	-70.272	-5.95	-72
12	50000	-8.46275	-78.12	-7.58	-80.9
13	60000	-8.90816	-88.992	-9.07	-87.89
14	64000	-9.1868	-94.464	-9.6	-90.38
15	70000	-10.9608	-93.744	-10.3	-93.19
16	80000	-11.55986	-97.92	-11.67	-98.48
17	90000	-12.20331	-102.384	-12.83	-102.86
18	100000	-12.89827	-108	-13.911	-107
19	200000	-23.60416	-102.96	-22.19	-133
20	300000	-29.62476	-149.04	-28.08	-146.23
21	400000	-31.25816	-155.52	-32.6	-154
22	500000	-36.98429	-178	-36.23	-159
23	1000000	-41.23036	-185.8	-48.09	-169
24	1280000	-43.35947	-193.104	-51.1	-171

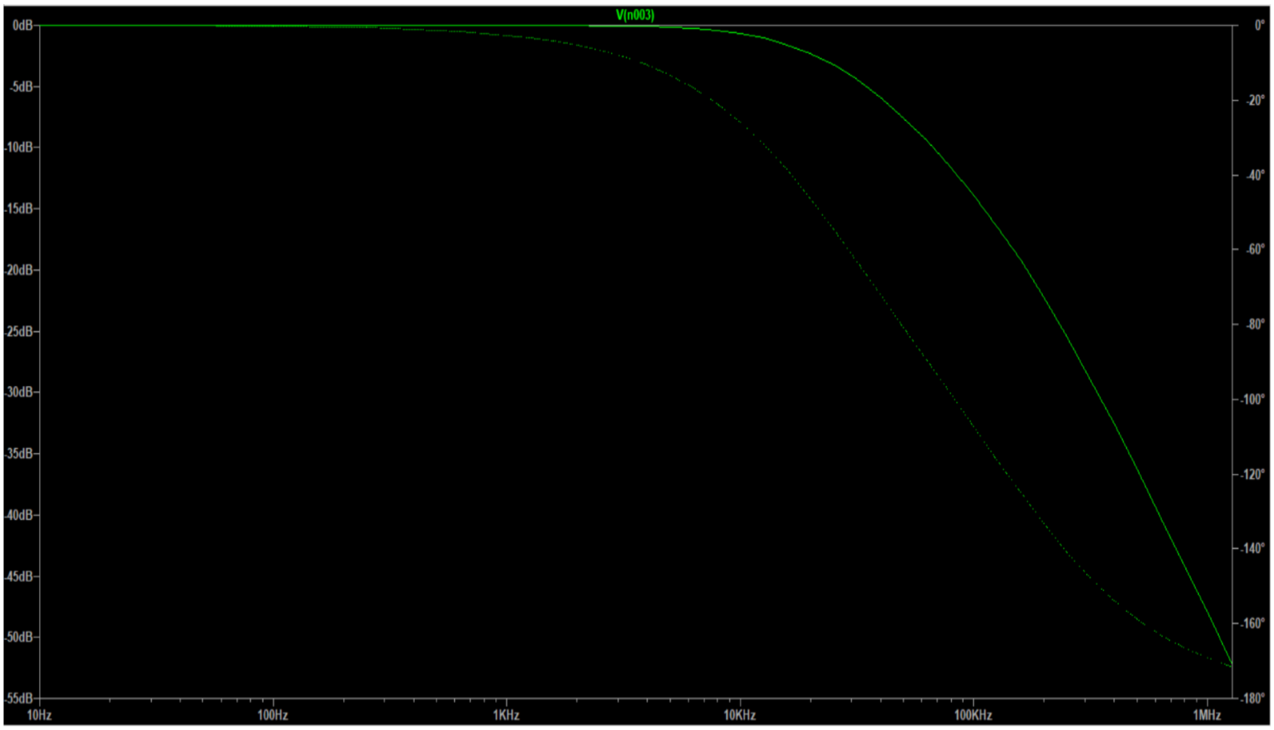




Deviation from experimental and LTspice model,

Simulation:

Graph derived from the LTspice



Experimental Value of R_1,R_2 and C_1,C_2 are 2.5kΩ,2.5kΩ and 1nF,1nF
Tweaked Value of R_1,R_2 and C_1,C_2 are 2.35kΩ,2.91kΩ and 1nF,1nF

Problem 2(a,b):

Aim:

To design a better double stage filter

- Passive corrected filter
- Active corrected filter

Material Required:

capacitors(0.1nF), resistor(25kΩ), multimeter, Oscilloscope and function generator.

Theory:

The primary reason for the difference in cutoff frequency (fc), in practice, between a single and a double-stage filter is due to the characteristics and constraints of the electronic devices used in the filters.

Resistors, capacitors, inductors, etc. have tolerances, and parasitic effects that cause variations in their true values, which affect the behavior of the filter.

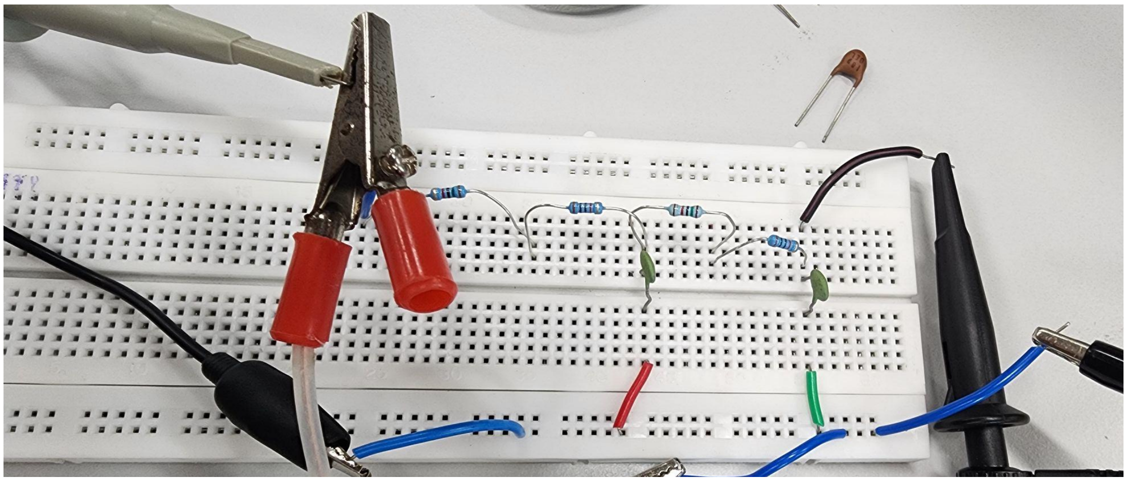
When the filter is in the second stage, the first stage that precedes it actually loads the second stage.

This load introduces resistance and influences the overall performance of a cascaded filter. Because the first stage changes the input impedance and interactions between the stages, it is difficult to isolate the behaviour of the second stage itself.

