• Sketch the filter requirements for a filter which must keep all frequencies < 22 kHz (to within ±5%) and reject all frequencies above 40 kHz by at least 60 dB.

• Using a table, design the filter, and for each 2nd-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 \( F_s = \frac{f_s}{f_p} = \frac{40}{22} = 1.82 \)

• Design of stage #1:
  \( \omega_c = 22 \times 0.343 = 7.55 \text{ kHz} \)
  \( \text{Gain} = 3 - 2\zeta = 3 - 2 \times 0.807 = 1.39 \)

• Design of stage #2:
  \( \omega_c = 22 \times 0.623 = 13.71 \text{ kHz} \)
  \( \text{Gain} = 3 - 2\zeta = 3 - 2 \times 0.377 = 2.25 \)

• Design of stage #3:
  \( \omega_c = 22 \times 0.878 = 19.32 \text{ kHz} \)
  \( \text{Gain} = 3 - 2\zeta = 3 - 2 \times 0.179 = 2.64 \)

• Design of stage #4:
  \( \omega_c = 22 \times 1.021 = 22.46 \text{ kHz} \)
  \( \text{Gain} = 3 - 2\zeta = 3 - 2 \times 0.054 = 2.89 \)
Design a 2$^{nd}$-order RLC low-pass filter, with $f_c = 22$ kHz and $\zeta = 0.6$. Use $C = 10$ nF.

Natural frequency: $\omega_c = 2\pi f_c = 2\pi \times (22 \text{ kHz}) = 138230$ rad/s

$$\omega_c = \frac{1}{\sqrt{LC}}, \quad \rightarrow \quad L = \frac{1}{\omega^2 \times C} = 5.23 \text{ mH}.$$  

$$\zeta = \frac{R}{2 \sqrt{\frac{C}{L}}}, \quad \rightarrow \quad R = 2\zeta \sqrt{\frac{L}{C}} = 868 \Omega$$
• Design a 2nd-order Salen-Key high-pass filter, with \( f_c = 2 \text{ kHz} \) 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: \( 2\zeta = 3 - G \)

\[
G = 3 - 2\zeta = 3 - 2 \times 0.7 = 1.60
\]

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