EE230: Labwork-7
Special Opamp Linear Circuits - Active Filters

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1 Overview of the experiment

1.1 Aim of the experiment

To understand the working of:
i) Sallen-Key (2-pole) Active Low-pass Filter
ii) Sallen-Key (2-pole) Active High-pass Filter
iii) Active Band-Pass Filter
by experimentally finding the filter responses of the above mentioned circuits.

1.2 Methods

We first constructed the circuits for:
i) Sallen-Key (2-pole) Active Low-pass Filter
ii) Sallen-Key (2-pole) Active High-pass Filter
iii) Active Band-Pass Filter
on the breadboard, and measured the output voltage V_o and thus the gain of the circuits as various frquencies. We recorded these parameters and analysed the frequency plots.

2 Design

The design for the three circuits are shown below.
They consists of an op-amp connected with capacitors and resistors with a negative feedback.

2.1 (a) Sallen-Key (2-pole) Active Low-pass Filter

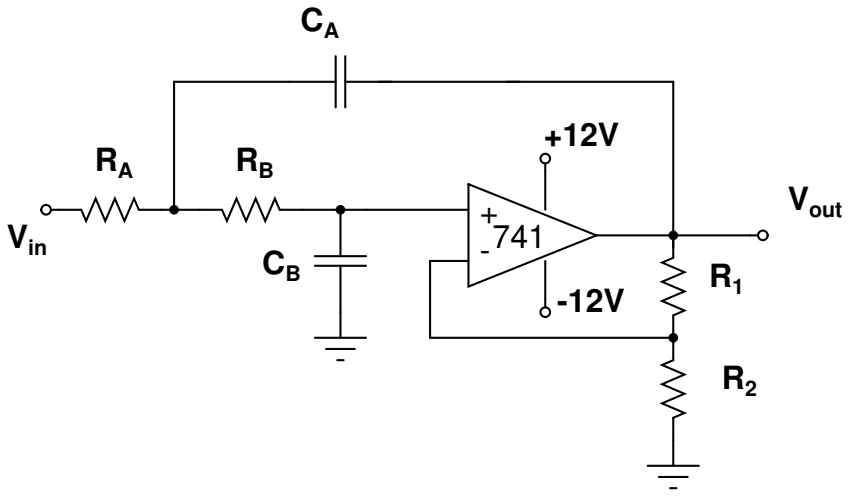

Figure 1: (a) Sallen-Key (2-pole) Active Low-pass Filter

2.2 (b) Sallen-Key (2-pole) Active High-pass Filter

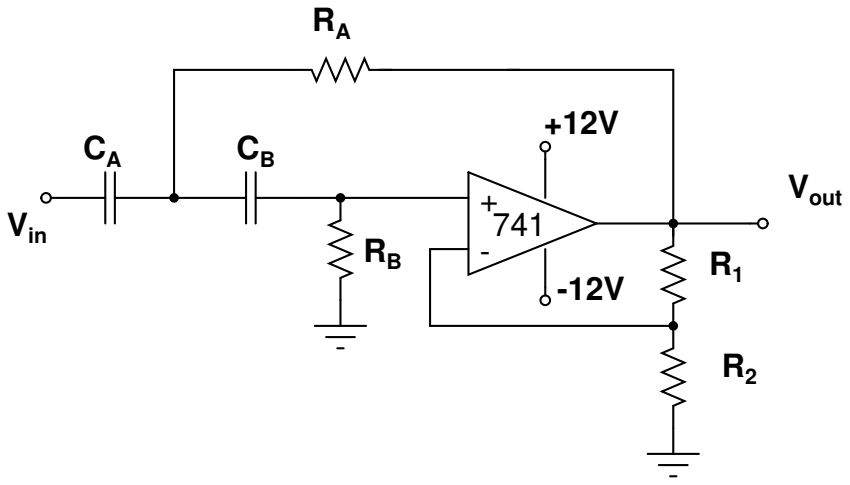

Figure 2: (b) Sallen-Key (2-pole) Active High-pass Filter

2.3 (c) Multiple-feedback Active Band-Pass Filter

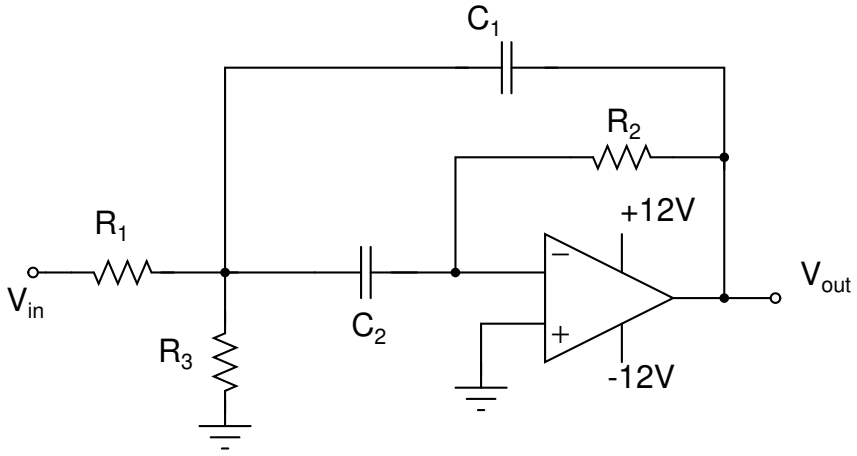

Figure 3: (c) Multiple-feedback Active Band-Pass Filter

3 Theoretical analysis

3.1 (a) Sallen-Key (2-pole) Active Low-pass Filter

The cut-off frequency of the filter is given by,

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

Substituting the given values, we get:

$$f_c = 338.62Hz \tag{2}$$

$$Bandwidth = f_c = 338.62Hz \tag{3}$$

3.2 (b) Sallen-Key (2-pole) Active High-pass Filter

The cut-off frequency of the filter is given by,

$$f_c = \frac{1}{2\pi RC} \tag{4}$$

Substituting the given values, we get:

