EE230: Experiment No.7
Special Opamp Linear Circuits - Active Filters

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1 Overview of the experiment

1.1 Aim of the experiment

The aim of this experiment is to understand what are different types of active filters, and how we can implement them using opamps and different types of resistors and capacitors. For these filters, we have to find out some parameters, like Bandwidth, CutOff Frequency, or maximum Gain Frequency. To calculate these parameters, there are different different circuits, which we analyse and found out the parameters by getting the output experimentally and doing some calculations. These circuits and calculations are shown in the Design section. These experimental results needs to be compared with the theoritical results.

1.2 Methods

First of all, as the circuit diagrams are given to us in the lab document, we make the circuit on the breadboard carefully. After checking the connections, we provide the required power supply to the board wherever required. The output which is required to do the calculations, are measured using Digital Multi-Meter, and the readings are taken. Using these readings, we calculate the required parameter values by doing the required calculations.
After that, these experimental values are compared with the theoritical values to check whether our experimental values are approximately same to theoritical values.

2 Design

2.1 Sallen-Key (2-pole) active low-pass filter

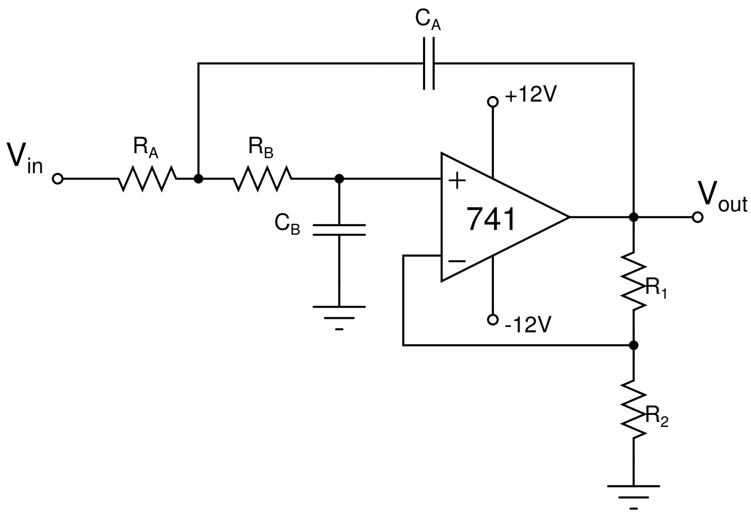


Figure 1: Sallen-Key (2-pole) active low-pass filter

Circuit values: $R_A = R_B = 4.7\text{k}\Omega$, $C_A = C_B = 0.1\text{uF}$, $R_1 = 1.8\text{k}\Omega$, $R_2 = 3.3\text{k}\Omega$.
The above diagram shows the active low-pass filter. This has a higher gain when the input is of low frequency. As we increase the frequency, we reach to a CutOff Frequency, where the V_{OUT} becomes $1/\sqrt{(}2)$ times its maximum value. After that, the gain plot has a much sharper roll-off of -40 dB/decade beyond the cut-off frequency. R_1 and R_2 values are chosen such that $R_1 = 0.586R_2$. The calculation for CutOff Frequency is as follows:

$$f_c = 1/(2\pi RC) \tag{1}$$

R = $R_A = R_B$, C = $C_A = C_B$.
Theoritical Result:

$$f_c = 1/(2\pi 4.710^{-4}) \tag{2}$$

$$f_c = 340Hz \tag{3}$$

So, for this low-pass filter, the above equation will give us thetheoritical value of f_c.

