EE 230: Analog Circuits Lab
Lab No. 7
Wien Bridge Oscillator and Active Filters

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1. Wien Bridge Oscillator:

1.1 Aim of the experiment

Design a Wien bridge oscillator and analyse it's parameters.

1.2 Design

1.2.1 Part - I

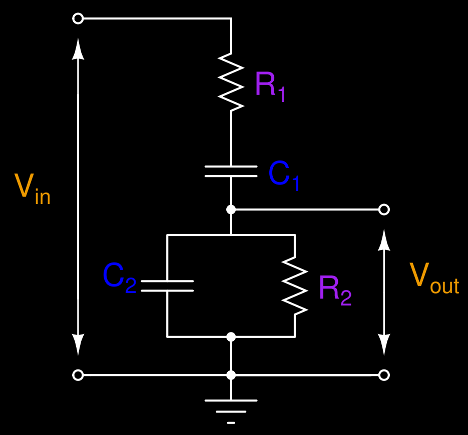


Figure 1:

$$\frac{Vout}{Vin} = \frac{j\omega RC}{1-(\omega RC)^2+3j\omega RC} \tag{1}$$

1.2.2 Part - II: Wein Bridge Oscillator

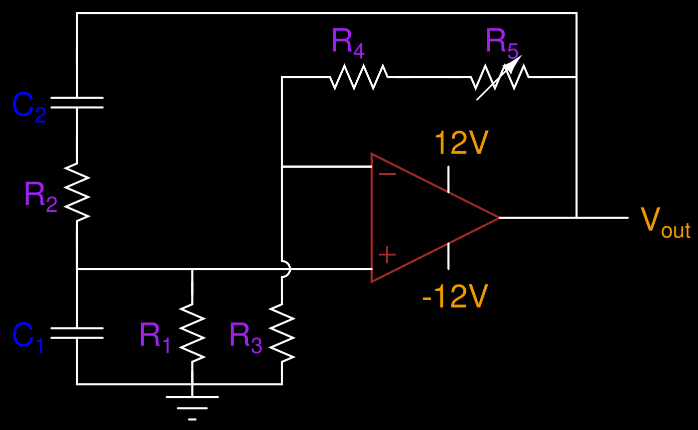


Figure 2: Wein Bridge Oscillator

Resonant Frequency of the circuit, can be found by Barkhausen condition on the closed loop gain **L(s)**. The below equations define the behaviour of the circuit:

$$L(j\omega) = \frac{1+\frac{R4+R5}{R3}}{3+j(\omega CR-\frac{1}{\omega CR})} \tag{2}$$

