Lab Report

Lab Session-6

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Experiment 1:

AIM:

To create a high pass filter sallen-key second order filters. Also, to plot a bode plot of the frequency response on semi-log paper

COMPONENTS:

Resistors(10K), Capacitors(1n), Function Generator, Oscilloscope, Breadboard, wires, DC bench power supply, IC -LM741 - 1

THEORY:

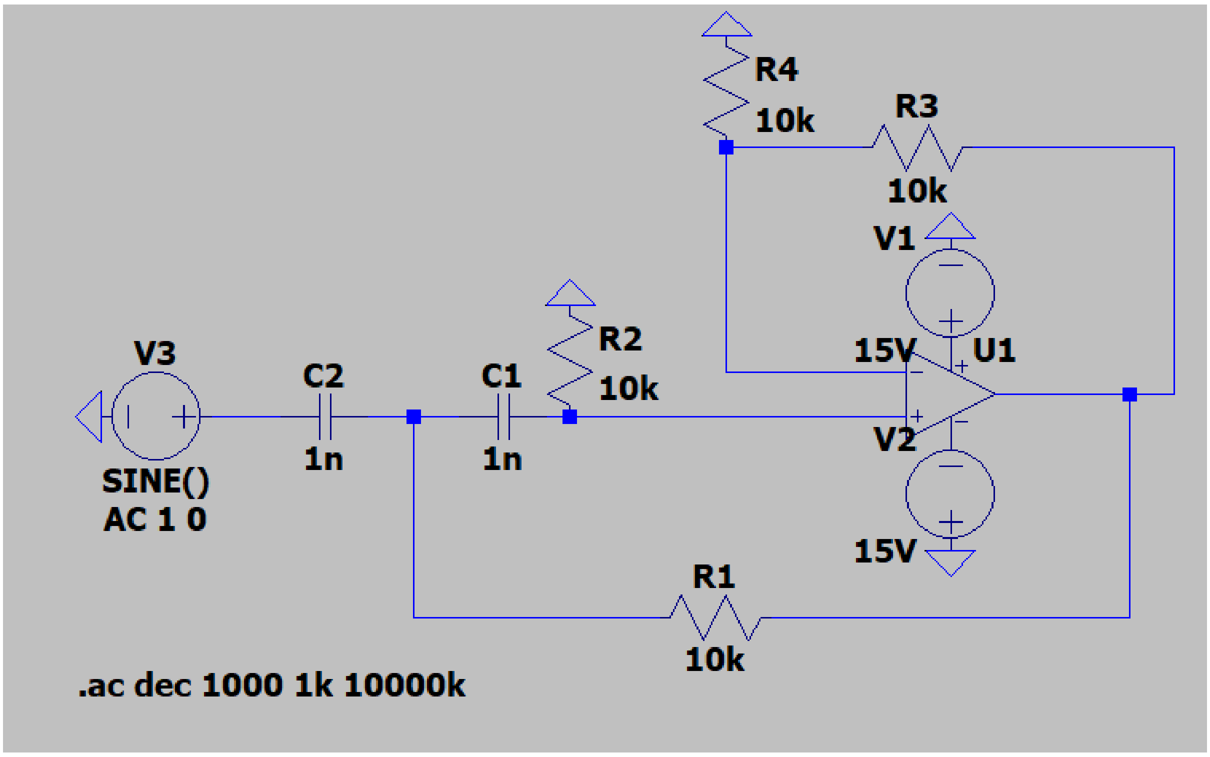
A high-pass filter is an electronic filter that passes signals with a frequency higher than a certain cut-off frequency and attenuates or blocks signals with frequencies lower than the cut-off frequency.

A Basic passive filter is created by using RC. But here, the output amplitude will always be less than the input, so it can never be greater than unity. Also, the external loading of the output by more RC stages or circuits will have an affect on the filter’s characteristics. One way to overcome this problem is to convert the passive RC filter into an “Active RC Filter” by adding an operational amplifier to the basic RC configuration.

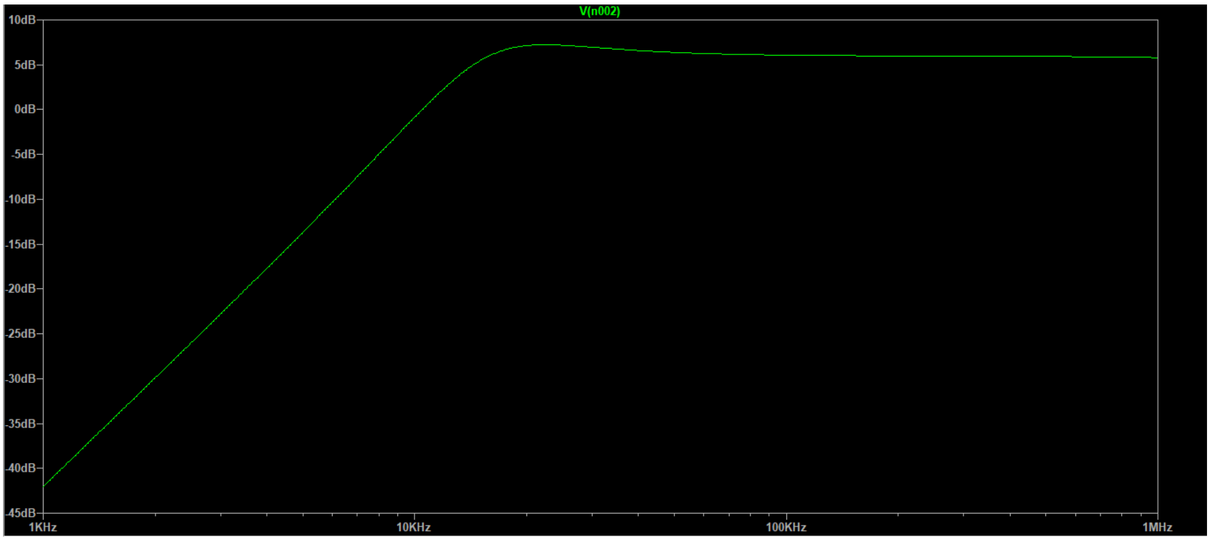
By adding an operational amplifier, the basic RC filter can be designed to provide a required amount of voltage gain at its output, thus changing the filter from an attenuator to an amplifier. Also, the high input impedance and low output impedance of an operational amplifier prevents external loading of the filter, allowing it to be easily adjusted over a wide frequency range without altering the designed frequency response.

