• Sketch the filter requirements for a filter which must keep all frequencies \(< 20 \text{kHz}\) (to within \(\pm 5\%\)) and reject all frequencies above 54 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 \text{FILTER} = \text{Chebychev 0.2dB}

Next, calculate \(F_s = f_s/f_p = 54/20 = 2.70\)

• Design of stage #1:
  \(\omega_c = 20 \times 0.46 = 9.20\ \text{kHz}\)
  \(\text{Gain} = 3 - 2\zeta = 3 - 2 \times 0.799 = 1.40\)

• Design of stage #2:
  \(\omega_c = 20 \times 0.803 = 16.06\ \text{kHz}\)
  \(\text{Gain} = 3 - 2\zeta = 3 - 2 \times 0.335 = 2.33\)

• Design of stage #3:
  \(\omega_c = 20 \times 1.038 = 20.76\ \text{kHz}\)
  \(\text{Gain} = 3 - 2\zeta = 3 - 2 \times 0.095 = 2.81\)
• Design a 2nd-order RLC low-pass filter, with $f_c = 20$ kHz and $\zeta = 1.1$. Use $C = 10$ nF.

Natural frequency: $\omega_c = 2\pi f_c = 2\pi(20 \text{ kHz}) = 125664 \text{ rad/s}$

$$\omega_c = \frac{1}{\sqrt{LC}}, \quad \rightarrow \quad L = \frac{1}{\omega^2 \times C} = 6.33 \text{ mH}.$$  

$$\zeta = \frac{R}{2 \sqrt{L/C}}, \quad \rightarrow \quad R = 2\zeta \sqrt{\frac{L}{C}} = 1751 \Omega$$
- 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 \( R_2 = 10 \) k\( \Omega \).

- Select cut-off frequency: \( \omega_c = 2\pi f_c = 2\pi (3 \) kHz) = 18850 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: \( 2\zeta = 3 - G \)

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

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

\[\text{Diagram}\]