• Sketch the filter requirements for a filter which must keep all frequencies < 22 kHz (to within ±5%) and reject all frequencies above 43 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 0.2 dB

Next, calculate $F_s = f_s/f_p = 43/22 = 1.95$

• Design of stage #1:
  $\omega_c = 22 \times 0.343 = 7.55$ kHz
  Gain = $3 - 2\zeta = 3 - 2 \times 0.807 = 1.39$

• Design of stage #2:
  $\omega_c = 22 \times 0.623 = 13.71$ kHz
  Gain = $3 - 2\zeta = 3 - 2 \times 0.377 = 2.25$

• Design of stage #3:
  $\omega_c = 22 \times 0.878 = 19.32$ kHz
  Gain = $3 - 2\zeta = 3 - 2 \times 0.179 = 2.64$

• Design of stage #4:
  $\omega_c = 22 \times 1.021 = 22.46$ kHz
  Gain = $3 - 2\zeta = 3 - 2 \times 0.054 = 2.89$
Design a 2\textsuperscript{nd}-order RLC low-pass filter, with $f_c = 22$ kHz and $\zeta = 0.8$. Use $C = 10$ nF.

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

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

\[
\zeta = \frac{R}{2\sqrt{LC}}, \quad \Rightarrow \quad R = 2\zeta\sqrt{\frac{L}{C}} = 1157 \Omega
\]
- Design a 2nd-order Salen-Key high-pass filter, with $f_c = 2$ kHz and $\zeta = 0.6$. Use $C = 10 \text{nF}$ and $R_2 = 10 \text{k}\Omega$.

- Select cut-off frequency: $\omega_c = 2\pi f_c = 2\pi(2 \text{ kHz}) = 12566 \text{ rad/s}$

$$\omega_c = \frac{1}{RC}, \quad \Rightarrow \quad R = \frac{1}{C \times \omega_c} = \frac{1}{12566 \times 10 \text{ nF}} = 7.96 \text{k}\Omega$$

- Select Gain: $2\zeta = 3 - G$

$G = 3 - 2\zeta = 3 - 2 \times 0.6 = 1.80$

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