By adding a second RC filter stage, we can convert the circuit into a second-order high-pass filter. Cascading one RC filter stage with another (identical or different RC values), does not work very well because each successive stage loads the previous one and when more RC stages are added, the cut-off frequency point moves further away from the designed or required frequency. One simple way to cascade together RC filter stages which do not interact or load each other to create higher-order filters (individual filter sections need not be identical) which can be easily tuned and designed to provide required voltage gain is to use *Sallen-key Filter* .

Sallen-Key is one of the most common filter configurations for designing first-order (1^{st}-order) and second-order (2^{nd}-order) filters and as such, is used as the basic building blocks for creating higher-order filters. The first-order/second order or low-pass/high pass sallen-key filters can easily be cascaded together.



The LTSpice circuit of the sallen key high pass filter.



The LTSpice simulation model of the sallen key high pass filter.

The passive components C_1, R_1, C_2 and R_2 form the second-order frequency-selective circuit.

Thus, at low frequencies, capacitors C_1 and C_2 appear as open circuits, so the input signal is blocked resulting in no output. At higher frequencies, C_1 and C_2 appear to the sinusoidal input signal as short circuits, so the signal is buffered directly to the output.

Sallen-key Cut-off frequency equation

$$f_c = \frac{1}{2\pi\sqrt{R1R2C1C2}}$$

If the two capacitors are made equal(C1=C2=C) and the two resistors are equal (R1=R2=R) , then the above equation simplifies to:

$$f_c = \frac{1}{2\pi\sqrt{RC}}$$

Procedure

We set up the circuit onto the breadboard by using the above circuit (the LTSpice circuit).

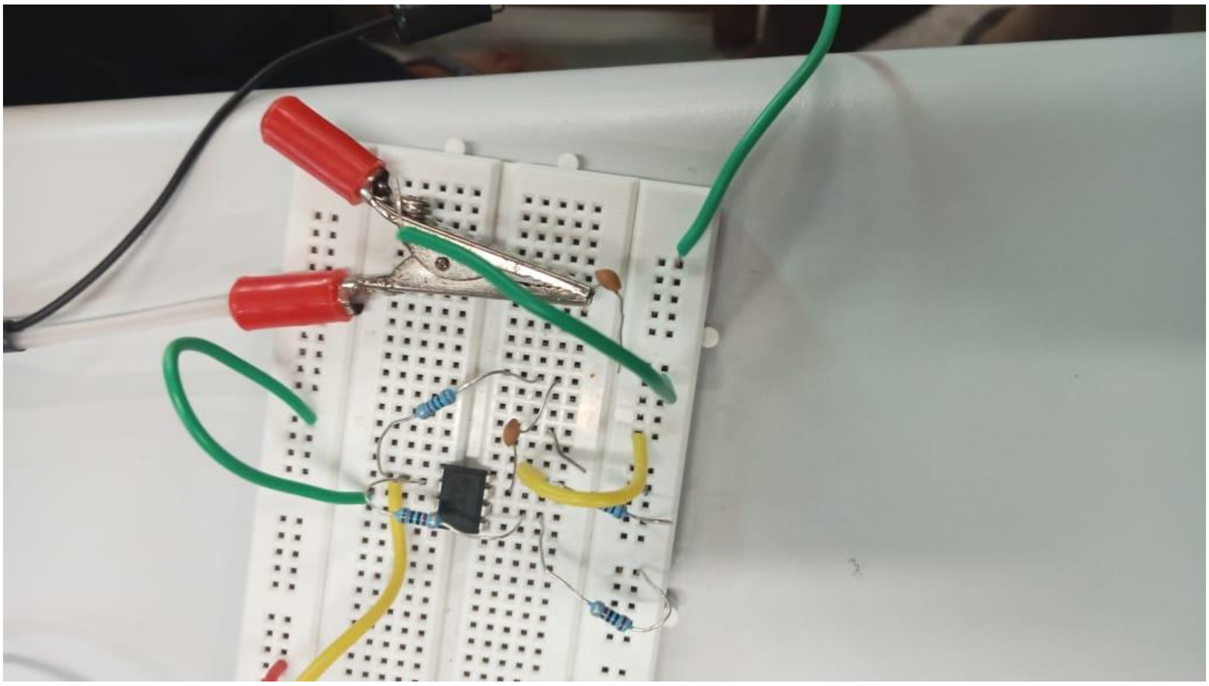
We give an input sinusoidal waveform using the function generator.2 Capacitors(1nF) and 2 resistors(10k) are wired as shown in the circuit diagram. We power the IC using a DC bench power supply. The IC is powered with 15V supply.

Pin 2 and Pin 6 are connected so to create a feedback loop.

The oscilloscope probe is connected to pin 6 to see the output and the other oscilloscope is connected to the outer leg of C2 to see the input waveform.

We set one of the side rails to a common ground. Then the DC Power bench supply is switched and we see the output on the oscilloscope.

To get the readings we note down the input and output voltages obtained when we change the frequency values.