$$\omega_o = \frac{1}{CR} \tag{3}$$

1.3 Experimental results

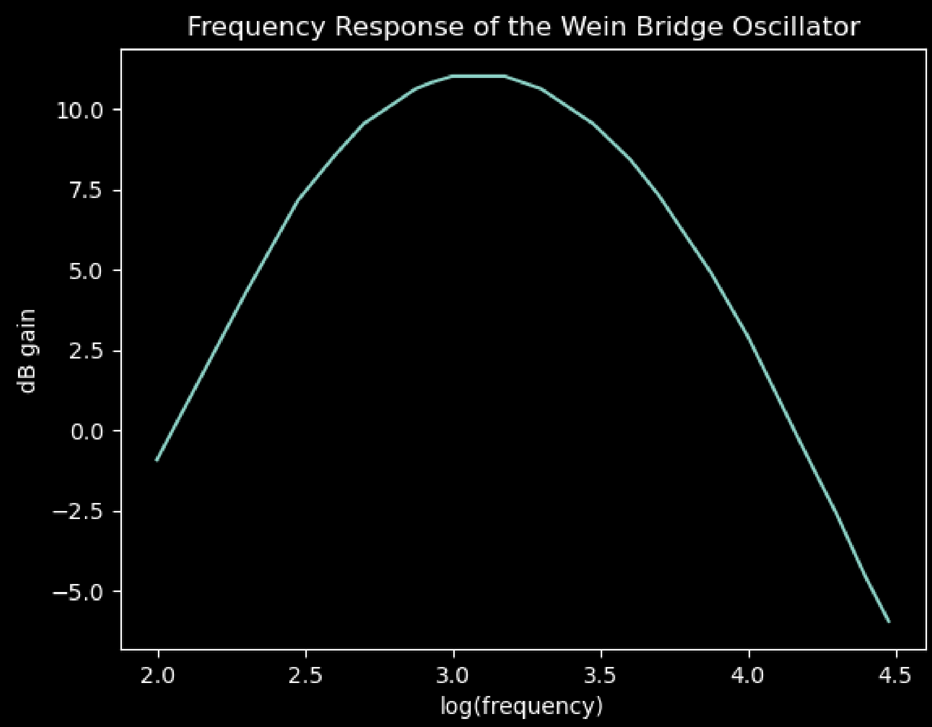
Part - I

The gain is maximum in the range from f = 1kHz to f = 1.5kHz. The V_o increases till the maximum value of 3.56V and then decreases. At this maximum value the phase difference between input and output is approximatey 0° (or -3°, to be precise). Thus this is a band pass filter.

This is an oscillatory circuit where R_3, R_4 and R_5 decide the reference voltage for inverting terminal and Z_1 and Z_2 cause delay (due to the R-C charging).

Using equation(2) and equation(3), we obtain the following values :-
$(f_o)_{theoretical} = 1.59$kHz and $(f_o)_{observed} = 1.142$kHz

$f(Hz)$	$V_o(V)$	$phase$	$f(Hz)$	V_o	$phase$
100	0.9	75.57°	2000	3.40	-19.55°
200	1.640	60.00°	3000	3.00	-33.58°
300	2.280	48.00°	4000	2.640	-42.69°
400	2.680	39.87°	5000	2.32	-49.68°
500	3	30.69°	7500	1.760	-59.45°
750	3.40	15.67°	10000	1.400	-66.96°
850	3.48	10.393°	15000	0.96	-70.79°
1000	3.56	4.320°	20000	0.740	-71.88°
1250	3.56	-3.597°	25000	0.592	-76.32°
1500	3.56	-10.08°	27500	0.544	-77.7°
			30000	0.504	-78.39°



Part - II: Wein Bridge

After adjusting the pot, the values weere -

$f_o = 1.342$kHz and $V_{out} = 22.40V_{pp}$ Next, if we change the value of the resistances, R_1 and R_2 to be 5kΩ each, we would get :-

$(f_o)_{theoretical} = 3.183$ kHz and $(f_o)_{experimental} = 2.35$ kHz

1.4 Conclusion and Inference

The measured resonant frequency was close to the calculated value. Hence, this method can be used to generate sinusoidal signals of required frequency with resonable accuracy.

1.5 Experiment completion status

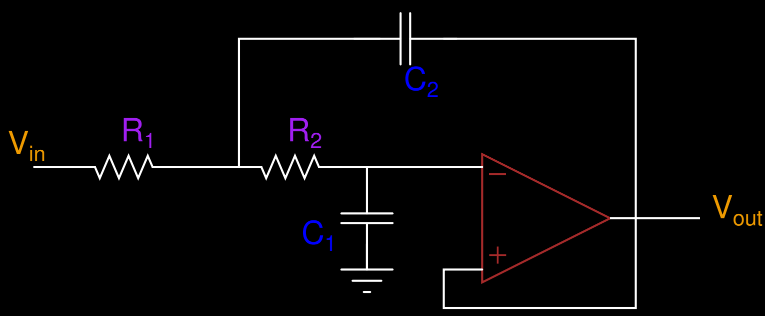
The experiment was completed during lab hours and the hand written report for the same was also submitted during lab hours.

2. Sallen-Key (2 pole) Active Low Pass Filter

2.1 Aim of the experiment

The experiment aims to analyse the working of Butterworth and Chebyshev active low pass filters, in Sallen - Key setting and compare their differences and their frequency response curves.

2.2 Design



The below equations, determine the behaviour of the circuit :-

$$f_c * FSF = \frac{1}{2\pi RC\sqrt{mn}} \tag{4}$$

$$Q = \frac{\sqrt{mn}}{m+1} \tag{5}$$

- where R_1 = m$\cdot R$; R_2 = R; C_1 = C and C_2 = n$\cdot C$ and
- FSF is the Frequency Scaling Factor and Q is the quality factor.
- The provided value of FSF = 1, Q = $\frac{1}{\sqrt{2}}$, R_2 = 18.4kΩ and C_1 = 0.01μF for ButterWorth Filter and
- The provided values of FSF = 0.8414, Q = 1.3049, R_2 = 7.32kΩ and C_1 = 0.01μF for ChebyShev Filter.

