Graphic Equalizer

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Center Frequencies:

- 100 Hz
- 1 kHz
- 10 kHz

Calculation :

Graphic Equalizer : Band Pass Filter

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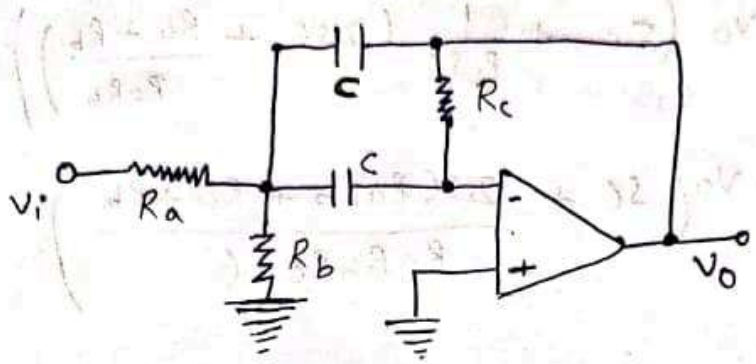


Here, the i through R_c and the capacitor will be same as the input impedance is infinite.

$$\frac{V_o}{R_c} = \frac{0-V}{1/sC} \quad \text{(Laplace domain)}$$

$$\therefore \quad V = \frac{-V_o}{R_c sC} \quad -(1)$$

Apply KCL to find V.

$$\therefore \quad \frac{V_i - V}{R_a} + \frac{V_o - V}{1/sC} + \frac{0-V}{1/sC} + \frac{0-V}{R_b} = 0$$

$$\frac{V_i}{R_a} + V_o sC = \frac{V}{R_a} + VsC + VsC + \frac{V}{R_b}$$

$$\frac{V_i}{R_a} + V_o sC = V\left(2sC + \frac{1}{R_a} + \frac{1}{R_b}\right)$$

$$\frac{V_i}{R_a} + V_o sC = -\frac{V_o}{R_c sC}\left(2sC + \frac{1}{R_a} + \frac{1}{R_b}\right)$$

$$\frac{V_i}{R_a} = -V_o\left(sC + \frac{1}{R_c sC}\left(2sC + \frac{R_a + R_b}{R_a R_b}\right)\right)$$

$$\frac{V_i}{R_a} = -V_o\left(sC + \frac{2sCR_aR_b + R_a + R_b}{R_aR_bR_c sC}\right)$$

$$\frac{V_i}{R_a} = -V_o\left(\frac{R_aR_bR_c s^2C^2 + 2sCR_aR_b + R_a + R_b}{R_aR_bR_c sC}\right)$$

$$-\frac{V_o}{V_i} = \frac{R_bR_c sC}{R_aR_bR_c s^2C^2 + 2sCR_aR_b + R_a + R_b}$$

$$\boxed{\frac{V_o}{V_i} = \frac{-s/R_aC}{s^2 + \frac{2s}{R_cC} + \left(\frac{1}{R_a} + \frac{1}{R_b}\right)\frac{1}{R_cC^2}}}$$

↳ This is transfer function of filter.

Comparing the transfer function with standard transfer function.

$$H(s) = \frac{-A_0 \frac{\omega_0}{Q} s}{s^2 + \frac{\omega_0}{Q} s + \omega_0^2}$$

$$\Rightarrow \boxed{\omega_0 = \sqrt{\left(\frac{1}{R_a} + \frac{1}{R_b}\right)\frac{1}{R_c C^2}}}$$

$$\Rightarrow \boxed{B = \frac{2}{R_c C}}$$

$$\Rightarrow \boxed{Q = \frac{\omega_0}{B} = \frac{1}{2}\sqrt{R_c\left(\frac{1}{R_a} + \frac{1}{R_b}\right)}}$$