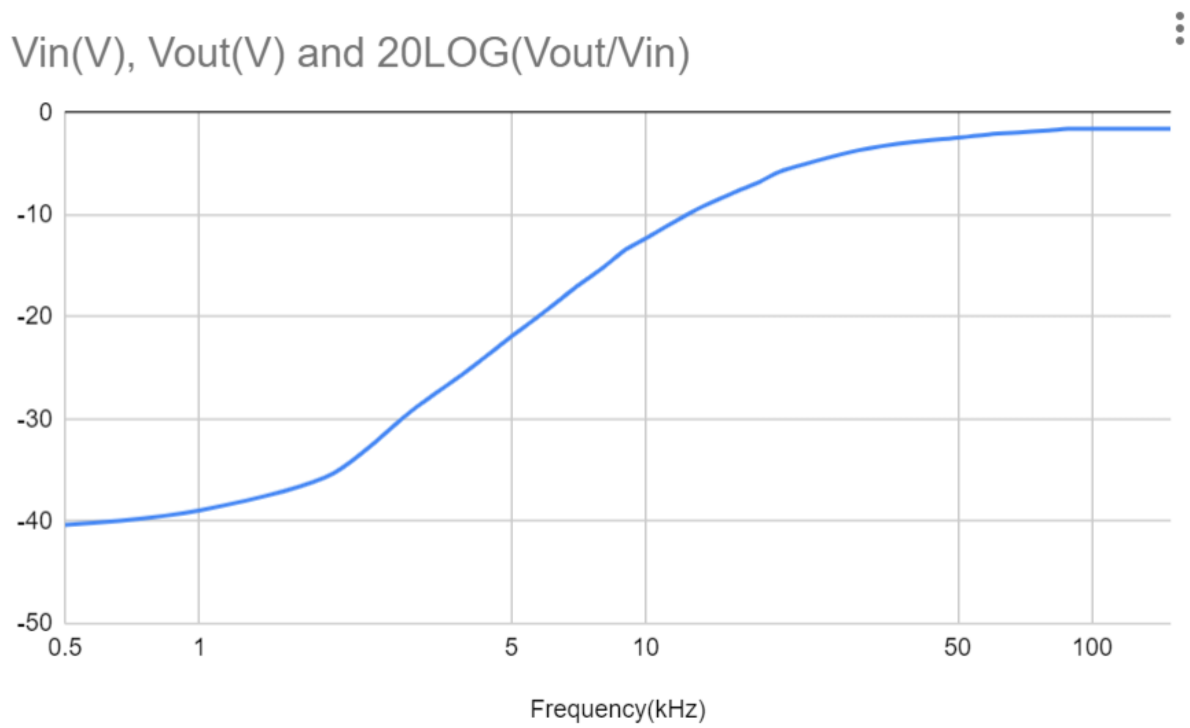


Readings

Frequency(kHz)	Vin(V)	Vout(V)	20LOG(Vout/Vin)
0.5	2.081	0.02	-40.34484169
1	2.12	0.024	-38.92249238
2	2.321	0.04	-35.27230298
3	2.401	0.084	-29.12225748
4	2.401	0.132	-25.19636458
5	2.441	0.196	-21.90623416
6	2.441	0.264	-19.31927705
7	2.441	0.344	-17.02018674
8	2.441	0.424	-15.20403846
9	2.441	0.52	-13.43128872
10	2.441	0.592	-12.30492145
13	2.441	0.82	-9.475078541
15.9	2.441	1.001	-7.742674039

18	2.441	1.121	-6.759243336
20	2.441	1.26	-5.743944686
30	2.441	1.6	-3.668955935
40	2.441	1.76	-2.841102232
50	2.441	1.84	-2.454999128
60	2.441	1.92	-2.085331014
70	2.441	1.96	-1.906234161
80	2.441	2.001	-1.726413816
90	2.441	2.04	-1.55875224
100	2.441	2.04	-1.55875224
150	2.441	2.04	-1.55875224

Using the values we plot a graph of 20LOG(Vout/Vin) vs Frequency



The cut-off frequency in our circuit is approximately ωo=15.9kHz.

$$\frac{Vout}{Vin}(jw) = \frac{\omega}{\sqrt{\omega^2 + \omega o^2}}$$

$$= \frac{\omega}{\sqrt{\omega^2 + \frac{1}{(RC)^2}}}$$

When ω<ωo , the magnitude curve attenuate the low frequency. Thus, the region from the initial point to the cut off frequency is known as the stop band

When ω>ωo, the filter circuit will allow the signal to pass and the region above the cut off frequency point is known as the pass band.

Hence we have created a sallen-key high pass filter.

Experiment 2:

AIM:

To create a low pass filter sallen-key second order filters. Also, to plot a bode plot of the frequency response on semi-log paper.

COMPONENTS:

Resistors(1K), Capacitors(1n), Function Generator, Oscilloscope, Breadboard, wires, DC bench power supply, IC -LM741 - 1