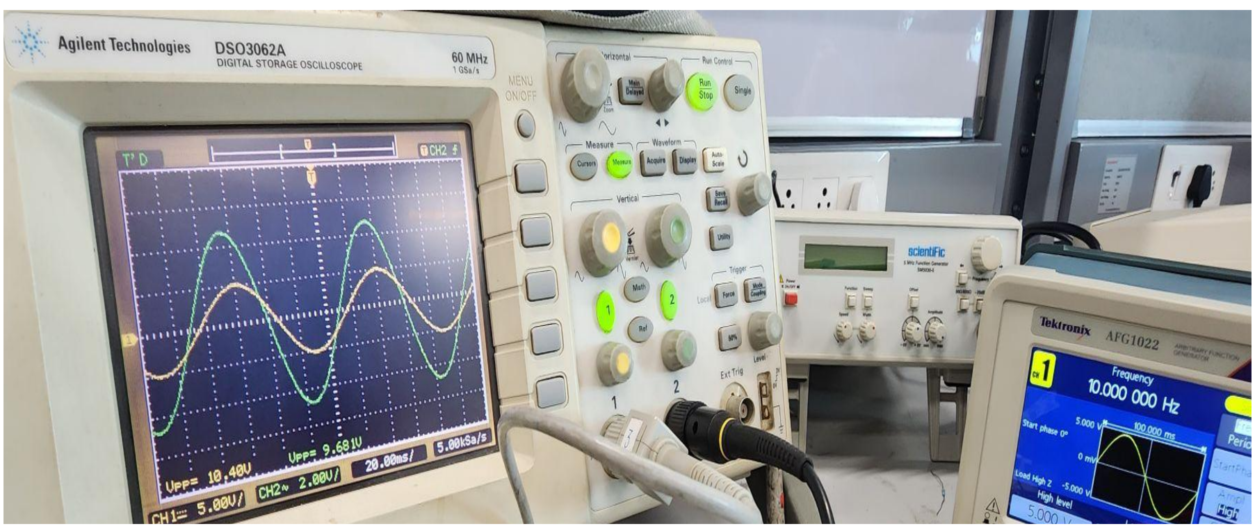
Measurement of the precise phase and gain at the output becomes difficult.

To solve this issue, we design the second stage passive high pass filter. The basic idea behind this filter is to increase the impedance within a cascaded filter configuration. By increasing the output impedance we are effectively increasing the output impedance so that we can measure a more magnified representation of the initial signal. As a result, this improves the gain and allows for more accurate measurements of the cut-off frequency (fc) so that we can better characterize the filter's performance.

Procedure:



Observations:

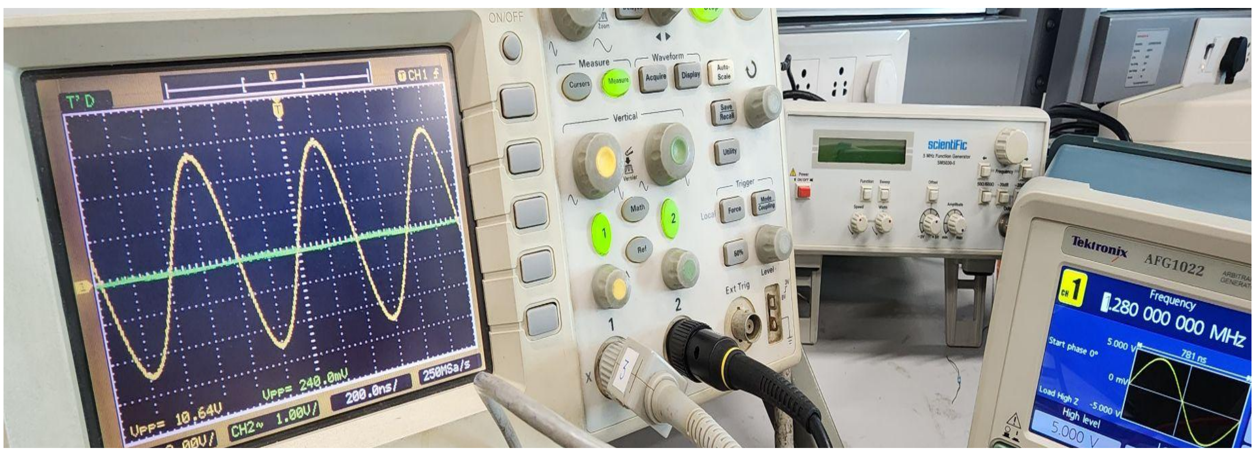


For lower frequency, we observe that

- Experimental gain = 0.3 and LTspice gain =-258E-09
- Experimental phase diff. = 0 and LTspice = -1.89E-02

For cutoff frequency, we observe that

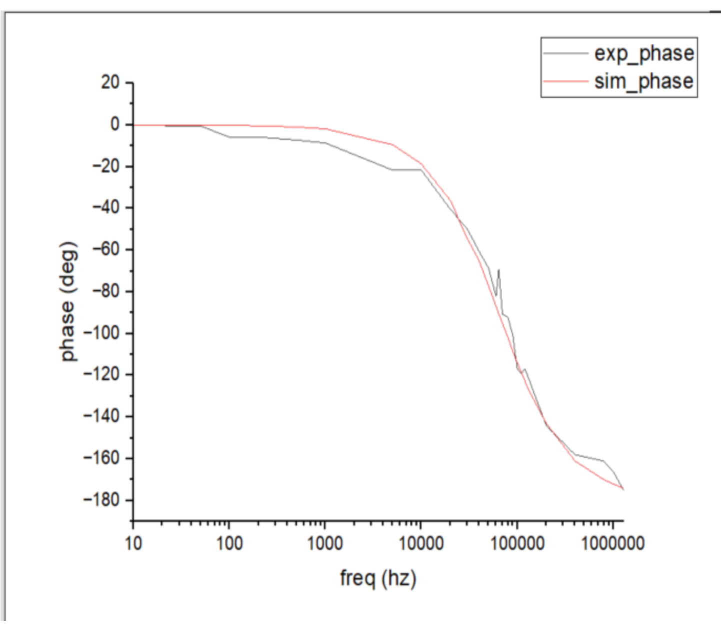
- Experimental gain = -6.429 and LTspice gain = -7.32
- Experimental phase diff. = -9.07E+01and LTspice = -94.98

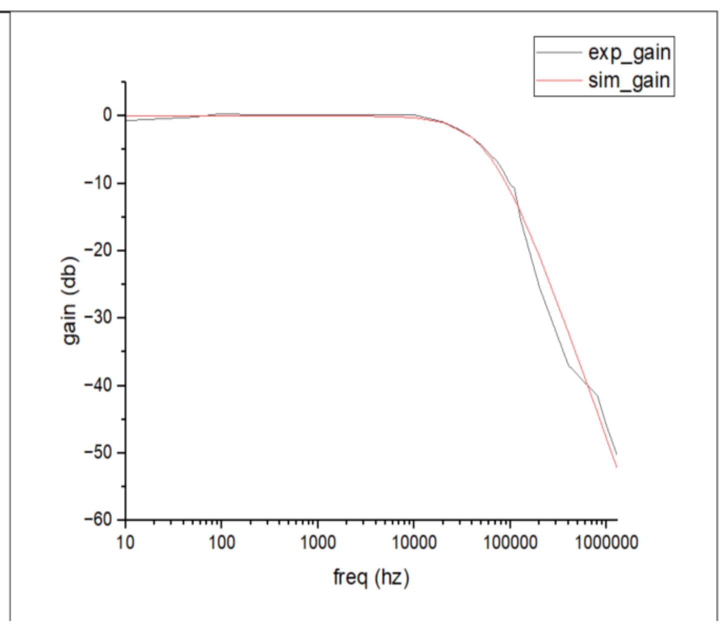


For higher frequency, we observe that

- Experimental gain = -43.69 and LTspice gain = -4.39E+01
- Experimental phase diff. = -1.84E+02 and LTspice = -1.70E+02

