• Sketch the filter requirements for a filter which must keep all frequencies < 21 kHz (to within ±5%) and reject all frequencies above 47 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 $F_s = f_s/f_p = 47/21 = 2.24$

• Design of stage #1:
  $\omega_c = 21 \times 0.343 = 7.20$ kHz
  Gain = $3 - 2\zeta = 3 - 2 \times 0.807 = 1.39$

• Design of stage #2:
  $\omega_c = 21 \times 0.623 = 13.08$ kHz
  Gain = $3 - 2\zeta = 3 - 2 \times 0.377 = 2.25$

• Design of stage #3:
  $\omega_c = 21 \times 0.878 = 18.44$ kHz
  Gain = $3 - 2\zeta = 3 - 2 \times 0.179 = 2.64$

• Design of stage #4:
  $\omega_c = 21 \times 1.021 = 21.44$ kHz
  Gain = $3 - 2\zeta = 3 - 2 \times 0.054 = 2.89$
- Design a 2nd-order RLC low-pass filter, with $f_c = 21\text{ kHz}$ and $\zeta = 0.9$. Use $C = 10\text{ nF}$.

Natural frequency: $\omega_c = 2\pi f_c = 2\pi (21\text{ kHz}) = 131947\text{ rad/s}$

$$\omega_c = \frac{1}{\sqrt{LC}}, \quad \Rightarrow \quad L = \frac{1}{\omega^2 \times C} = 5.74\text{ mH}.$$  

$$\zeta = \frac{R}{2} \sqrt{\frac{C}{L}}, \quad \Rightarrow \quad R = 2\zeta \sqrt{\frac{L}{C}} = 1364\Omega$$
• Design a 2\textsuperscript{nd}-order Salen-Key high-pass filter, with \( f_c = 2 \) kHz and \( \zeta = 0.8 \). Use \( C = 10 \) nF and \( R_2 = 10 \) k\( \Omega \).

• Select cut-off frequency: \( \omega_c = 2\pi f_c = 2\pi (2 \) kHz\) = 12566 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: \( 2\zeta = 3 - G \)

\[
G = 3 - 2\zeta = 3 - 2 \times 0.8 = 1.40
\]

\[
G = 1 + \frac{R_1}{R_2}, \quad \rightarrow \quad R_1 = R_2 \times (G - 1), \quad \rightarrow \quad 4.00 \text{ k}\Omega
\]