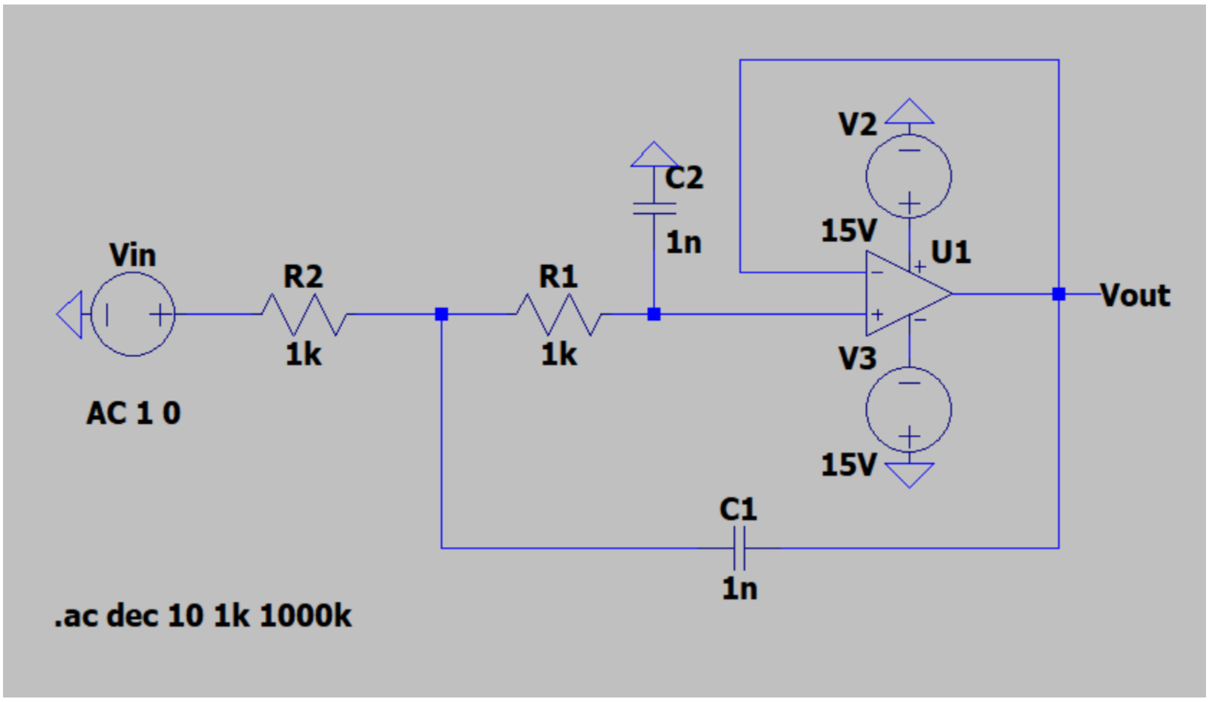
THEORY:

A Sallen-Key low pass filter is an active filter that uses an amplifier along with resistors and capacitors to strengthen the input signal. It consists of two stages of RC in order to increase the overall gain of the filter. The two stages are followed by a non-inverting IC741 to bypass the attenuation which is the loss of signal due to passing through multiple stages of RC.

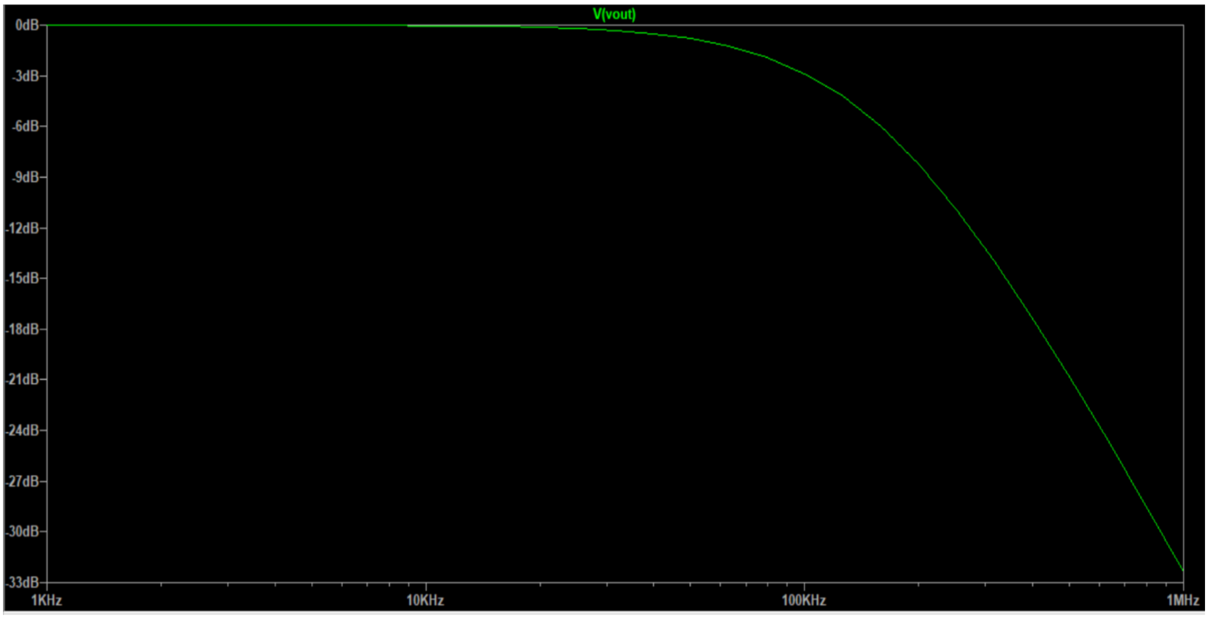
Frequency gain (A_f), Voltage gain (A_v) , f_c=159kHz

$$(A_v) = \frac{V_{out}}{V_{in}} = \frac{A_f}{\sqrt{1+\left(\frac{f}{fc}\right)^2}}$$

The active low pass filter maintains a constant gain A_f from 0Hz to the cut-off frequency. At the cut-off frequency, the gain decreases to $0.707A_f$, and afterward, it decreases at a constant rate as the frequency increases. This behaviour allows the filter to selectively attenuate higher frequencies while allowing lower frequencies to pass through relatively unaffected.



The LTSpice circuit of the sallen key low pass filter.



The LTSpice simulation model of the sallen key high pass filter.

The passive components C_1, R_1, C_2 and R_2 form the second-order frequency-selective circuit.

Thus, at low frequencies, capacitors C_1 and C_2 appear as open circuits, so the input signal is sent to non-inverting pin of the IC741, resulting in a weaker output as seen in the LTspice bode graph. At higher frequencies, C_1 and C_2 appear to the sinusoidal input signal as short circuits, so the input signal is blocked at C_2 ,resulting in a blocked output signal.

Sallen-key Cut-off frequency equation

$$f_c=\frac{1}{2\pi\sqrt{R1R2C1C2}}$$

If the two capacitors are made equal(C1=C2=C) and the two resistors are equal (R1=R2=R) , then the above equation simplifies to:

$$f_c=\frac{1}{2\pi\sqrt{RC}}$$

PROCEDURE

We set up the circuit onto the breadboard by using the above circuit (the LTSpice circuit).