$$\Rightarrow \boxed{A_0 = \frac{-R_c}{2R_a}}$$

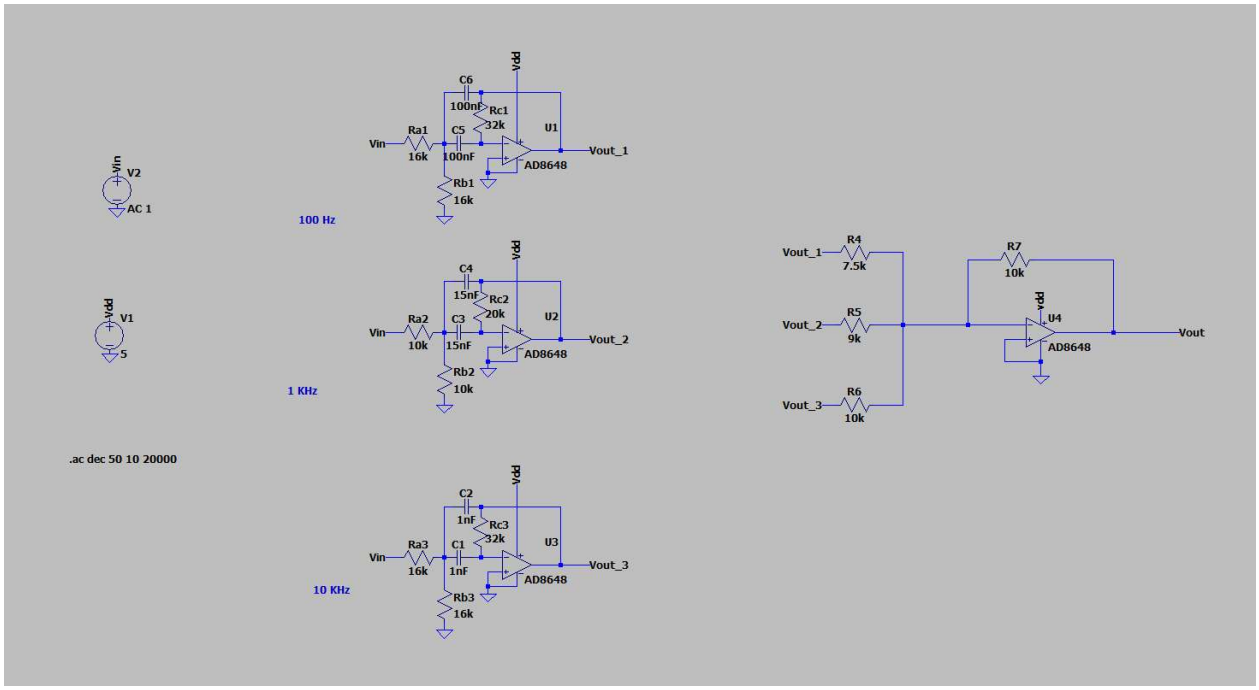
- Assuming a constant capacitance 'C',

$$\boxed{R_c = \frac{2Q}{\omega_0 C}}$$

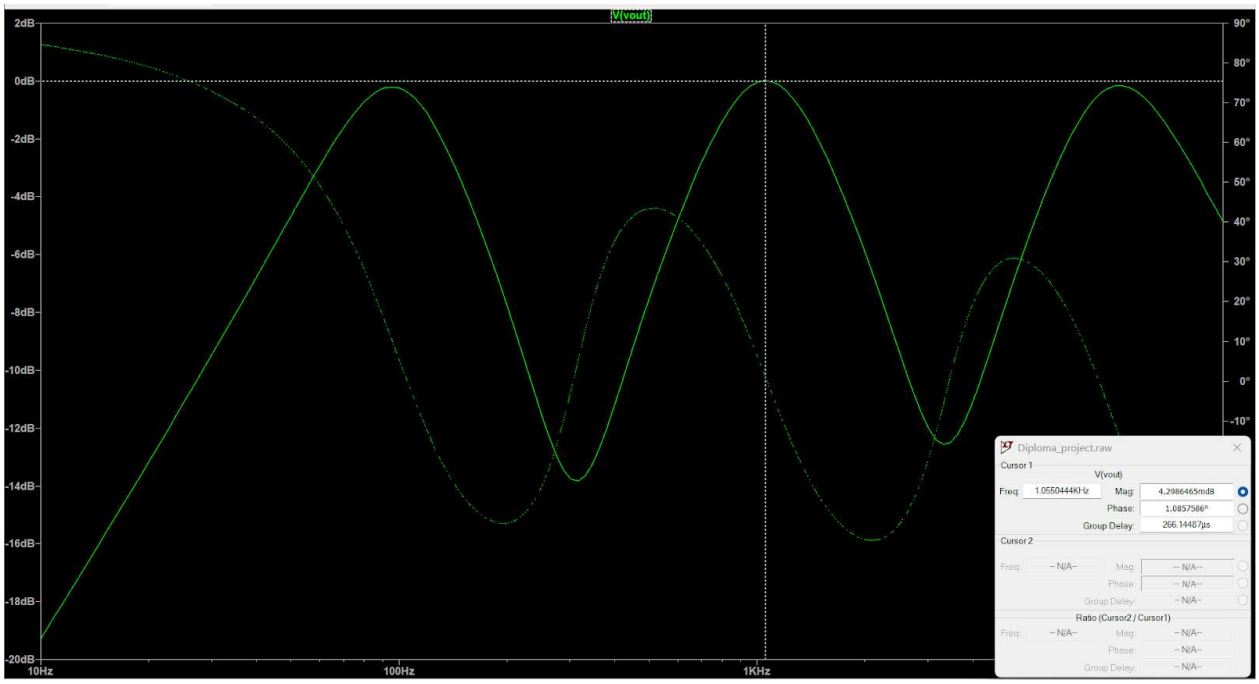
$$\boxed{R_a = \frac{Q}{A_0 \omega_0 C}}$$