2.3 Experimental results

(a) ButterWorth Filter

Based on equation(4) and equation(5) and using the provided values, we get m = 0.22 and n = 3.4.
Thus, we get $R_1 = 0.22 \times 18.4\text{k}\Omega = 4.048\text{k}\Omega$ and $C_2 = 3.4 \times 10nF = 34\text{nF}$.

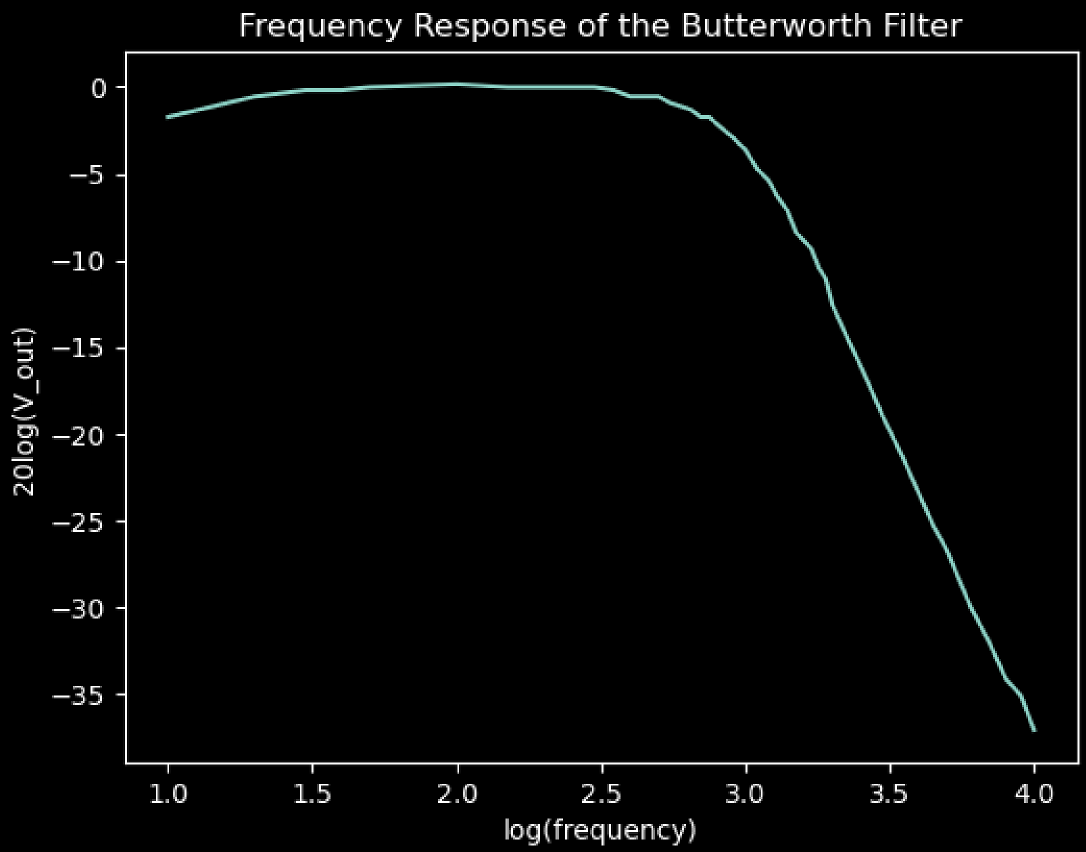
The frequency response of the filter, and observed peak-to-peak output voltages on applying a $1V_{pp}$ input are tabulated below :

$frequency$	$log(frequency)$	V_{out}	$20 \cdot log(V_{out})$
10	1.0	0.82	-1.723722952
20	1.301029996	0.94	-0.537442928
30	1.477121255	0.98	-0.175478486
40	1.602059991	0.98	-0.175478486
50	1.698970004	1.0	0.0
100	2.0	1.02	0.172003435
150	2.176091259	1.0	0.0
200	2.301029996	1.0	0.0
250	2.397940009	1.0	0.0
300	2.477121255	1.0	0.0
350	2.544068044	0.98	-0.175478486
400	2.602059991	0.94	-0.537442928
450	2.653212514	0.94	-0.537442928
500	2.698970004	0.94	-0.537442928
550	2.740362689	0.9	-0.915149811
600	2.77815125	0.88	-1.110346557
650	2.812913357	0.86	-1.310030975
700	2.84509804	0.82	-1.723722952
750	2.875061263	0.82	-1.723722952
800	2.903089987	0.78	-2.158107946
900	2.954242509	0.72	-2.853350071
1000	3.0	0.66	-3.609121289