$$f_c = 338.62Hz \tag{5}$$

$$Bandwidth = f_c = 338.62Hz \tag{6}$$

3.3 (c) Multiple-feedback Active Band-Pass Filter

Centre frequency f_0 is given by:

$$f_0 = \frac{1}{2\pi C}\sqrt{\frac{R_1 + R_2}{R_1 R_2 R_3}} \tag{7}$$

Substituting the given values, we get:

$$f_0 = 736.13Hz \tag{8}$$

Bandwidth is given by:

$$BW = \frac{f_0}{Q} \tag{9}$$

$$Q = \pi f_0 C R_0 \tag{10}$$

$$\therefore BW = 176.84Hz \tag{11}$$

Cut-off frequencies are given by:

$$f_{c1} = \frac{BW}{2} + f_0 = 824.55Hz \tag{12}$$

$$f_{c2} = \frac{BW}{2} - f_0 = 647.71Hz \tag{13}$$

4 Experimental results

For the three circuits, the following parameters were measured by varying the input frequency.

1. input frequency
2. output voltage V_o
3. gain ($\frac{V_o}{V_{in}}$)
4. gain (dB)

4.1 (a) Sallen-Key (2-pole) Active Low-pass Filter

Input voltage	Input Freq (in Hz)	Output voltage	Gain(db)	Gain
2.12	10	3.16	3.467024434	1.490566038
2.12	50	3.16	3.467024434	1.490566038
2.12	100	3.12	3.356374662	1.471698113
2.12	150	3.12	3.356374662	1.471698113
2.12	200	3.04	3.130754454	1.433962264
2.12	250	2.96	2.899117003	1.396226415
2.12	300	2.8	2.416443408	1.320754717
2.12	338	2.64	1.905361319	1.245283019
2.12	350	2.64	1.905361319	1.245283019
2.12	400	2.4	1.077507616	1.132075472
2.12	450	2.16	0.162357804	1.018867925
2.12	500	1.96	-0.681595791	0.924528302
2.12	550	1.76	-1.616463862	0.830188679
2.12	600	1.52	-2.88984546	0.716981132
2.12	650	1.36	-3.855939051	0.641509434
2.12	700	1.24	-4.658283515	0.58490566
2.12	800	0.96	-6.881292558	0.452830189
2.12	900	0.8	-8.464917479	0.377358491
2.12	1000	0.68	-9.876538964	0.320754717
2.12	1250	0.48	-12.90189247	0.226415094
2.12	1500	0.36	-15.4006672	0.169811321
2.12	1750	0.24	-18.92249238	0.113207547
2.12	2000	0.24	-18.92249238	0.113207547
2.12	432	2.23	0.439380042	1.051886792

Figure 4: (a) Sallen-Key (2-pole) Active Low-pass Filter Measurements

Experimental cut-off frequency = 432 Hz
Experimental Bandwidth = 432 Hz

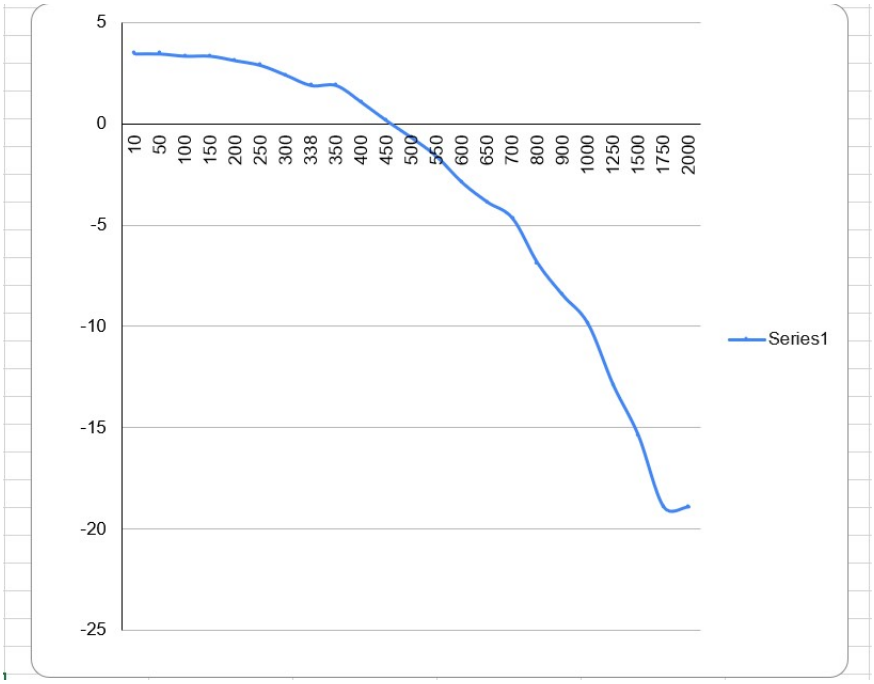

Figure 5: (a) Sallen-Key (2-pole) Active Low-pass Filter Frequency plot

4.2 (b) Sallen-Key (2-pole) Active High-pass

Experimental cut-off frequency = 471 Hz
Experimental Bandwidth = 471 Hz

Input voltage	Input Freq (in Hz)	Output voltage	Gain(db)	Gain
2.04	50	0.064	-30.06900387	0.031372549
2.04	100	0.18	-21.08715325	0.088235294
2.04	150	0.38	-14.59693142	0.18627451
2.04	200	0.64	-10.06900387	0.31372549
2.04	250	0.96	-6.547178688	0.470588235
2.04	300	1.28	-4.048403956	0.62745098
2.04	350	1.56	-2.330111381	0.764705882
2.04	400	1.84	-0.896246888	0.901960784
2.04	450	2.12	0.33411387	1.039215686
2.04	500	2.32	1.117156349	1.137254902
2.04	550	2.48	1.696430268	1.215686275
2.04	600	2.6	2.106863611	1.274509804
2.04	650	2.68	2.370092532	1.31372549
2.04	700	2.8	2.750557278	1.37254902
2.04	800	2.88	2.995246407	1.411764706
2.04	900	2.96	3.233230873	1.450980392
2.04	1000	2.96	3.233230873	1.450980392
2.04	1250	3.04	3.464868324	1.490196078
2.04	1500	3.08	3.578410981	1.509803922
2.04	1750	3.08	3.578410981	1.509803922
2.04	2000	3.08	3.578410981	1.509803922
2.04	471	2.18	0.576526524	1.068627451

Figure 6: (b) Sallen-Key (2-pole) Active High-pass Filter Measurements

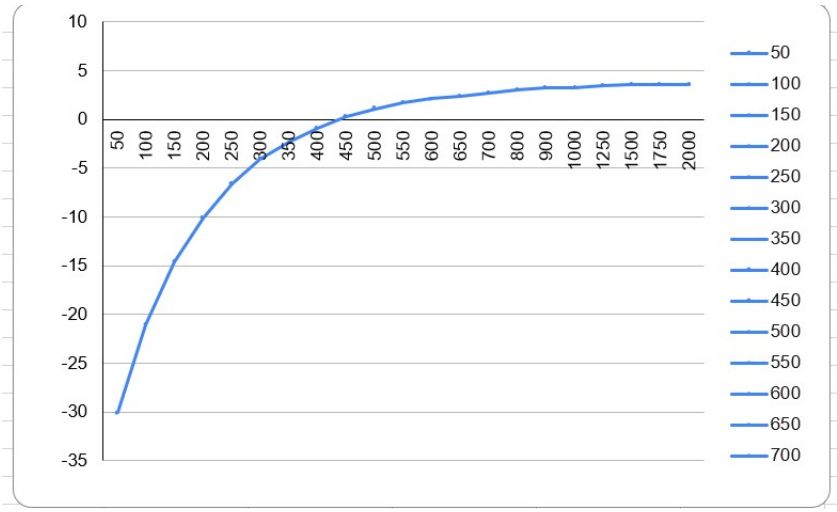

Figure 7: (b) Sallen-Key (2-pole) Active High-pass Filter Frequency plot

4.3 (c) Multiple-feedback Active Band-Pass Filter

Input voltage	Input Freq (in Hz)	Output voltage	Gain(db)	Gain
2.08	50	0.08	-28.29946696	0.038461538
2.08	100	0.12	-24.77764178	0.057692308
2.08	150	0.2	-20.34066679	0.096153846
2.08	200	0.28	-17.41810607	0.134615385
2.08	250	0.32	-16.25826713	0.153846154
2.08	300	0.4	-14.32006687	0.192307692
2.08	350	0.52	-12.04119983	0.25
2.08	400	0.64	-10.23766722	0.307692308
2.08	450	0.88	-7.471613256	0.423076923
2.08	500	1.12	-5.376906246	0.538461539
2.08	550	1.52	-2.72439494	0.730769231
2.08	600	2	-0.340666786	0.961538462
2.08	650	2.08	0	1
2.08	700	1.76	-1.451013343	0.846153846
2.08	750	1.44	-3.194016857	0.692307692
2.08	800	1.16	-5.072106915	0.557692308
2.08	850	0.96	-6.715842038	0.461538462
2.08	900	0.88	-7.471613256	0.423076923
2.08	950	0.72	-9.214616771	0.346153846
2.08	1000	0.68	-9.711088445	0.326923077
2.08	1050	0.64	-10.23766722	0.307692308
2.08	1100	0.56	-11.39750616	0.269230769
2.08	1200	0.48	-12.73644195	0.230769231
2.08	1300	0.4	-14.32006687	0.192307692
2.08	1400	0.4	-14.32006687	0.192307692
2.08	1500	0.36	-15.23521668	0.173076923
2.08	547	1.48	-2.956032391	0.711538462
2.08	742	1.48	-2.956032391	0.711538462

Figure 8: (c) Multiple-feedback Active Band-Pass Filter Measurements

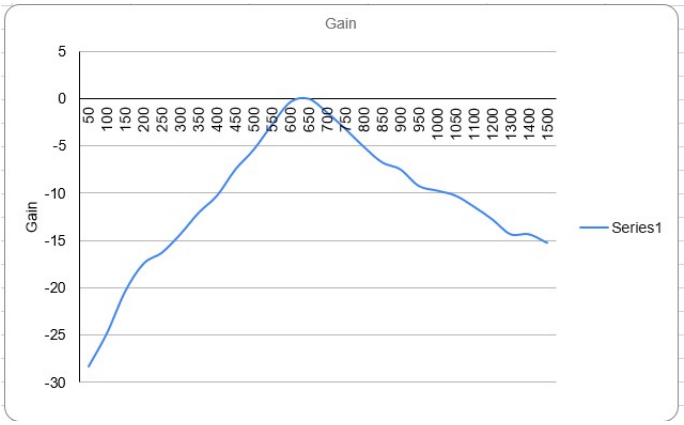

Figure 9: (c) Multiple-feedback Active Band-Pass Filter Frequency plot

Experimental cut-off frequencies:
f_{c1}= **547 Hz**
f_{c2}= **742 Hz**

Experimental centre frequency:
f_0= **650 Hz**

Experimental Bandwidth = 742 - 547 = 195 Hz

5 Conclusion

Therefore, our experimental results are matching with our theoretical results with some slight deviations due to experimental errors.

6 Experiment completion status

All of the sections of the lab-6 were completed in the lab:

Special Opamp Linear Circuits - Active Filters

1. (a) Sallen-Key (2-pole) Active Low-pass Filter
2. (b) Sallen-Key (2-pole) Active High-pass Filter
3. (c) Multiple-feedback Active Band-Pass Filter