$$\boxed{R_b = \frac{Q}{\omega_0 C (2Q^2 - A_0)}}$$

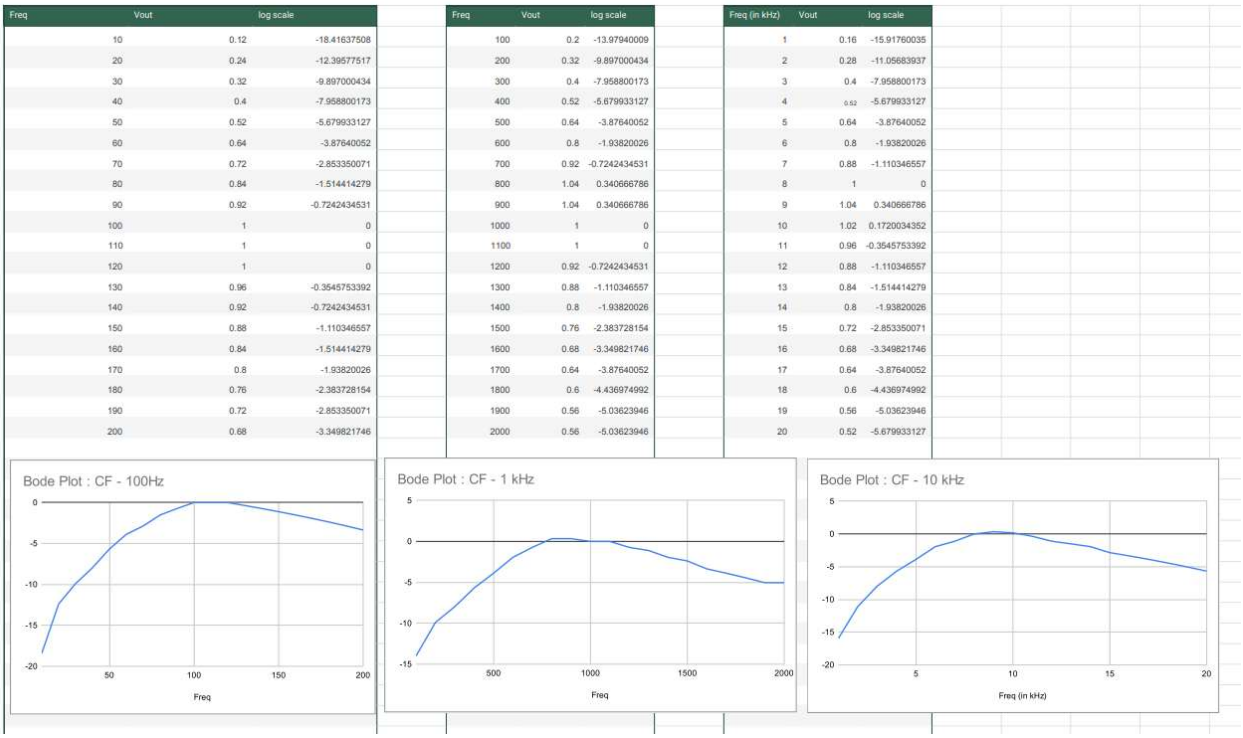
LT Spice Circuit:



LT Spice - Bode Plot:



Individual Bandpass Bode Plots:



Freq	Vout	log scale
10	0.12	-18.41637508
20	0.24	-12.39577517
30	0.32	-9.897000434
40	0.4	-7.958800173
50	0.52	-5.679933127
60	0.64	-3.87640052
70	0.72	-2.853350071
80	0.84	-1.514414279
90	0.92	-0.7242434531
100	1	0
110	1	0
120	1	0
130	0.96	-0.3545753392
140	0.92	-0.7242434531
150	0.88	-1.110346557
160	0.84	-1.514414279
170	0.8	-1.93820026
180	0.76	-2.383728154
190	0.72	-2.853350071
200	0.68	-3.349821746

Freq	Vout	log scale
100	0.2	-13.97940009
200	0.32	-9.897000434
300	0.4	-7.958800173
400	0.52	-5.679933127
500	0.64	-3.87640052
600	0.8	-1.93820026
700	0.92	-0.7242434531
800	1.04	0.340666786
900	1.04	0.340666786
1000	1	0
1100	1	0
1200	0.92	-0.7242434531
1300	0.88	-1.110346557
1400	0.8	-1.93820026
1500	0.76	-2.383728154
1600	0.68	-3.349821746
1700	0.64	-3.87640052
1800	0.6	-4.436974992
1900	0.56	-5.03623946
2000	0.56	-5.03623946