	A(X)	B(Y)	C(Y)	D(Y)	E(Y)
Long Name	freq	gain	phase	gain	phase
Units	hz	db	deg	db	deg
Comments		exp_gain	exp_phase	sim_gain	sim_phase
F(x)=					
1	10	-0.69524	-0.144	-2.58E-7	-0.0189
2	50	-0.16866	-0.54	-6.49E-6	-0.0947
3	100	0.32781	-5.76	-2.58E-5	-0.189
4	200	0.16545	-5.76	-1.03E-4	-0.377
5	500	0.16545	-7.2	-6.49E-4	-0.947
6	1000	0.16545	-8.64	-0.00258	-1.89
7	5000	0.16545	-21.6	-0.0646	-9.45
8	10000	0.16545	-21.6	-0.253	-18.7
9	20000	-0.87719	-40.3	-0.957	-36.1
10	30000	-2.06333	-49.7	-2.19	-54.2
11	40000	-3.19281	-60.5	-3.21	-65.1
12	50000	-4.32495	-68.4	-4.59	-77
13	60000	-5.50031	-82.1	-5.998	-86.92785
14	64000	-6.01893	-69.1	-6.492	-90.5082
15	70000	-6.42928	-90.7	-7.32	-94.98919
16	80000	-7.62898	-92.2	-8.69	-102
17	90000	-8.92747	-101	-9.987	-108.60398
18	100000	-10.23495	-117	-11.2	-114
19	110000	-10.68034	-119	-12.368	-118.5388
20	120000	-13.33183	-117	-13.433	-122.50248
21	128000	-15.42548	-120	-14.309	-125.95298
22	200000	-25.37691	-144	-20.8	-143
23	400000	-36.93543	-158	-32.1	-161
24	800000	-41.45101	-161	-43.9	-170
25	1000000	-46.0206	-166	-47.9	-172
26	1280000	-50.23767	-175	-52.2	-174

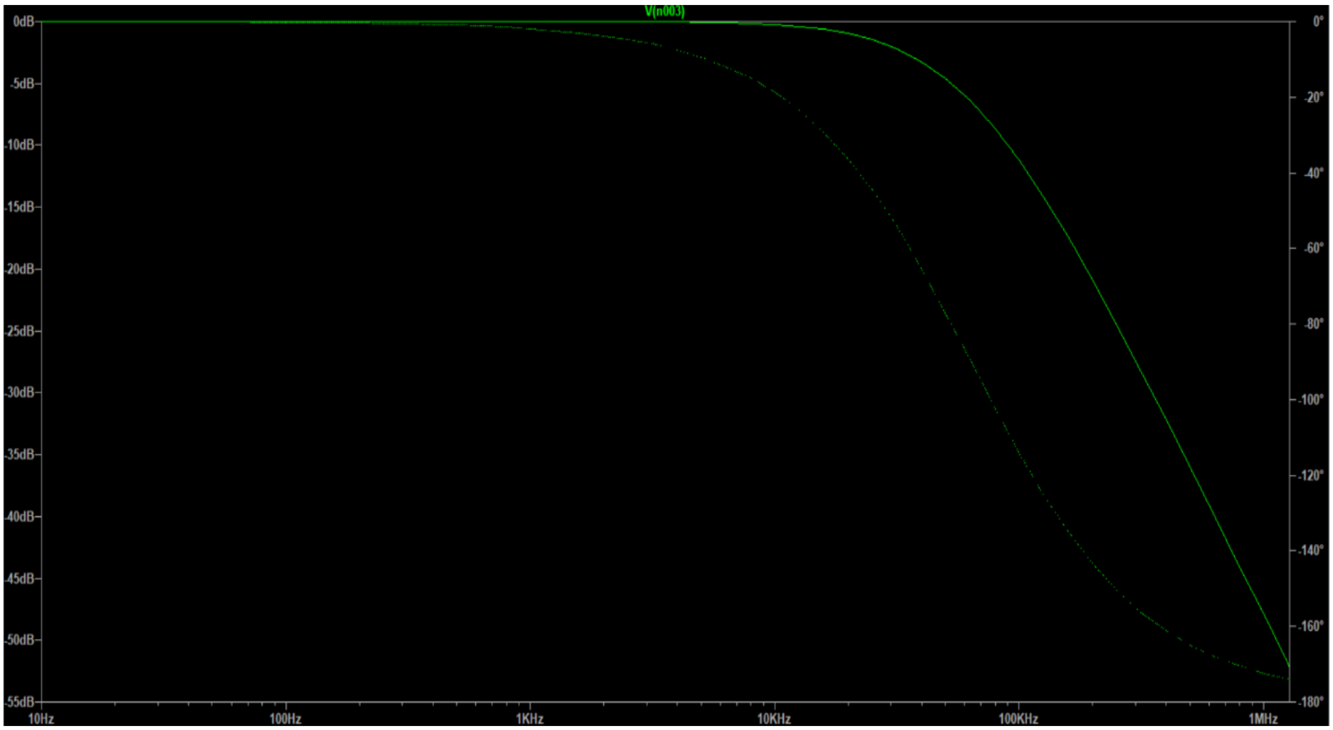




Deviation from experimental and LTspice model,

Simulation:

Graph derived from LTspice model



Problem 2(c):

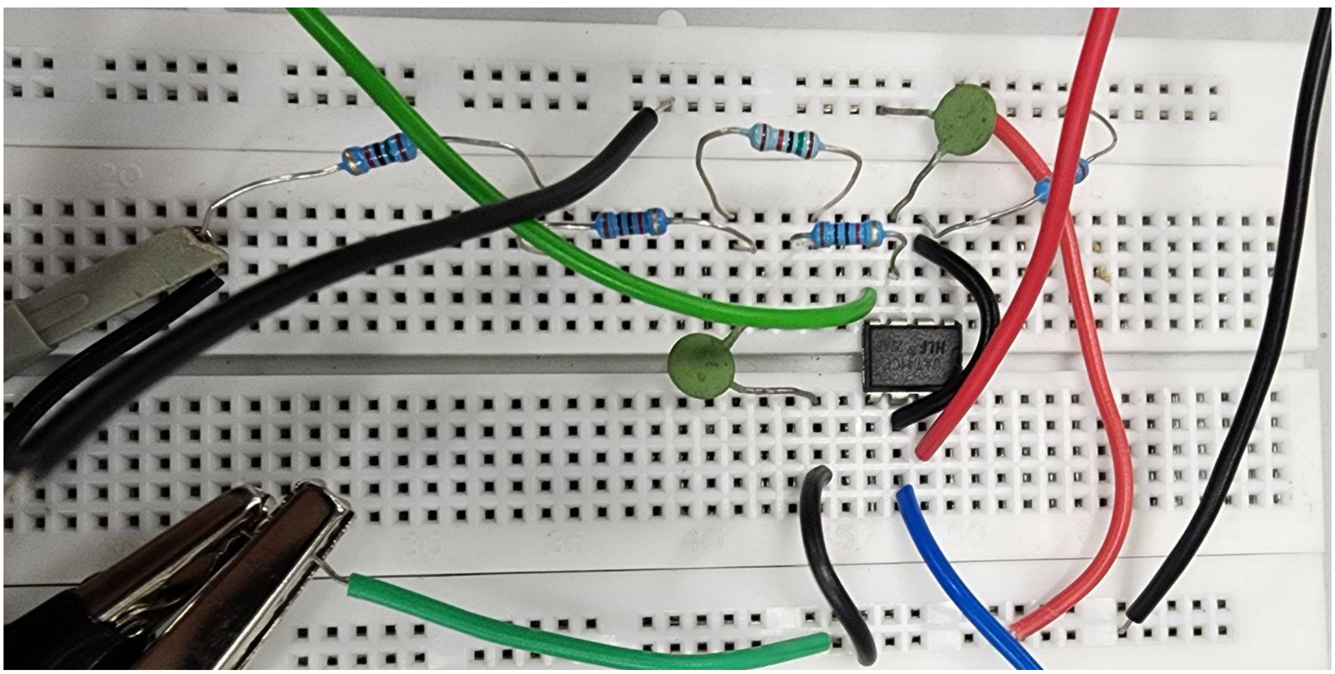
Aim:

To design an active low pass filter.

