• Sketch the filter requirements for a filter which must keep all frequencies < 28 kHz (to within ±5%) and reject all frequencies above 89 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 FILTTER = Chebychev 0.2dB

Next, calculate $F_s = f_s/f_p = 89/28 = 3.18$

• Design of stage #1:
  $\omega_c = 28 \times 0.46 = 12.88$ kHz
  Gain = $3 - 2\zeta = 3 - 2 \times 0.799 = 1.40$

• Design of stage #2:
  $\omega_c = 28 \times 0.803 = 22.48$ kHz
  Gain = $3 - 2\zeta = 3 - 2 \times 0.335 = 2.33$

• Design of stage #3:
  $\omega_c = 28 \times 1.038 = 29.06$ kHz
  Gain = $3 - 2\zeta = 3 - 2 \times 0.095 = 2.81$
• Design a 2\textsuperscript{nd}-order RLC low-pass filter, with \( f_c = 28 \text{kHz} \) and \( \zeta = 1.2 \). Use \( C = 10 \text{nF} \).

Natural frequency: \( \omega_c = 2\pi f_c = 2\pi (28 \text{kHz}) = 175929 \text{rad/s} \)

\[
\omega_c = \frac{1}{\sqrt{LC}}, \quad \rightarrow \quad L = \frac{1}{\omega^2 \times C} = 3.23 \text{mH}.
\]

\[
\zeta = \frac{R}{2 \sqrt{LC}}, \quad \rightarrow \quad R = 2\zeta \sqrt{\frac{L}{C}} = 1364 \Omega
\]
• Design a 2nd-order Salen-Key high-pass filter, with \( f_c = 3 \text{ kHz} \) and \( \zeta = 0.6 \). Use \( C = 10 \text{ nF} \) and \( R_2 = 10 \text{ k} \Omega \).

• Select cut-off frequency: \( \omega_c = 2\pi f_c = 2\pi (3 \text{ kHz}) = 18850 \text{ rad/s} \)

\[
\omega_c = \frac{1}{RC}, \quad \Rightarrow \quad R = \frac{1}{C \times \omega_c} = \frac{1}{18850 \times 10 \text{ nF}} = 5.31 \text{ k} \Omega
\]

• Select Gain: \( 2\zeta = 3 - G \)

\[
G = 3 - 2\zeta = 3 - 2 \times 0.6 = 1.80
\]

\[
G = 1 + \frac{R_1}{R_2}, \quad \Rightarrow \quad R_1 = R_2 \times (G - 1), \quad \Rightarrow \quad 8.00 \text{ k} \Omega
\]