Rest values are continued on the next page

$frequency$	$log(frequency)$	V_{out}	$20 \cdot log(V_{out})$
1100	3.041392685	0.58	-4.731440129
1200	3.079181246	0.54	-5.352124804
1300	3.113943352	0.48	-6.375175252
1400	3.146128036	0.44	-7.13094647
1500	3.176091259	0.38	-8.404328068
1600	3.204119983	0.36	-8.873949985
1700	3.230448921	0.34	-9.370421659
1800	3.255272505	0.3	-10.45757491
1900	3.278753601	0.28	-11.05683937
2000	3.301029996	0.236	-12.54175994
2250	3.352182518	0.19	-14.42492798
2500	3.397940009	0.158	-16.02685826
2750	3.439332694	0.132	-17.58852138
3000	3.477121255	0.112	-19.01563955
3500	3.544068044	0.086	-21.31003098
4000	3.602059991	0.067	-23.47850395
4500	3.653212514	0.054	-25.3521248
5000	3.698970004	0.046	-26.74484337
5500	3.740362689	0.038	-28.40432807
6000	3.77815125	0.032	-29.89700043
7000	3.84509804	0.025	-32.04119983
8000	3.903089987	0.0196	-34.15487857
9000	3.954242509	0.0176	-35.08974664
10000	4.0	0.014	-37.07743929

The Bode plot for the Butterworth Filter is on the next page

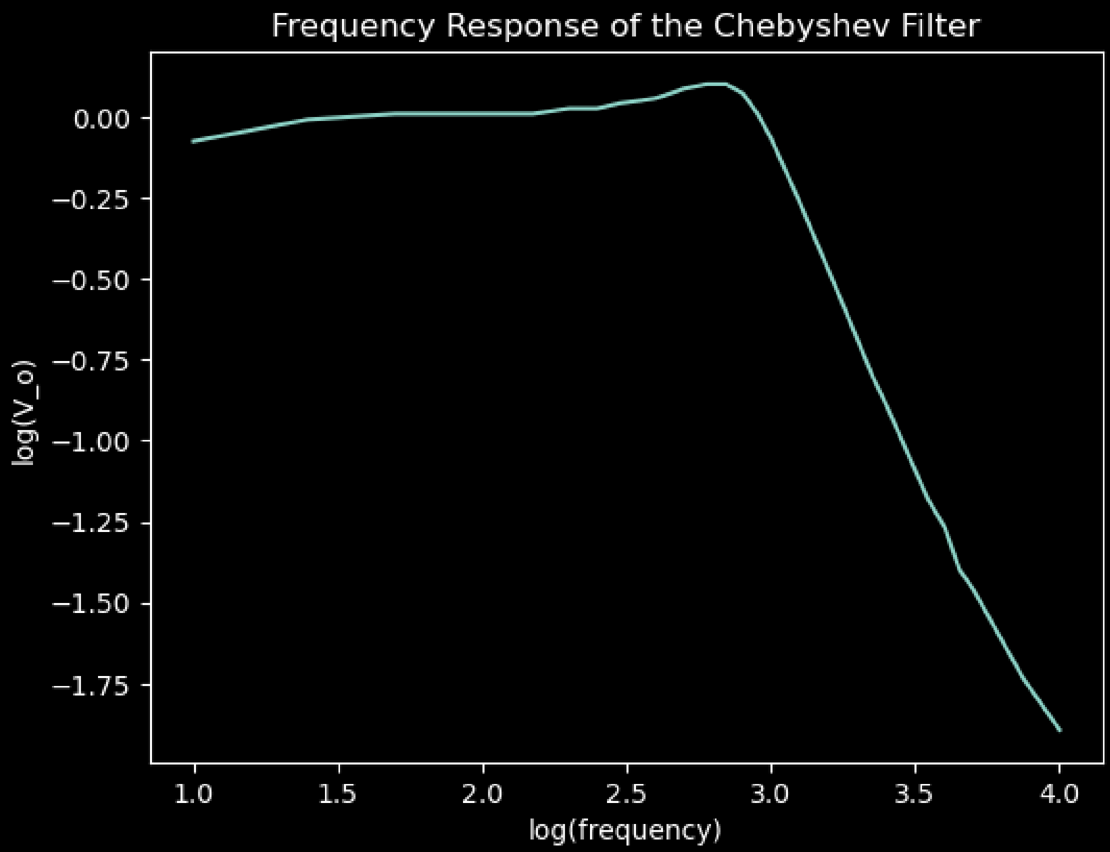


(b) Chebyshev Filter

Based on equation(4) and equation(5) and using the provided values, we get m = 0.98 and n = 6.818
Thus, we get $R_1 = 0.98 \times 7.32\text{k}\Omega = 7.17\text{k}\Omega$ and $C_2 = 6.818 \times 10nF = 68$nF.
The frequency response of the filter, and observed peak-to-peak output voltages on applying a $1V_{pp}$ input are tabulated below :

$freq$	$log(freq)$	v_o	$log(v_o)$
10	1.0	0.84	-0.075720714
25	1.397940009	0.98	-0.008773924
50	1.698970004	1.02	0.008600172
100	2.0	1.02	0.008600172
150	2.176091259	1.02	0.008600172
200	2.301029996	1.06	0.025305865
250	2.397940009	1.06	0.025305865
300	2.477121255	1.1	0.041392685
350	2.544068044	1.12	0.049218023
400	2.602059991	1.14	0.056904851
450	2.653212514	1.18	0.071882007
500	2.698970004	1.22	0.086359831
600	2.77815125	1.26	0.100370545
700	2.84509804	1.26	0.100370545
800	2.903089987	1.18	0.071882007
900	2.954242509	1.02	0.008600172
1000	3.0	0.86	-0.065501549
1250	3.096910013	0.552	-0.258060922
1500	3.176091259	0.376	-0.424812155
1750	3.243038049	0.272	-0.565431096
2000	3.301029996	0.204	-0.690369833
2250	3.352182518	0.158	-0.801342913
2500	3.397940009	0.13	-0.886056648
3000	3.477121255	0.09	-1.045757491
3500	3.544068044	0.066	-1.180456064
4000	3.602059991	0.054	-1.26760624
4500	3.653212514	0.04	-1.397940009
5000	3.698970004	0.035	-1.455931956
7500	3.875061263	0.0184	-1.735182177
10000	4.0	0.0128	-1.89279003

The Bode plot for the Chebyschev Filter is on the next page



Frequency Response of the Chebyshev Filter
0.00
−0.25
−0.50
−0.75
−1.00
−1.25
−1.50
−1.75
log(V_o)
1.0
1.5
2.0
2.5
3.0
3.5
4.0
log(frequency)

2.4 Conclusion and Inference

- The Butterworth filter shows a smooth, monotonic decrease, while the Chebyshev filter shows ripples in the pass-band.
- The Chebyshev filter has a steeper roll-off.
- Thus, Butterworth slowly annhilates the frequency and may let even little bit higher frequencies pass through but the Chebyshev Filter totally annhilates the frequency and does not allow the frequencies beyond a certain point to pass through, at all.

2.5 Experiment completion status

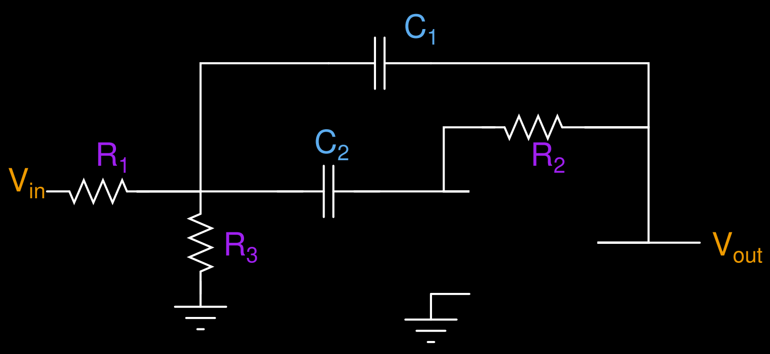
The experiment was completed during lab hours and the hand written report for the same was also submitted during lab hours.

3. Multiple-feedback Active Band-Pass Filter:

3.1 Aim of the experiment

The experiment aims to build a multiple feedback active band pass filter.

3.2 Design



now, the center frequency of the filter can be determined by the formula:

$$f_c = \frac{1}{2\pi C}\sqrt{\frac{R_1 + R_3}{R_1 R_2 R_3}} \tag{6}$$

the filter's Quality Factor Q is given by:

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

also, the Bandwidth of the filter is given by:

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

3.3 Experimental results

3.4 Conclusion and Inference

3.5 Experiment completion status

The experiment could not be completed during the lab hours, due to lack of time management.