2.2 Sallen-Key (2-pole) active high-pass filter

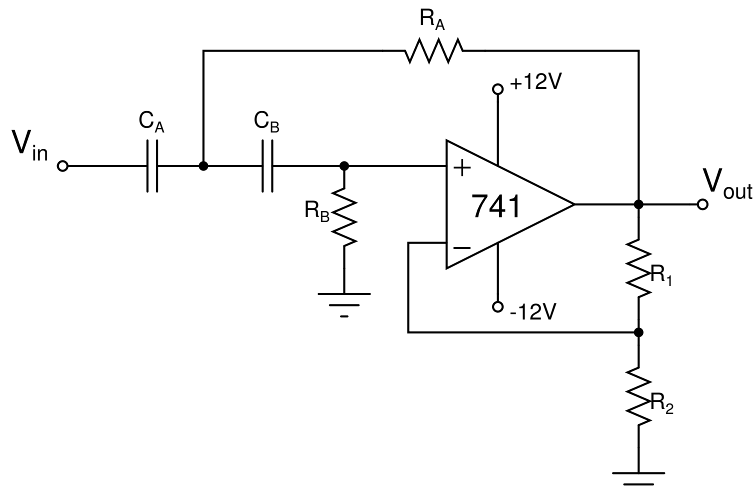


Figure 2: Sallen-Key (2-pole) active high-pass filter

Circuit values: $R_A = R_B = 4.7\text{k}\Omega$, $C_A = C_B = 0.1\text{uF}$, $R_1 = 1.8\text{k}\Omega$, $R_2 = 3.3\text{k}\Omega$.
The above diagram shows the active high-pass filter. This has a lower gain when the input is of low frequency. As we increase the frequency, we reach to a CutOff Frequency, where the V_{OUT} becomes $1/\sqrt{2}$ times its maximum value. After that, the gain plot has a much sharper roll-off of 40 dB/decade beyond the cut-off frequency. R_1 and R_2 values are chosen such that $R_1 = 0.586R_2$. The calculation for CutOff Frequency is as follows:

$$f_c = 1/(2\pi RC) \tag{4}$$

R = $R_A = R_B$, C = $C_A = C_B$.
Theoritical Result:

$$f_c = 1/(2\pi 4.710^{-4}) \tag{5}$$

$$f_c = 340Hz \tag{6}$$

So, for this high-pass filter, the above equation will give us thetheoritical value of f_c.

2.3 Multiple-feedback Active Band-Pass Filter

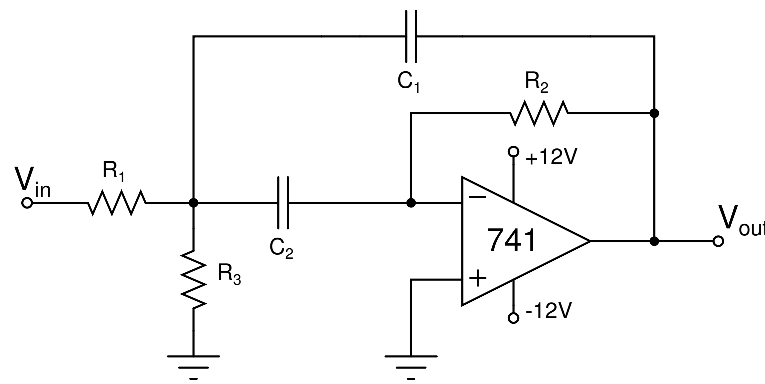


Figure 3: Multiple-feedback Active Band-Pass Filter

Circuit values: $R_3 = 2.7\text{k}\Omega$, $C_1 = C_2 = 0.01\text{uF}$, $R_1 = 68\text{k}\Omega$, $R_2 = 180\text{k}\Omega$. The above diagram shows the Multiple-feedback Active Band-Pass Filter. This has a lower gain when the input is of low frequency. As we increase the frequency, the gain increases. After some frequency, gains reaches to maximum value, after that if we increase the frequency, then gain starts to decrease again. The following equations are used to find the theoritical values:

$$Q = \pi f_o C R_2 \tag{7}$$

$$BW = f_o/Q \tag{8}$$

$$f_o = (1/(2\pi C)) * \sqrt{(R_1 + R_2)/(R_1 R_2 R_3)} \tag{9}$$

Theoritical Result:

$$f_o = 15.92 * 10 * 8.66 = 729Hz \tag{10}$$

$$BW = 1/(\pi C R_2) = 176Hz \tag{11}$$

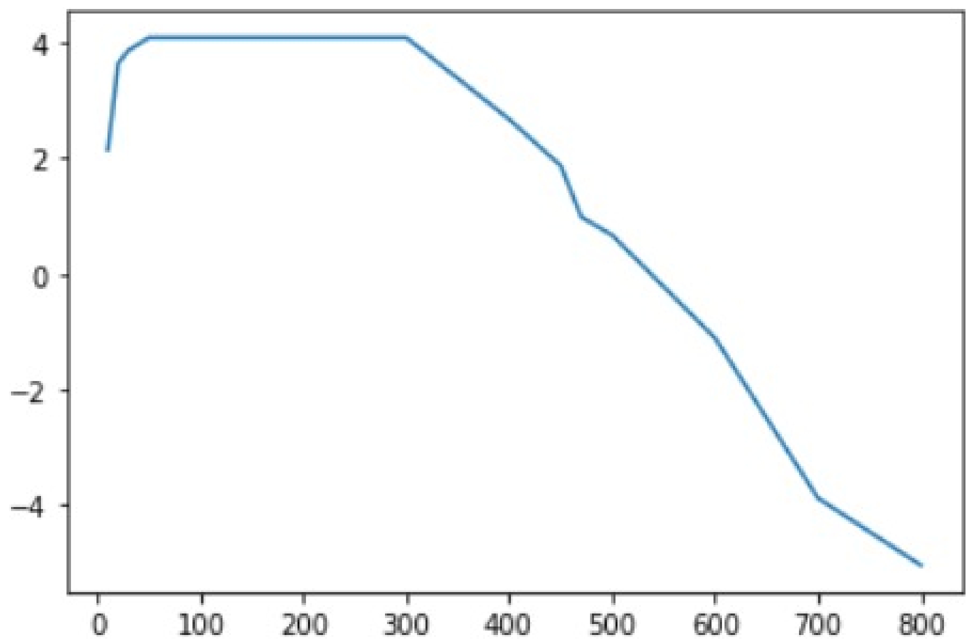
So, for this filter, the above equation will give us thetheoritical value of f_o and BW.

3 Experimental results

3.1 Sallen-Key (2-pole) active low-pass filter

f(in Hz)	V_{OUT} **(in V)**
10	2.56
20	3.04
30	3.12
50	3.2
100	3.2
200	3.2
300	3.2
400	2.72
450	2.48
470	2.24
500	2.16
600	1.76
700	1.28
800	1.12

Following is the Bode-Plot of the Output:

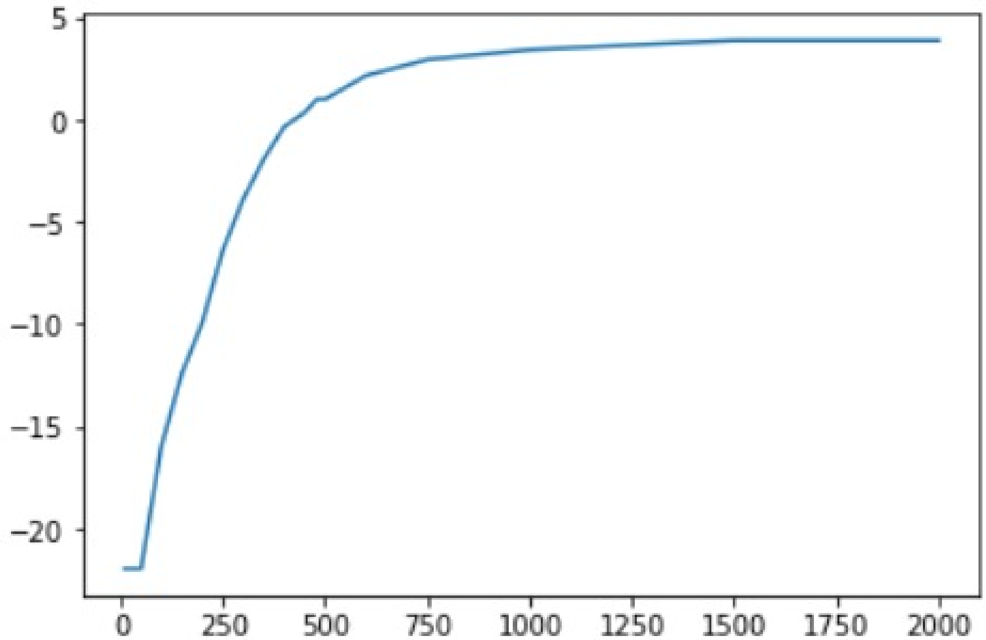


From here, we can see that our experimental f_c is at 470Hz (at which V_{OUT} becomes $3.2/\sqrt{2}$).
Theoritical f_c is at 338Hz.

