Sketch the filter requirements for a filter which must keep all frequencies \( < 26 \text{ kHz} \) (to within \( \pm 5\% \)) and reject all frequencies above 47 kHz by at least 60 dB.

Using a table, design the filter, and for each 2\(^{nd}\)-order stage in the filter, calculate \( \omega_c \) and \( \zeta \).

First, convert 5\% to dB

\[
20 \log_{10}(1.05) = 0.42, \quad 20 \log_{10}(1.05) = -0.45
\]

In table, choose **FILTER = Chebychev 0.2dB**

Next, calculate \( F_s = f_s/f_p = 47/26 = 1.81 \)

- **Design of stage #1:**
  \[ \omega_c = 26 \times 0.343 = 8.92 \text{ kHz} \]
  \[ \text{Gain} = 3 - 2\zeta = 3 - 2 \times 0.807 = 1.39 \]

- **Design of stage #2:**
  \[ \omega_c = 26 \times 0.623 = 16.20 \text{ kHz} \]
  \[ \text{Gain} = 3 - 2\zeta = 3 - 2 \times 0.377 = 2.25 \]

- **Design of stage #3:**
  \[ \omega_c = 26 \times 0.878 = 22.83 \text{ kHz} \]
  \[ \text{Gain} = 3 - 2\zeta = 3 - 2 \times 0.179 = 2.64 \]

- **Design of stage #4:**
  \[ \omega_c = 26 \times 1.021 = 26.55 \text{ kHz} \]
  \[ \text{Gain} = 3 - 2\zeta = 3 - 2 \times 0.054 = 2.89 \]
Design a 2nd-order RLC low-pass filter, with $f_c = 26$ kHz and $\zeta = 0.8$. Use $C = 10$ nF.

Natural frequency: $\omega_c = 2\pi f_c = 2\pi (26$ kHz$) = 163363$ rad/s

$$\omega_c = \frac{1}{\sqrt{LC}}, \quad \Rightarrow \quad L = \frac{1}{\omega^2 \times C} = 3.75$\, mH.

$$\zeta = \frac{R}{2\sqrt{L/C}}, \quad \Rightarrow \quad R = 2\zeta\sqrt{\frac{L}{C}} = 979$\, Ω
• Design a 2nd-order Salen-Key high-pass filter, with $f_c = 2$ kHz and $\zeta = 0.7$. Use $C = 10 \text{nF}$ and $R_2 = 10 \text{k}\Omega$.

• Select cut-off frequency: $\omega_c = 2\pi f_c = 2\pi (2 \text{ kHz}) = 12566 \text{ rad/s}$

$$\omega_c = \frac{1}{RC}, \quad \Rightarrow \quad R = \frac{1}{C \times \omega_c} = \frac{1}{12566 \times 10 \text{ nF}} = 7.96 \text{k}\Omega$$

• Select Gain: $2\zeta = 3 - G$

$G = 3 - 2\zeta = 3 - 2 \times 0.7 = 1.60$

$$G = 1 + \frac{R_1}{R_2}, \quad \Rightarrow \quad R_1 = R_2 \times (G - 1), \quad \Rightarrow \quad 6.00 \text{k}\Omega$$