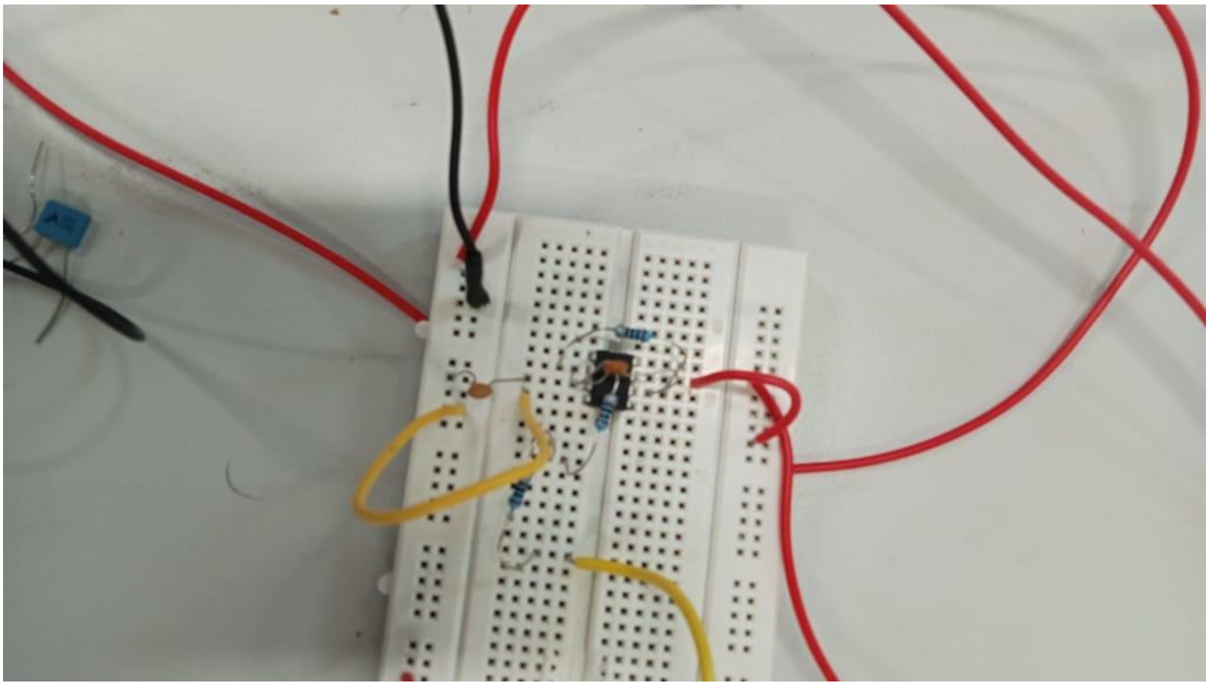
We give an input sinusoidal waveform using the function generator.2 Capacitors(1nF) and 2 resistors(1k) are wired as shown in the circuit diagram. We power the IC using a DC bench power supply. The IC is powered with 15V supply.

Pin 2 and Pin 6 are connected so to create a feedback loop.

The oscilloscope probe is connected to pin 6 to see the output and the other oscilloscope is connected to the outer leg of R2 to see the input waveform.

We set one of the side rails to a common ground. Then the DC Power bench supply is switched and we see the output on the oscilloscope.

To get the readings we note down the input and output voltages obtained when we change the frequency values.