3.2 Sallen-Key (2-pole) active high-pass filter

f(in Hz)	V_{OUT} **(in V)**
10	0.16
50	0.16
100	0.32
150	0.48
200	0.64
250	0.96
300	1.28
350	1.6
400	1.92
450	2.08
480	2.24
500	2.24
600	2.56
750	2.8
1000	2.96
1500	3.12
2000	3.12

Following is the Bode-Plot of the Output:

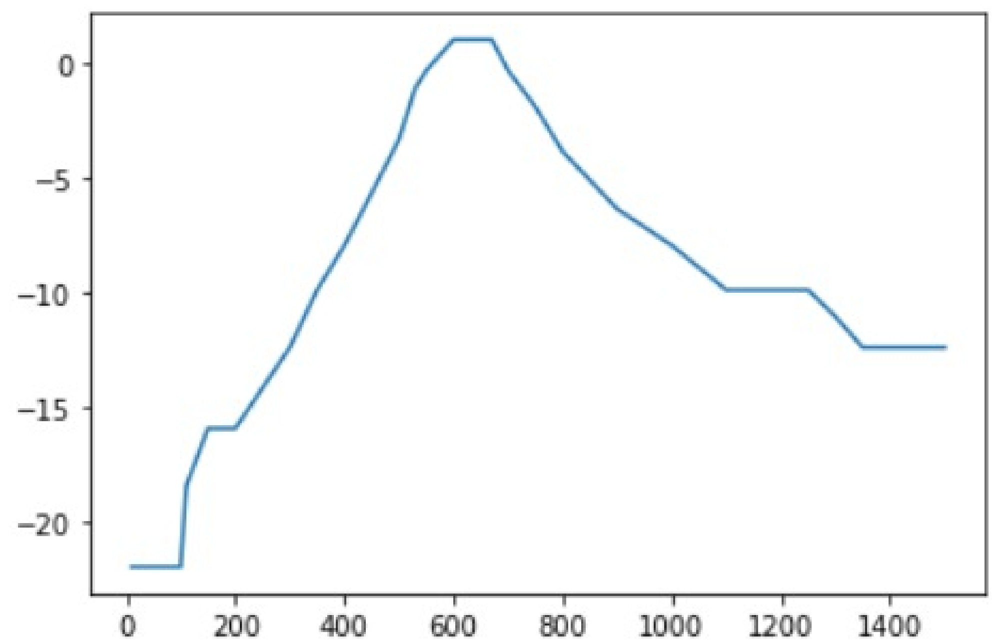


From here, we can see that our experimental f_c is at 480Hz (at which V_{OUT} becomes $3.12/\sqrt{2}$).
Theoritical f_c is at 338Hz.

3.3 Multiple-feedback Active Band-Pass Filter

f(in Hz)	V_{OUT} **(in V)**
10	0.16
50	0.16
100	0.16
110	0.24
150	0.32
200	0.32
300	0.48
350	0.64
400	0.8
450	1.04
500	1.36
530	1.76
550	1.92
600	2.24
650	2.24
670	2.24
700	1.92
724	1.76
750	1.6
800	1.28
900	0.96
1000	0.8
1100	0.64
1250	0.64
1300	0.56
1350	0.48
1500	0.48

Following is the Bode-Plot of the Output:



From here, we can see that our experimental f_o is at 670Hz (at which V_{OUT} becomes 2.24V).
BW = 724Hz - 530Hz
So, our BandWidth is 194Hz.
Theoritical f_o is at 729Hz.
Theoritical BW is 176Hz.

4 Experiment completion status

All the parts of this experiment are completed successfully.