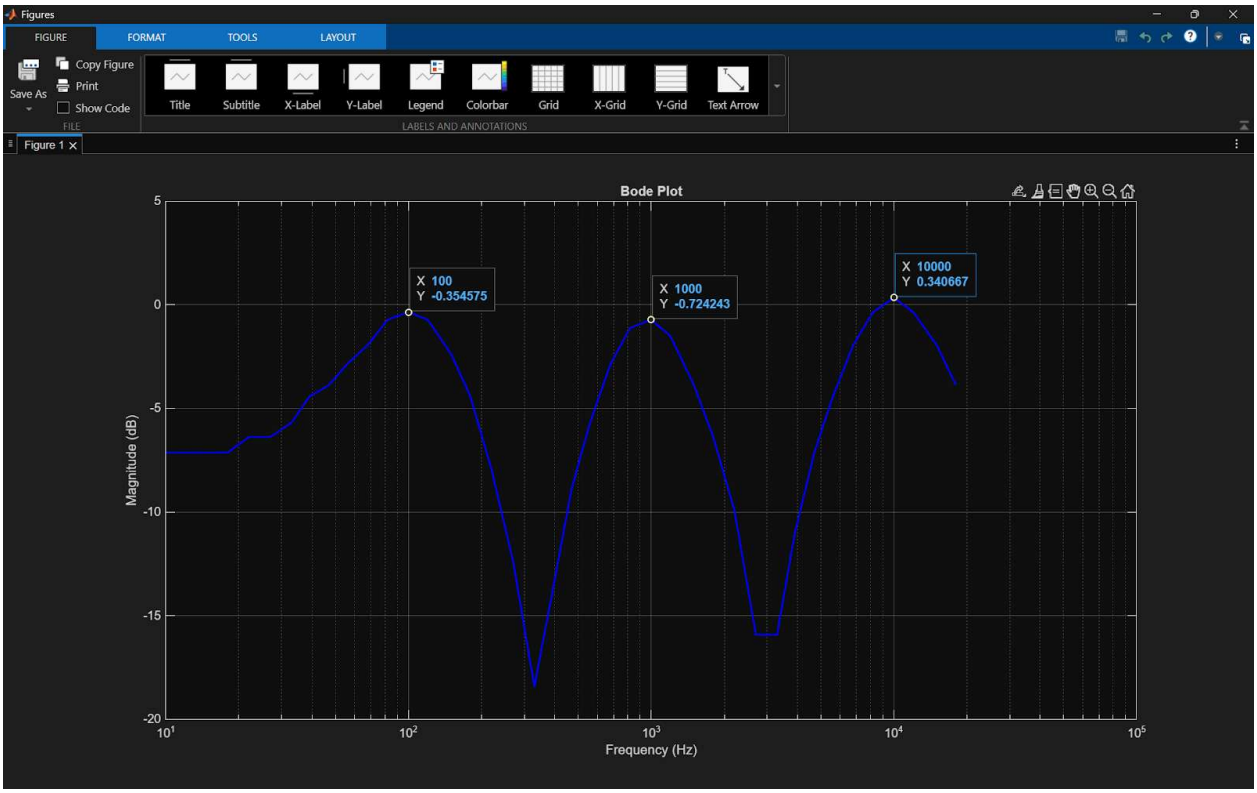
Freq (in kHz)	Vout	log scale
1	0.16	-15.91760035
2	0.28	-11.05683937
3	0.4	-7.958800173
4	0.52	-5.679933127
5	0.64	-3.87640052
6	0.8	-1.93820026
7	0.88	-1.110346557
8	1	0
9	1.04	0.340666786
10	1.02	0.1720034352
11	0.96	-0.3545753392
12	0.88	-1.110346557
13	0.84	-1.514414279
14	0.8	-1.93820026
15	0.72	-2.853350071
16	0.68	-3.349821746
17	0.64	-3.87640052
18	0.6	-4.436974992
19	0.56	-5.03623946
20	0.52	-5.679933127

Individual Bandpass Data Link

Matlab Code:

```
filename = 'Diploma_Project_Bode_plot.csv';
data = readtable(filename);
freq = data.Frequency;
Vin = 1000; %in mV
Vout = data.V_out; %in mV
magnitude_ratio = Vout ./ Vin;
magnitude_dB = 20 * log10(magnitude_ratio);
figure;
semilogx(freq, magnitude_dB, 'b', 'LineWidth', 1.5);
grid on;
title('Bode Plot');
ylabel('Magnitude (dB)');
xlabel('Frequency (Hz)');
```

Bode Plot (with Adder):



Data file

Circuit: