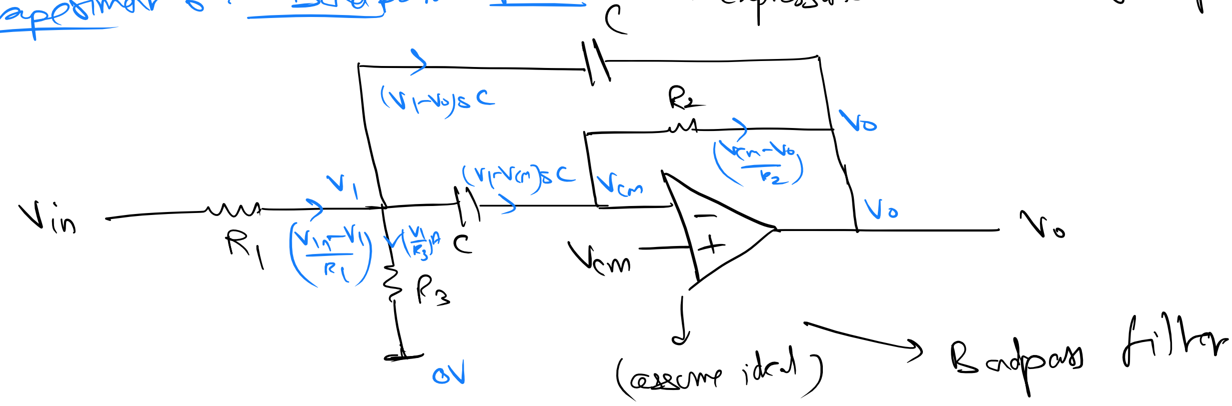
→ Experiment 6 :- Bandpass filter (Expressions & values for parameters)

↳



↳ $\frac{V_o}{V_i} = H(s)$?

→ ① $\frac{V_{in} - V_1}{R_1} = (V_1 - V_o)sC + (V_1 - V_{cm})sC + \frac{V_1}{R_3}$

② $(V_1 - V_{cm})sC = \left(\frac{V_{cm} - V_o}{R_2}\right)$

↳ $V_1 = V_{cm} + \frac{1}{R_2 sC}(V_{cm} - V_o)$

$= V_{cm}\left(1 + \frac{1}{R_2 sC}\right) - \frac{V_o}{R_2 sC}$

↳ For finding $H(s)$, V_{cm} can be made zero.. It only adds an offset to the output and we are concerned with frequency response

∴ $\frac{V_{in}}{R_1} + V_o sC = V_1\left(\frac{1}{R_1} + \frac{1}{R_3} + 2sC\right)$

& $V_1 = -\frac{V_o}{R_2 sC}$

→ ∴ $\frac{V_{in}}{R_1} + V_o sC = \left(\frac{-V_o}{R_2 sC}\right)\left(\frac{1}{R_1} + \frac{1}{R_3} + 2sC\right)$

→ $\frac{\frac{1}{R_1}}{\left(-\frac{1}{R_2 sC}\right)\left(\frac{1}{R_1} + \frac{1}{R_3} + 2sC\right) - sC} = H(s)$

↳ $H(s) = \frac{-1/R_1 \times R_2 sC}{\left(\frac{1}{R_1} + \frac{1}{R_3} + 2sC\right) + R_2 s^2 C^2}$

$= -\frac{R_2/R_1 \, sC}{(R_2 C^2) s^2 + (2C)s + \left(\frac{1}{R_1} + \frac{1}{R_3}\right)}$

↳ Comparing with standard bandpass filter $H(s) = \left(\dfrac{A_0 \frac{\omega_0}{Q_0} s}{s^2 + \frac{\omega_0}{Q_0} s + \omega_0^2} \right)$

$$\Rightarrow \frac{A_0 \omega_0}{Q_0} = \frac{\cancel{R_2 C}}{R_1} \times \frac{1}{\cancel{R_2} C^{\cancel{2}}} \qquad \rightarrow A_0 = \frac{1}{R_1 \cancel{C}} \times \frac{R_2 \cancel{C}}{2} = \frac{R_2}{2R_1}$$

$$\frac{\omega_0}{Q_0} = \frac{2C}{R_2 C^2} = \frac{2}{R_2 C} \qquad \omega_0 = \frac{1}{C}\sqrt{\frac{\frac{1}{R_1} + \frac{1}{R_3}}{R_2}} = \frac{\sqrt{R_1 + R_3}}{C\sqrt{R_1 R_2 R_3}}$$

$$\omega_0^2 = \frac{\left(\frac{1}{R_1} + \frac{1}{R_3}\right)}{R_2 C^2} \qquad Q_0 = \omega_0 \times \frac{R_2 C}{2} = \frac{R_2}{2}\sqrt{\frac{\frac{1}{R_1} + \frac{1}{R_3}}{R_2}}$$

$$= \frac{\sqrt{R_1 + R_3}\sqrt{R_2}}{2\sqrt{R_1 R_3}}$$

⇒ We desire to design bandpass filters with

↳ $A_{01} = A_{02} = 1$

$Q_{01} = Q_{02} = 10$

$f_{01} = 1\,kHz$

$f_{02} = 3\,kHz$

⇒ Calculating values

↳ $R_2 = 2R_1$

↳ $2\pi \times f = \dfrac{\sqrt{R_1 + R_3}}{C\sqrt{R_1 R_2 R_3}}$

↳ $10 = \dfrac{\sqrt{R_1 + R_3}\sqrt{R_2}}{2\sqrt{R_1 R_3}}$

→ 4 variables, 3 equations. Choose free variable ⇒ R_1

∴ $R_2 = 2R_1$

↳ $10 = \dfrac{\sqrt{R_1 + R_3}\,\sqrt{2\cancel{R_1}}}{\sqrt{2}\; 2\sqrt{\cancel{R_1} R_3}}$

→ $(10\sqrt{2})\sqrt{R_3} = \sqrt{R_1 + R_3}$

→ $200 R_3 = R_1 + R_3$

→ $R_3 = \dfrac{1}{199} R_1$

$$\rightarrow 2\pi \times f = \frac{\sqrt{\cancel{R_1}\left(1 + \frac{1}{199}\right)}\;\cancel{\sqrt{200}}\,(10)}{(R_1)(C)\left(\sqrt{(\cancel{R_1})\left(\frac{1}{199}\cancel{R_1}\right)\left(2\cancel{R_1}\right)}\right)}$$

↳ $C = \dfrac{10}{R_1 \times 2\pi f}$ → For filter 1 → $C = \dfrac{10 / 2\pi \times 10^3}{R_1}$

filter 2 ⇒ $C = \dfrac{10 / 2\pi \times 3 \times 10^3}{R_1}$