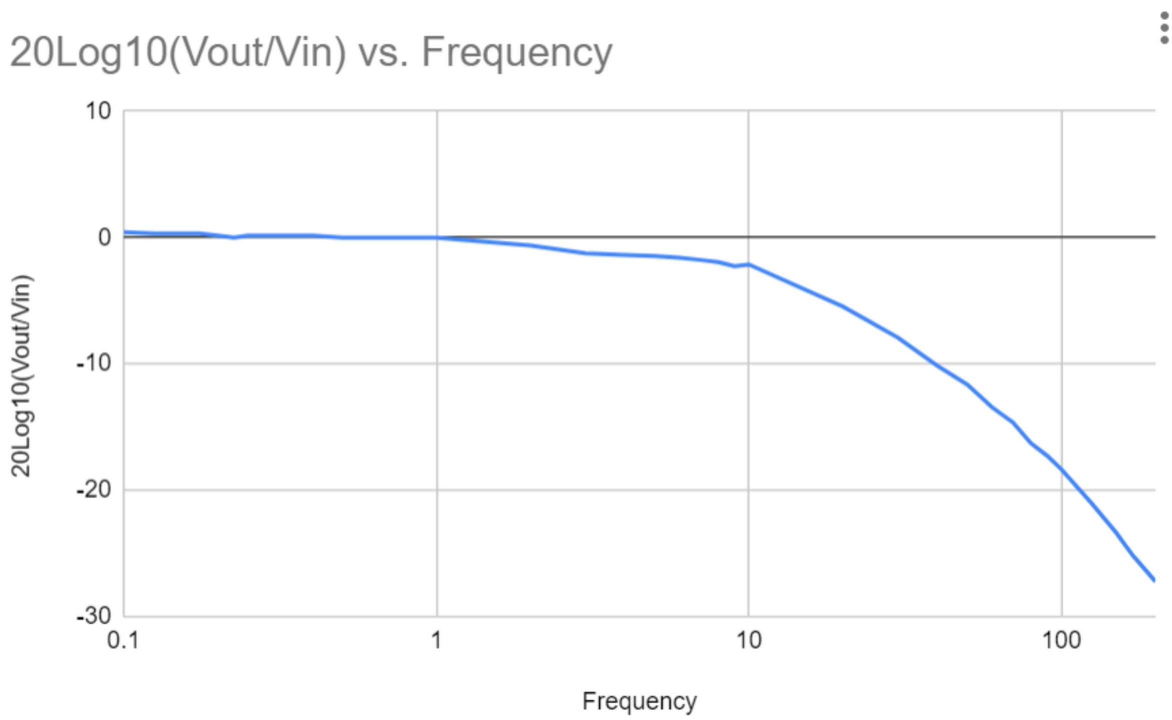


READINGS

Frequency	Vin	Vout	20LOG(Vout/Vin)
0.1	2.08	2.186	0.431736
0.125	2.08	2.16	0.327808
0.15	2.081	2.16	0.323633
0.175	2.081	2.16	0.323633
0.2	2.081	2.12	0.161276
0.225	2.081	2.08	-0.00417
0.25	2.041	2.08	0.164407
0.275	2.04	2.08	0.168663
0.3	2.04	2.08	0.168663
0.4	2.04	2.08	0.168663
0.5	2.081	2.081	0
1	2.12	2.121	0.004096
2	2.32	2.16	-0.62068
3	2.401	2.08	-1.24658
4	2.401	2.81	-1.3876
5	2.41	2.04	-1.44774
6	2.401	2.001	-1.5829
7	2.401		-1.7689
8	2.401	1.921	-1.9373

9	2.441	1.881	-2.26358
10	2.401	1.88	-2.12469
20	2.441	1.301	-5.46581
30	2.441	0.98	-7.92683
40	2.441	0.76	-10.1351
50	2.441	0.64	-11.6278
60	2.441	0.52	-13.4313
70	2.481	0.46	-14.6374
80	2.481	0.38	-16.2969
90	2.481	0.34	-17.263
100	2.481	0.3	-18.3501
125	2.481	0.22	-21.0441
150	2.481	0.168	-23.3863
159	2.481	0.152	-24.2557
170	2.481	0.136	-25.2218
200	2.481	0.108	-27.2241

Using the values, we plot a graph of 20LOG(Vout/Vin) vs Frequency



Hence we have created a sallen-key low pass filter.

Experiment 3:

AIM:

To create a band pass filter sallen-key second order filters. Also, to plot a bode plot of the frequency response on semi-log paper.

COMPONENTS:

Resistors(10K), Capacitors(1n), Function Generator, Oscilloscope, Breadboard, wires, DC bench power supply, IC -LM741 - 2

THEORY:

A bandpass filter allows through components in a specified band of frequencies, called its passband but blocks components with frequencies above or below this band.

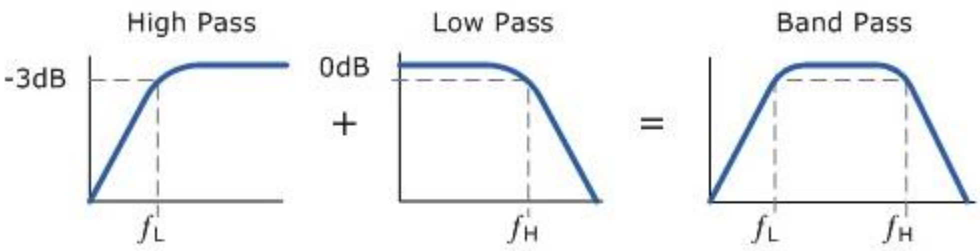
An ideal bandpass filter would have a completely flat **passband**: which is the range of frequencies allowed to pass through with minimal attenuation, and **stopbands** on either side of the passband that attenuate frequencies outside the desired range.

We make the bandpass circuit using sallen key configuration. It uses operational amplifiers and passive electronic components, such as resistors and capacitors, to create the desired frequency response. The circuit consists of an op-amp with feedback resistors and capacitors arranged in a specific configuration.

Bandpass filters find application in areas such as audio processing, telecommunications, wireless communication etc. They are used to isolate specific frequency components, remove unwanted noise, separate different signals, or extract information from a signal within a particular frequency range.

We make sallen-key high pass and sallen-key low pass filters. We then cascade them to make a bandpass filter. Cascading is easy and not problematic since we are using sallen – key configuration while making the high pass and low pass filters.

So We take the input output of the low-pass filter and treat it as an input to the low pass filter.



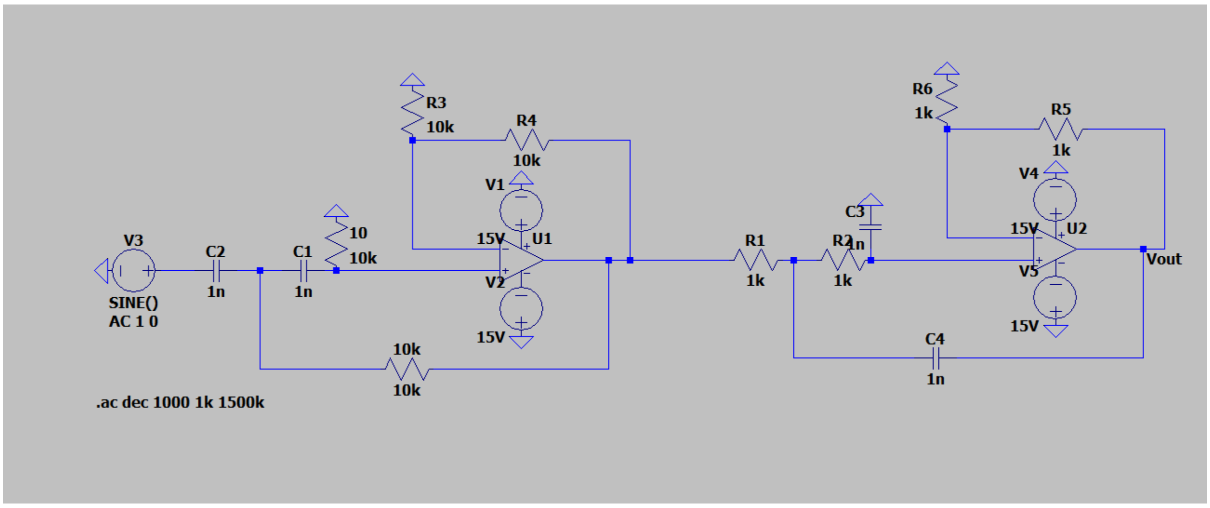
The above diagram depicts how the band pass filter is created by cascading the LPF and HPF. f_L is obtained from the high pass filter(15.9KHz) and the f_H is obtained from the low pass filter(159KHz). The Bandwidth of the filter is the difference between f_L and f_H.

Bandwidth=f_H-f_L.

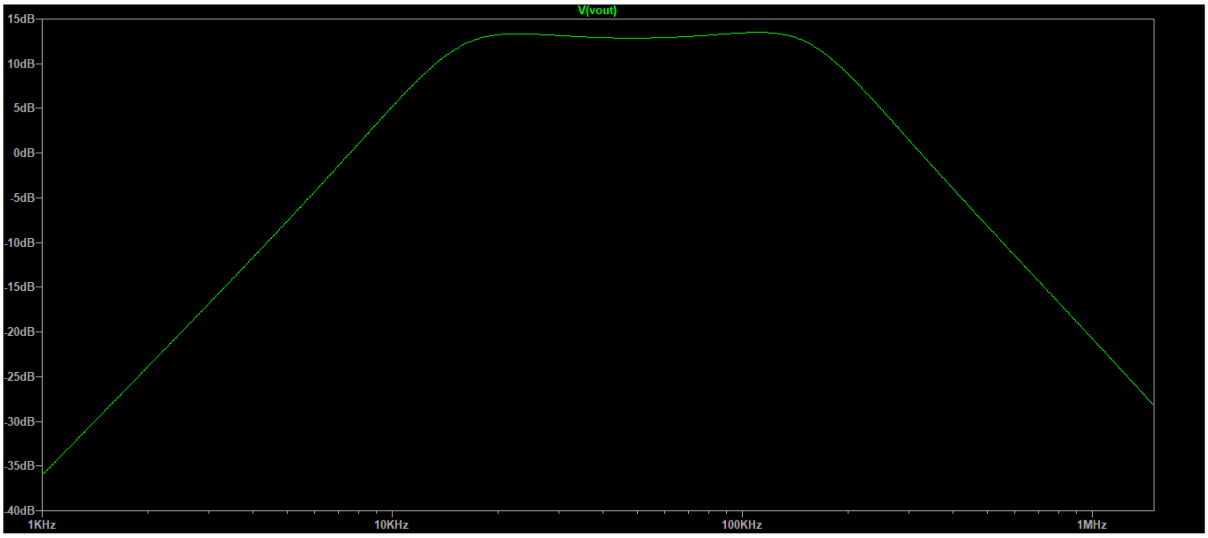
We also need to make sure that the circuit has desired quality factor(Q).It is a parameter that influences the shape and characteristics of the filter's frequency response ,it determines the sharpness of roll-off of the filter.

The quality factor is calculated using $Q=\frac{1}{3-A}$.

Here A represents gain of the filter in the passband.



The LTSpice circuit of the sallen key band pass filter.



The LTSpice simulation model of the sallen key high pass filter.

PROCEDURE

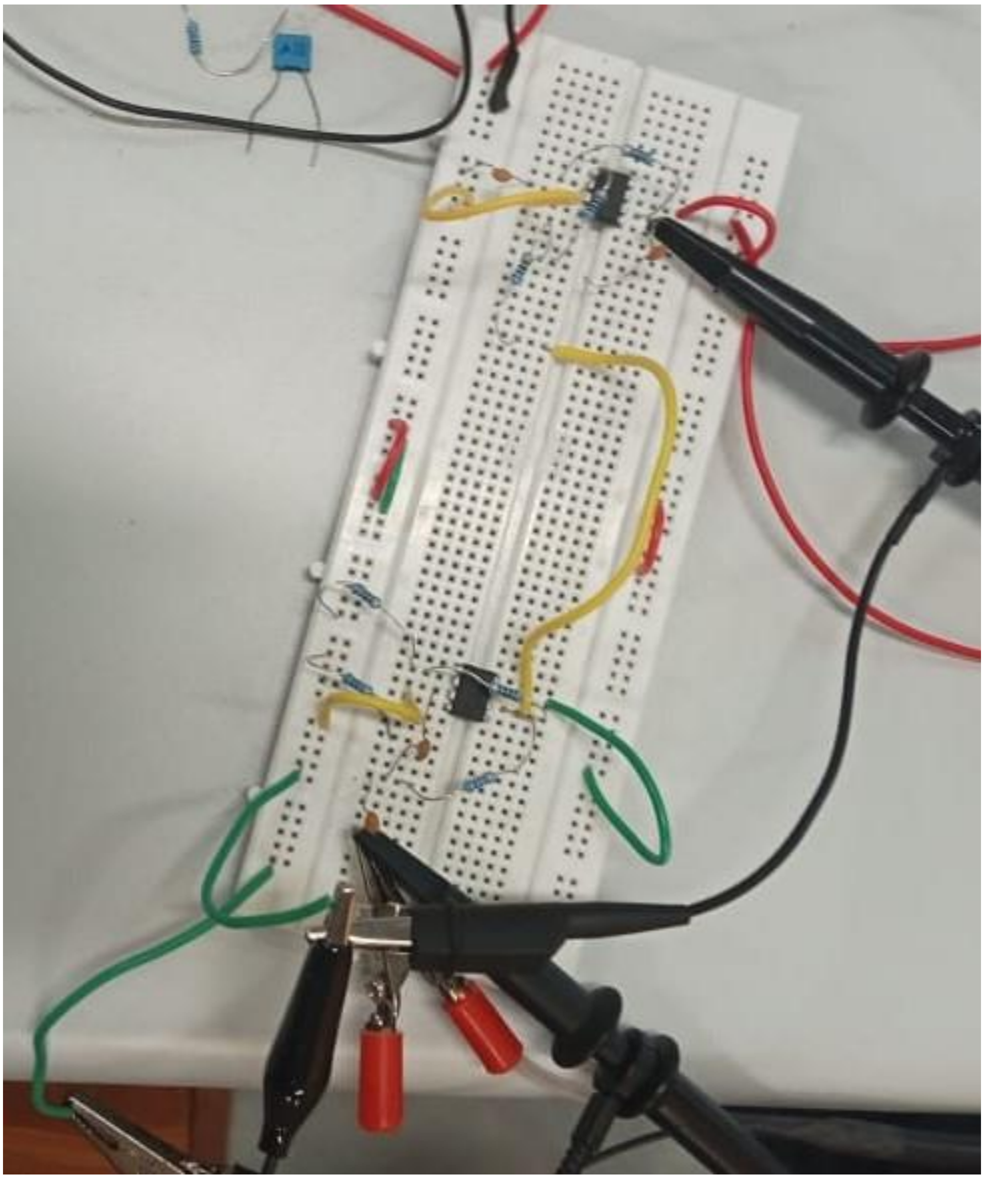
As stated in the above experiments we set up the circuits for High pass filter (HPF) and low pass filter (LPF) on the breadboard.