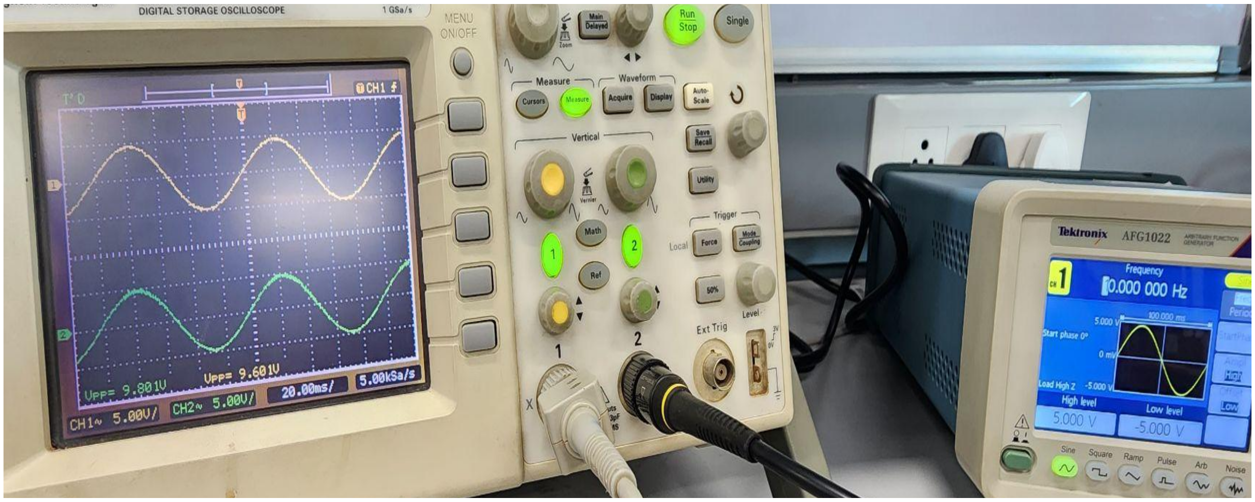
Material Required:

25kΩ resistor ,0.1nF capacitor, multimeter, breadboard, wires, function generator, oscilloscope.

Procedure:

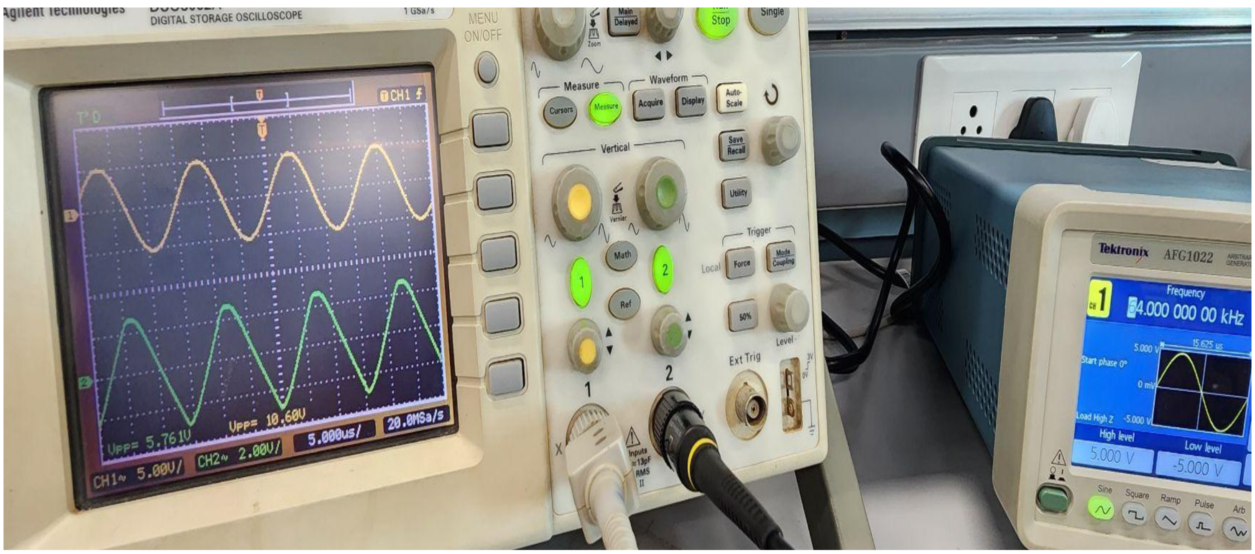


Obeservations



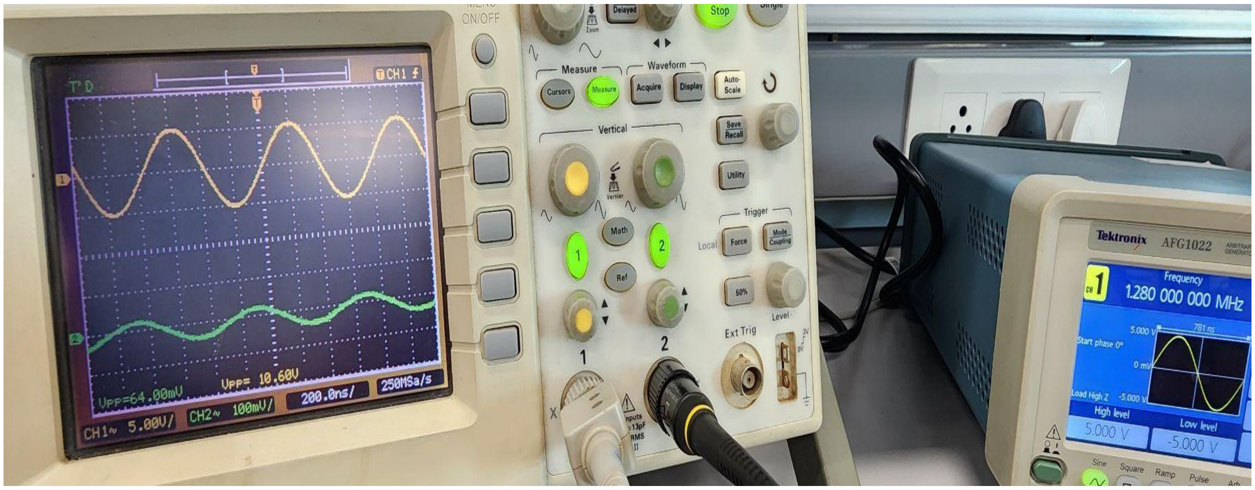
For lower frequency, we observe that

- Experimental gain = -0.179 and LTspice gain = 2.50E-04
- Experimental phase diff. = 0 and LTspice = -1.86E-02



For higher frequency, we observe that

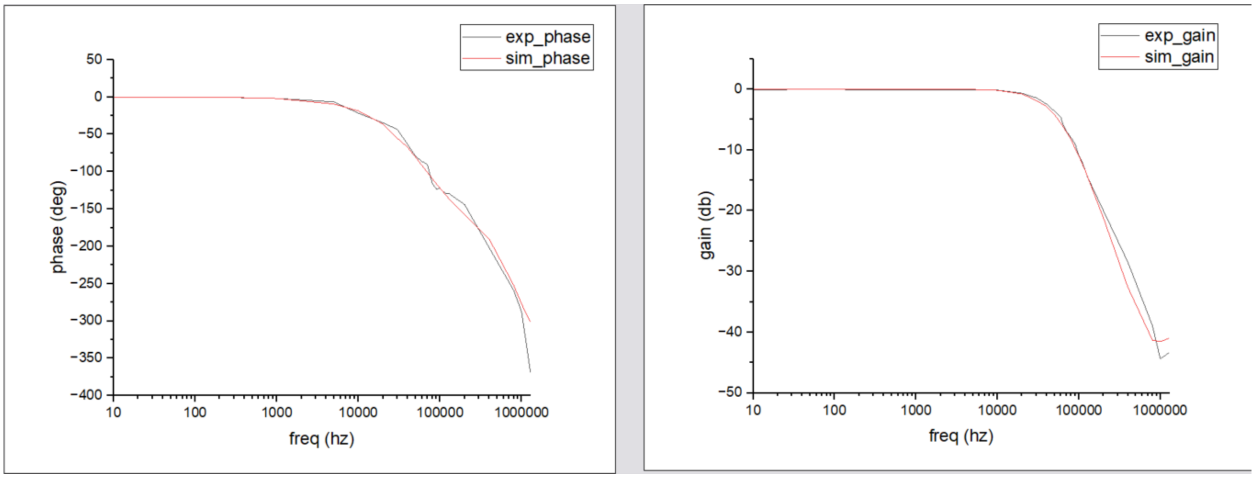
- Experimental gain = -5.858 and LTspice gain = -6.182
- Experimental phase diff. = -87.552 and LTspice = -95.647



For higher frequency, we observe that

- Experimental gain = -44.382and LTspice gain = -4.10E+01
- Experimental phase diff. = -368.64 and LTspice = -301.293

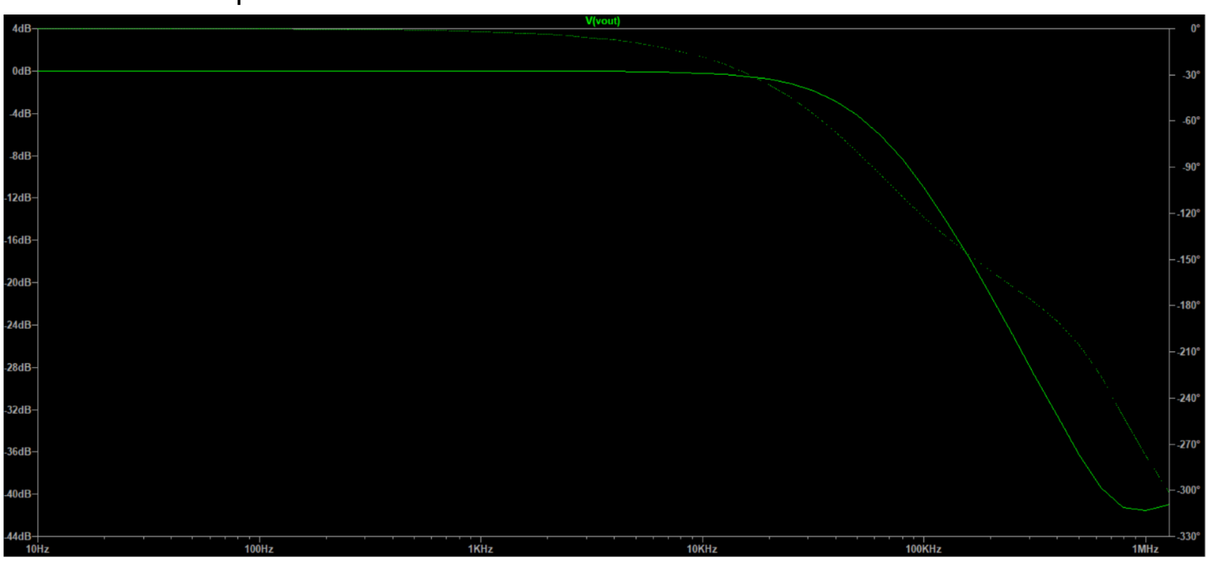
	A(X)	B(Y)	C(Y)	D(Y)	E(Y)
Long Name	freq	gain	phase	gain	phase
Units	hz	db	deg	db	deg
Comments		exp_gain	exp_phase	sim_gain	sim_phase
F(x)=					
1	10	-0.1791	0	2.5E-4	-0.0186
2	50	0	-0.036	2.45E-4	-0.0933
3	100	0	-0.1152	2.3E-4	-0.186
4	200	-0.16545	-0.2448	1.69E-4	-0.371
5	500	-0.16545	-1.08	-2.66E-4	-0.933
6	1000	-0.16545	-1.872	-0.00181	-1.86
7	5000	-0.16545	-6.48	-0.0513	-9.31
8	10000	-0.16545	-21.6	-0.204	-18.5
9	20000	-0.6816	-34.56	-0.79	-36.2
10	30000	-1.42127	-43.2	-1.88	-55.2
11	40000	-2.44432	-63.36	-2.84	-67.1
12	50000	-3.60416	-79.2	-4.19	-80.4
13	60000	-4.60243	-86.4	-5.624	-91.588
14	64000	-5.85824	-87.552	-6.182	-95.647
15	70000	-6.88129	-90.72	-7.003	-100.748
16	80000	-7.9588	-115.2	-8.29	-109
17	90000	-9.00236	-123.12	-9.789	-116.23
18	100000	-10.9608	-122.4	-11	-122
19	110000	-12.00522	-126.72	-12.31	-127.611
20	120000	-13.42011	-129.6	-13.43	-132.613
21	128000	-14.48118	-129.024	-14.46	-135.731
22	200000	-19.99181	-144	-21.2	-157
23	400000	-28.46492	-201.6	-32.6	-190.049
24	800000	-38.92249	-259.2	-41.3	-252.306
25	1000000	-44.38252	-288	-41.5	-277.432
26	1280000	-43.35947	-368.64	-41	-301.293



Deviation from experimental and LTspice model

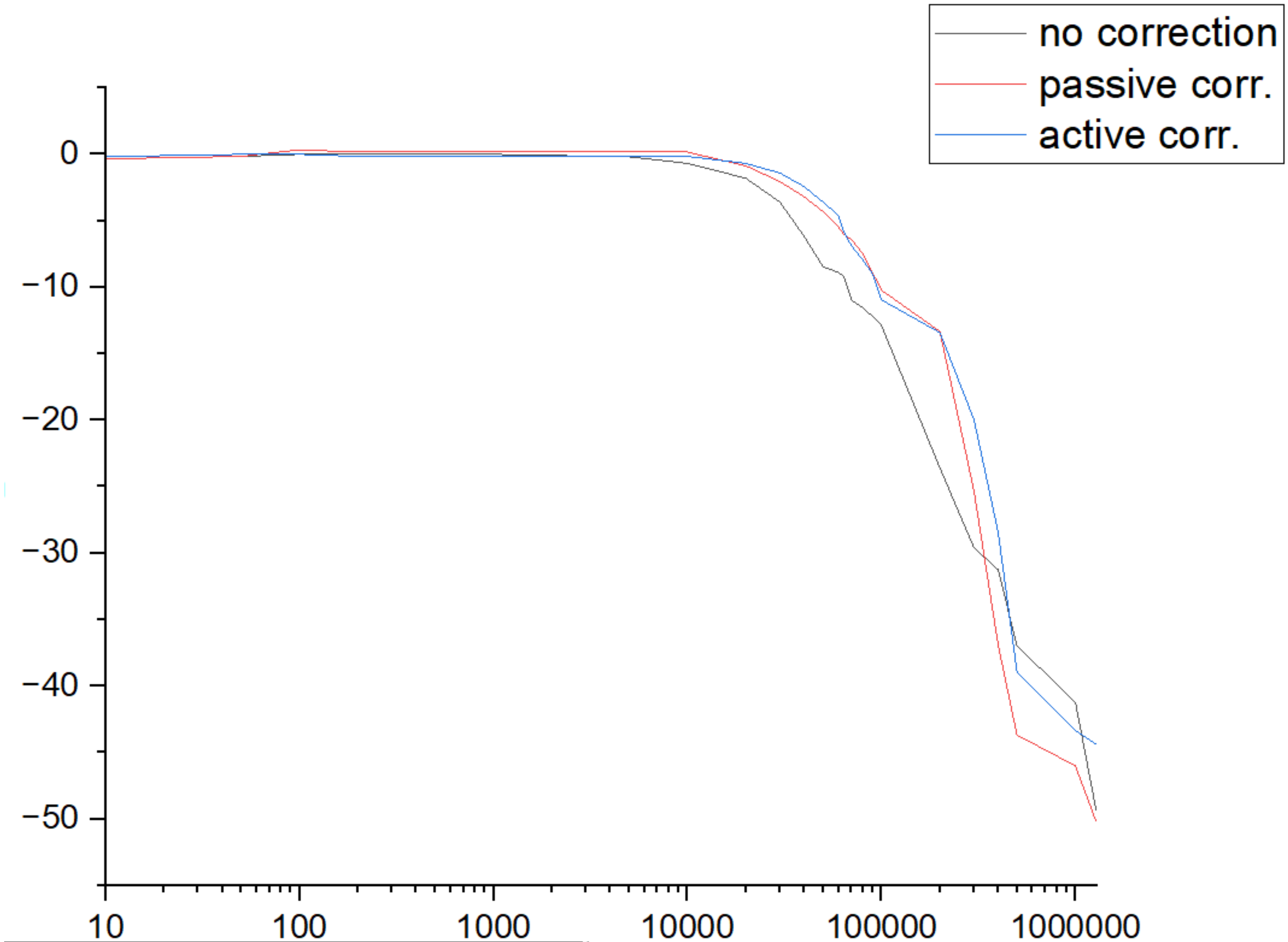
Simulation:

Graph derived from LTspice model



Problem 2d:

	A(X)	B(Y)	C(Y)	D(Y)
Long Name				
Units				
Comments		no correctio	passive corr	active corr.
F(x)=				
1	10	-0.35458	-0.35458	-0.1791
2	50	-0.16866	-0.16866	0
3	100	0	0.32781	0
4	200	0	0.16545	-0.16545
5	500	0	0.16545	-0.16545
6	1000	0	0.16545	-0.16545
7	5000	-0.19808	0.16545	-0.16545
8	10000	-0.69434	0.16545	-0.16545
9	20000	-1.81514	-0.87719	-0.6816
10	30000	-3.60292	-2.06333	-1.42127
11	40000	-6.18438	-3.19281	-2.44432
12	50000	-8.46275	-4.32495	-3.60416
13	60000	-8.90816	-5.50031	-4.60243
14	64000	-9.1868	-6.01893	-5.85824
15	70000	-10.9608	-6.42928	-6.88129
16	80000	-11.55986	-7.46964	-7.9588
17	90000	-12.20331	-8.92747	-9.00236
18	100000	-12.89827	-10.23495	-10.9608
19	200000	-23.60416	-13.33183	-13.42011
20	300000	-29.62476	-25.37691	-19.99181
21	400000	-31.25816	-36.93543	-28.46492
22	500000	-36.98429	-43.69049	-38.92249
23	1000000	-41.23036	-46.0206	-43.35947
24	1280000	-49.38007	-50.23767	-44.38252



Problem 3:

Aim:

To design band pass LC filter with lower cut off frequency equal 5khz and higher cut off frequency equal 250khz.

Material Required:

Breadboard, Resistor(19.6kΩ), capacitor(2.2nF), inductor(4mH), multimeter, Oscilloscope and function generator

Theory:

A bandpass filter is a type of electronic circuit that uses a combination of capacitors and inductors to selectively filter out certain frequencies while allowing others to pass through.
In this experiment, we have to create a bandpass filter with a lower cutoff frequency () of 5 kHz and a higher cutoff frequency () of 250 kHz.
f_l= 7 kHz and f_h= 350 kHz.
To determine the necessary values for the resistance (R), capacitance (C), and inductance (L) in the circuit, we need to solve two equations,

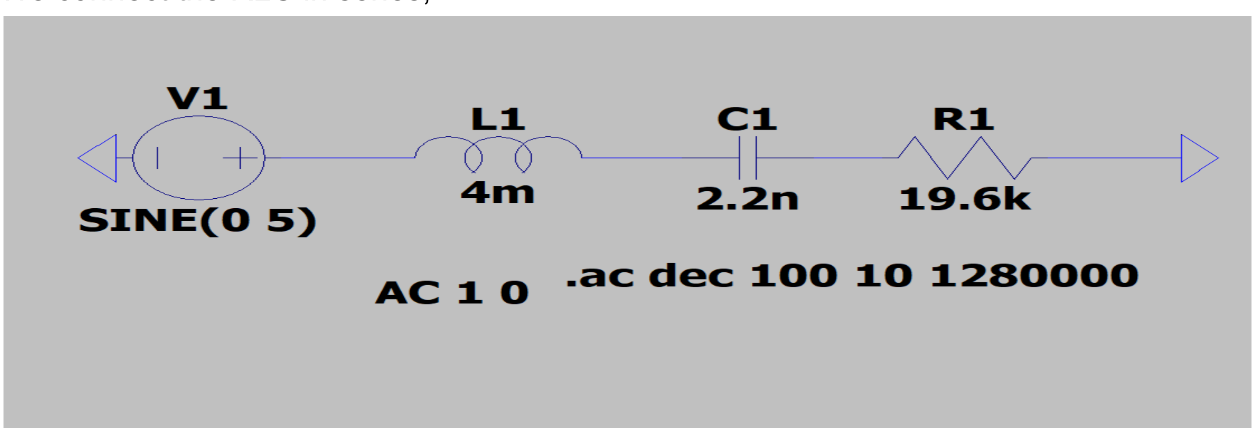
$$2\pi f_l = -\frac{R}{2L} + \sqrt{\left(\frac{R}{2L}\right)^2 + \frac{1}{LC}}$$

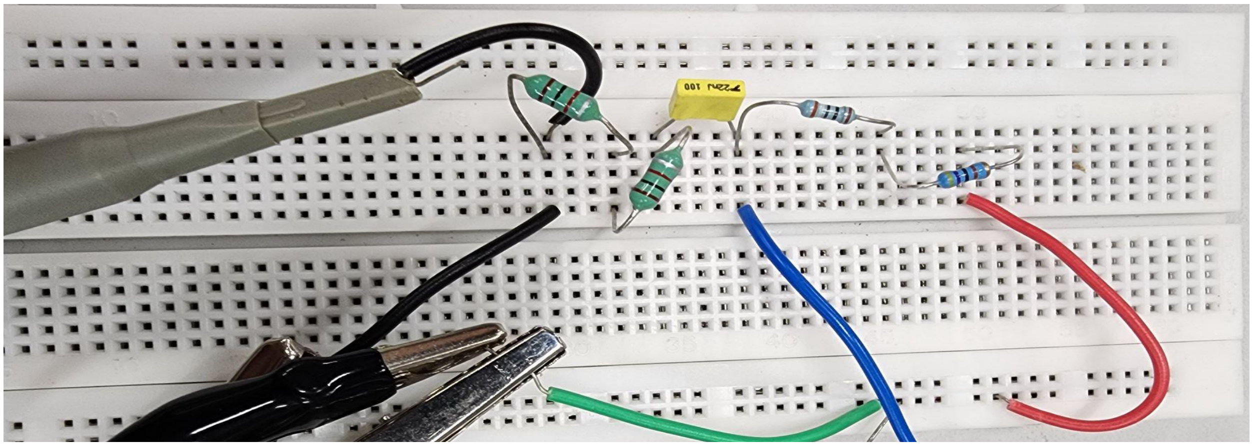
$$2\pi f_h = \frac{R}{2L} + \sqrt{\left(\frac{R}{2L}\right)^2 + \frac{1}{LC}}$$

By solving the above two equations, we get,
L = 4 mH, C = 0.5 nF and R = 19.6kΩ.
And, centre frequency = $\sqrt{f_l * f_h}$ = 35kHz

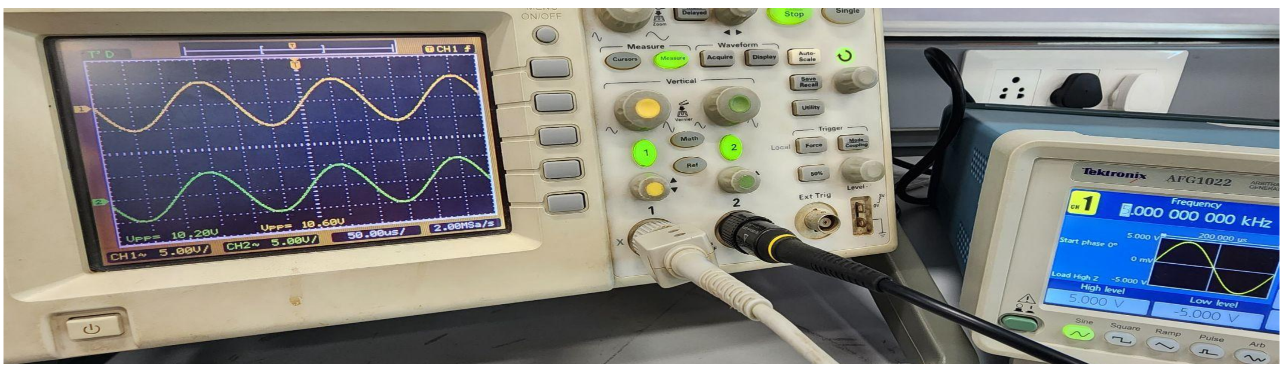
Procedure:

We connect the RLC in series,



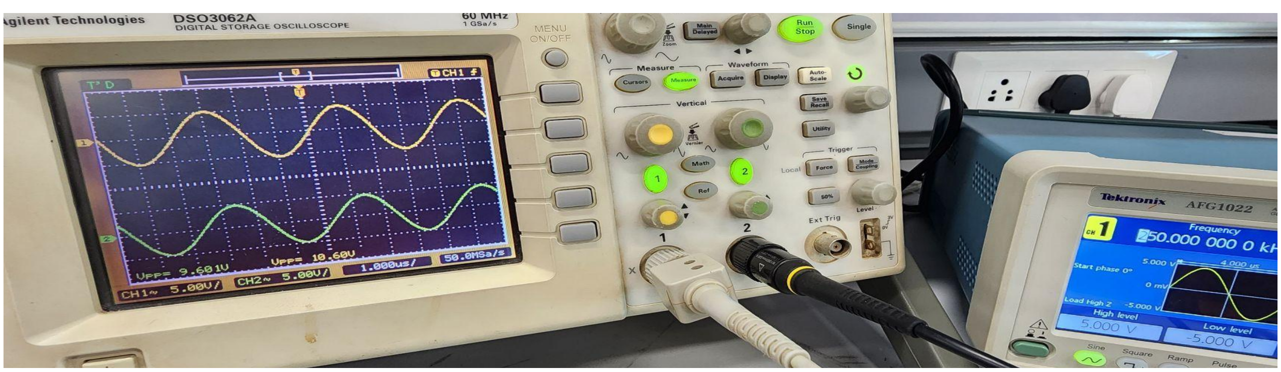


Observations:



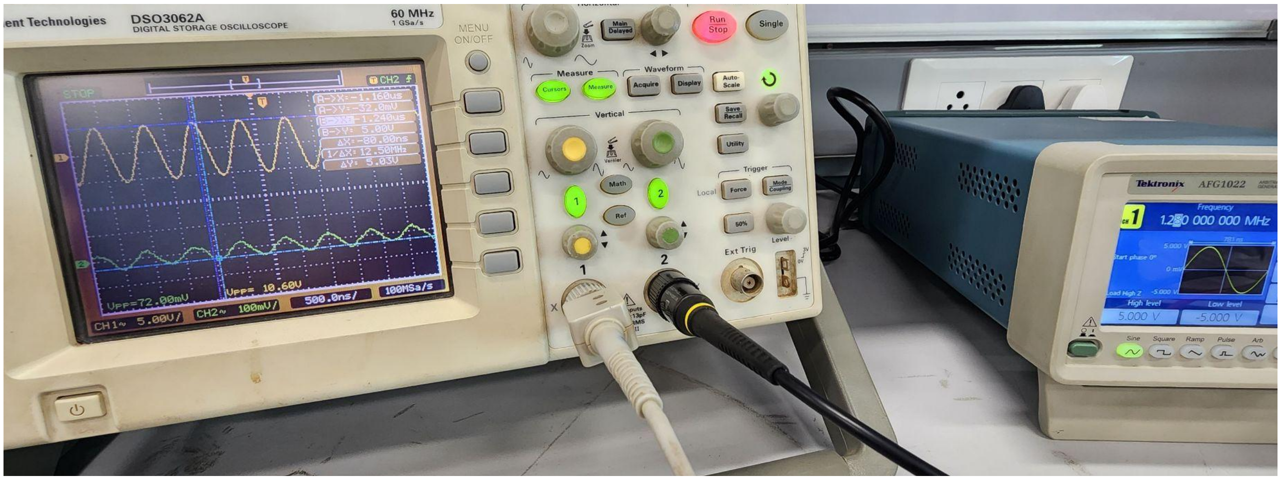
For lower frequency, we observe that

- Experimental gain = -0.368 and LTspice gain = -134.13E-09
- Experimental phase diff. = 0 and LTspice = -2.7E-02



For cutoff frequency, we observe that

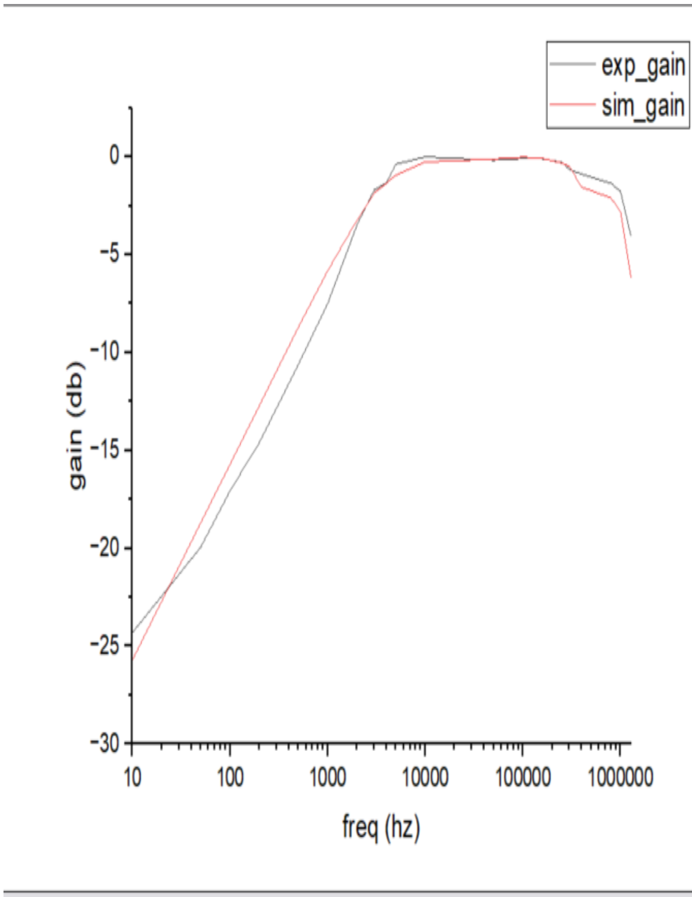
- Experimental gain = -0.137 and LTspice gain = -0.102
- Experimental phase diff. = 0.41 and LTspice = -0.357

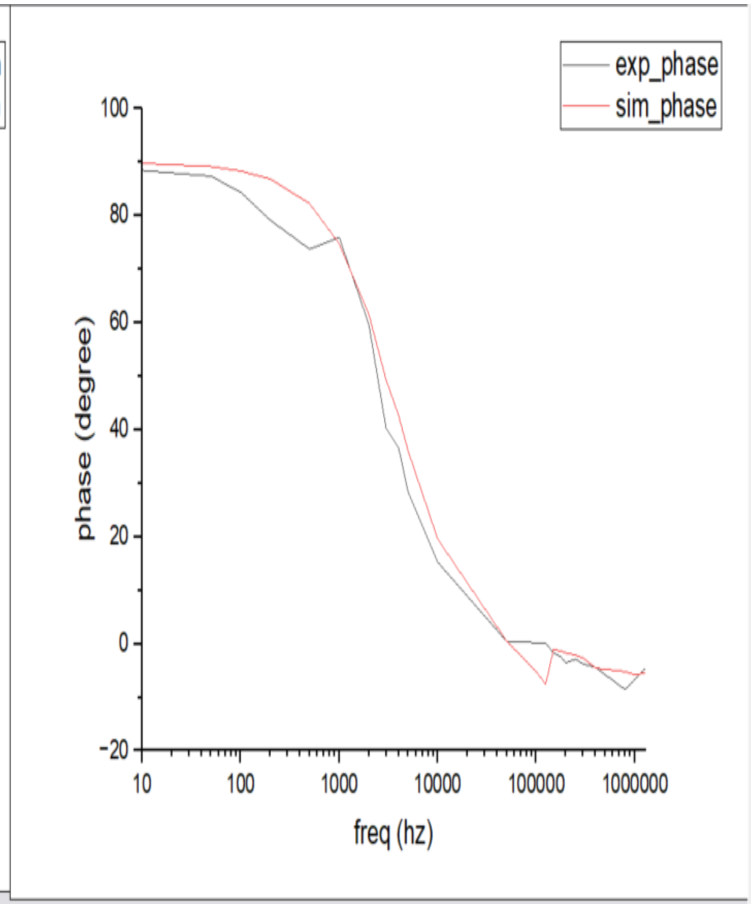


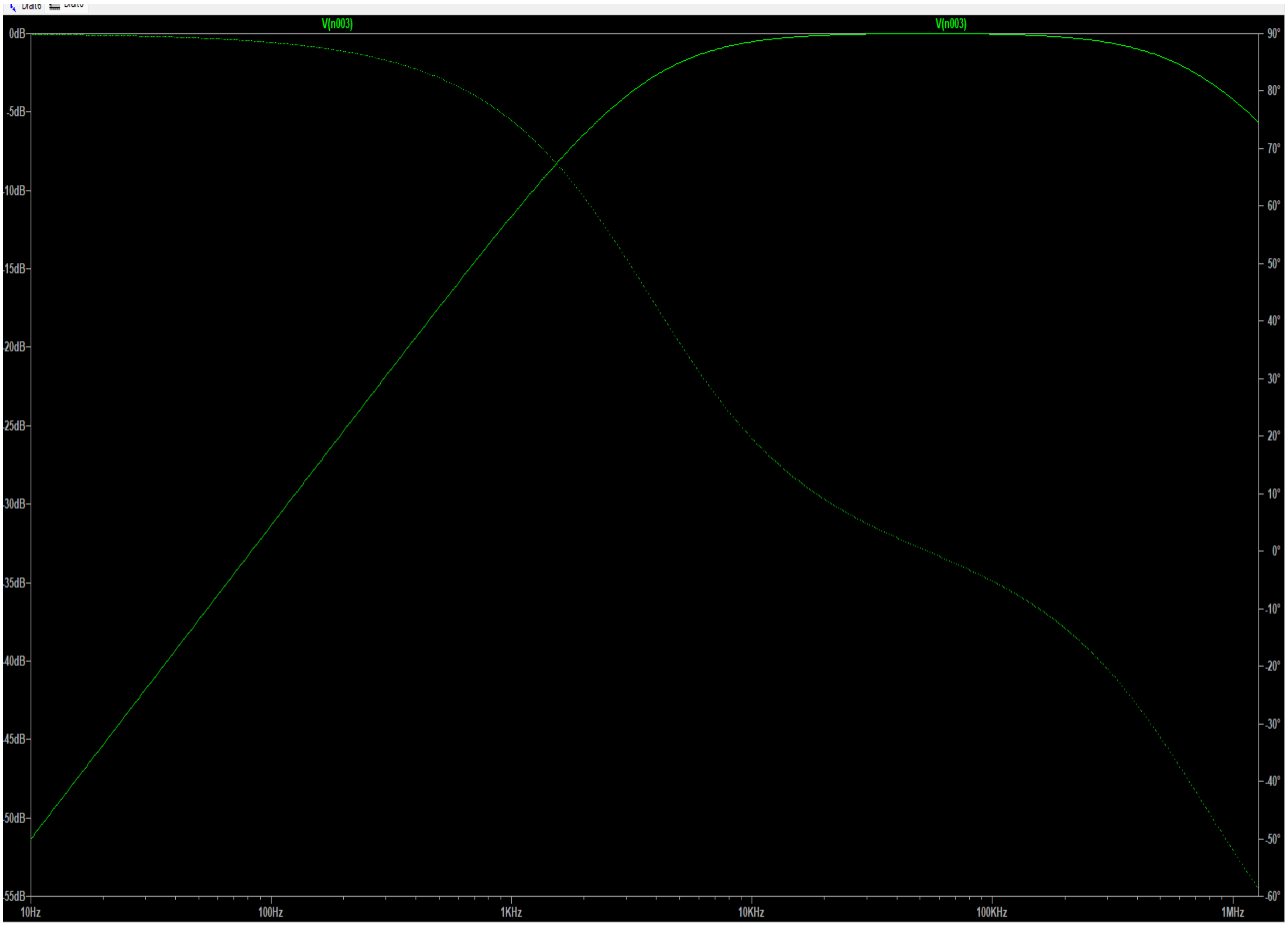
For higher frequency, we observe that

- Experimental gain = -4.03 and LTspice gain = -6.16
- Experimental phase diff. = -4.608 and LTspice = -5.43

	A(X)	B(Y)	C(Y)	D(Y)	E(Y)
Long Name	freq	gain	phase	gain	phase
Units	hz	db	degree	db	deg
Comments		exp_gain	exp_phase	sim_gain	sim_phase
F(x)=					
1	10	-24.29947	88.5	-25.7	89.8
2	50	-19.94309	87.4	-18.7	89.2
3	100	-17.0522	84.4	-15.7	88.4
4	200	-14.58356	79.2	-12.7	86.9
5	500	-10.6095	73.8	-8.71	82.3
6	1000	-7.49283	76	-5.82	74.8
7	2000	-3.48203	59.71	-3.22	61.6
8	3000	-1.69524	40.24	-1.86	49.3
9	4000	-1.31615	36.67	-1.34	42.7
10	5000	-0.36866	28.34	-0.928	36.1
11	10000	0	15.28	-0.259	19.6
12	50000	-0.16545	0.46	-0.116	0.537
13	100000	-0.08273	0.22	-0.018	-5.22
14	125000	-0.03341	0.17	-0.0376	-7.53
15	150000	-0.08433	-1.73	-0.0692	-1.02
16	175000	-0.11735	-2.34	-0.119	-1.34
17	200000	-0.20157	-3.52	-0.196	-1.71
18	250000	-0.27059	-2.89	-0.313	-2.15
19	300000	-0.64859	-3.76	-0.487	-2.66
20	400000	-0.87641	-4.43	-1.54	-4.54
21	800000	-1.3575	-8.56	-2.1	-5.2
22	1000000	-1.74961	-6.61	-2.78	-5.82
23	1280000	-4.03158	-4.608	-6.16	-5.43


exp_gain
sim_gain
gain (db)
0
-5
-10
-15
-20
-25
-30
10
100
1000
10000
100000
1000000
freq (hz)


exp_phase
sim_phase
phase (degree)
100
80
60
40
20
0
-20
10
100
1000
10000
100000
1000000
freq (hz)



Experimental Value of R,L and C are kΩ ,0.5nF and 4mH
Tweaked Value of R, L and C are 19.6kΩ, 2.2nF and 4mH