- Sketch the filter requirements for a filter which must keep all frequencies \(< 23\,\text{kHz}\) (to within \(\pm 5\%\)) and reject all frequencies above 78 kHz by at least 60 dB.

- Using a table, design the filter, and for each 2\textsuperscript{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 \texttt{FILTER} = Chebychev 0.2\texttt{dB}

Next, calculate \(F_s = f_s/f_p = 78/23 = 3.39\)

- Design of stage #1:
  \(\omega_c = 23 \times 0.46 = 10.58\,\text{kHz}\)
  
  Gain = \(3 - 2\zeta = 3 - 2 \times 0.799 = 1.40\)

- Design of stage #2:
  \(\omega_c = 23 \times 0.803 = 18.47\,\text{kHz}\)
  
  Gain = \(3 - 2\zeta = 3 - 2 \times 0.335 = 2.33\)

- Design of stage #3:
  \(\omega_c = 23 \times 1.038 = 23.87\,\text{kHz}\)
  
  Gain = \(3 - 2\zeta = 3 - 2 \times 0.095 = 2.81\)
• Design a 2nd-order RLC low-pass filter, with \( f_c = 23 \text{ kHz} \) and \( \zeta = 1.3 \). Use \( C = 10 \text{ nF} \).

Natural frequency: \( \omega_c = 2\pi f_c = 2\pi (23 \text{ kHz}) = 144513 \text{ rad/s} \)

\[
\omega_c = \frac{1}{\sqrt{LC}}, \quad \rightarrow \quad L = \frac{1}{\omega^2 \times C} = 4.79 \text{ mH}.
\]

\[
\zeta = \frac{R}{2} \sqrt{\frac{C}{L}}, \quad \rightarrow \quad R = 2\zeta \sqrt{\frac{L}{C}} = 1799 \Omega
\]
• Design a 2\textsuperscript{nd}-order Salen-Key high-pass filter, with $f_c = 3$ kHz and $\zeta = 0.6$. Use $C = 10$ nF and $R_2 = 10$ kΩ.

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

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

• Select Gain: $2\zeta = 3 - G$

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

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