We then cascade HPF and LPF by connecting pin 6 of HPF to one leg of the resistor R1 of LPF.

We then set the side rails to +15V,-15V and ground voltage levels using the DC bench power supply. We connect pin 4 of both IC's to -15V siderail and pin 7 of both IC's to the +15V siderail in order to power the circuit.

The oscilloscope probe is connected to pin 6 of the LPF to see the output and the other oscilloscope is connected to the outer leg of C2 of HPF to see the input waveform.

To get the readings we note down the input and output voltages obtained when we change the frequency values.

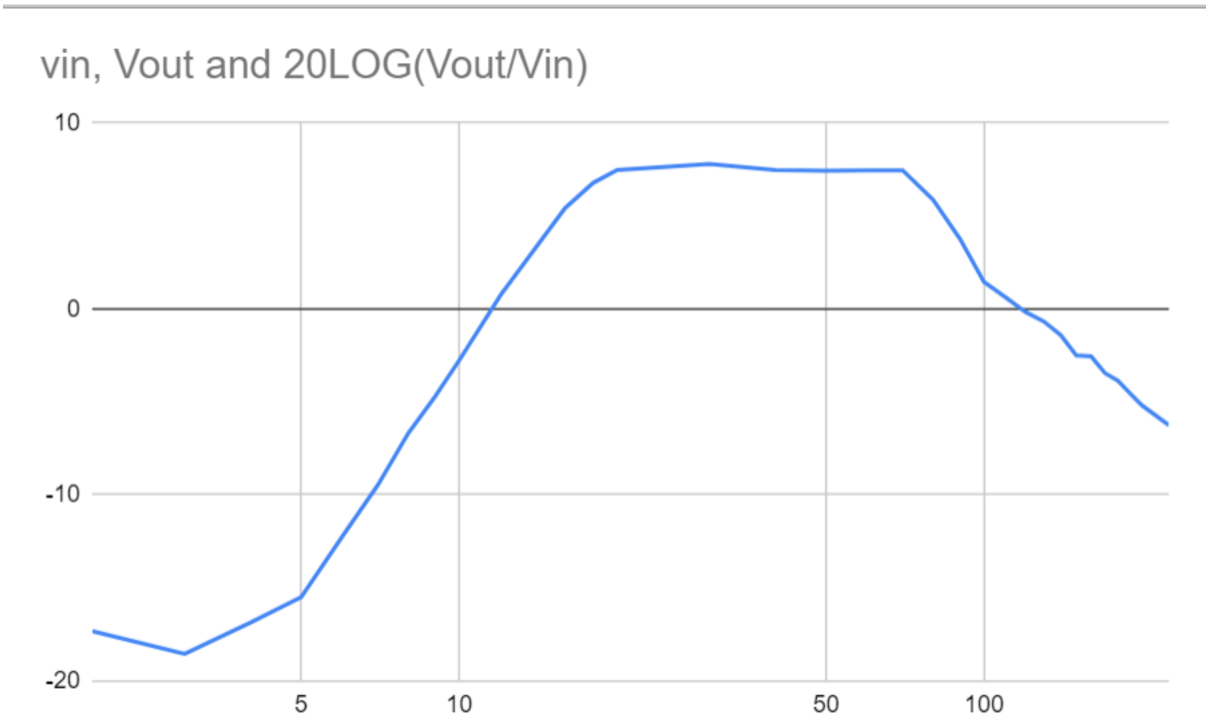


READINGS

Frequency	vin	Vout	20LOG(Vout/Vin)
1	4.24	0.56	-17.5836
2	4.4	0.12	-17.3268
3	4.32	0.256	-18.5432
4	4.4	0.48	-16.8653
5	4.4	0.74	-15.4844
6	4.4	1.08	-12.2006
7	4.4	1.48	-9.46382
8	4.4	2.04	-6.67645
9	4.4	2.56	-4.70425
10	4.4	3.2	-2.76605

12	4.4	4.8	0.755771
15.9	4.4	8.2	5.407224
18	4.4	9.6	6.776371
20	4.4	10.4	7.471613
30	4.4	10.8	7.799422
40	4.32	10.2	7.462328
50	4.4	9.6	7.4356
60	4.4	8.8	7.4569
70	4.4	7.2	7.4587
80	4.4	6.8	5.876
90	4.4	6	3.7654
100	4.4	5.2	1.451013
110	4.32	4.64	0.620685
120	4.4	4.32	-0.15938
130	4.32	4	-0.66848
140	4.32	3.68	-1.39272
150	4.48	3.36	-2.49877
160	4.4	3.28	-2.55158
170	4.4	2.96	-3.44322
180	4.24	2.72	-3.85594
190	4.32	2.56	-4.54488
200	4.432	2.441	-5.18064
225	4.432	2.16	-6.24292

Using the values we plot a graph of 20LOG(Vout/Vin) vs Frequency



Hence we have created a sallen-key band pass filter.