• Sketch the filter requirements for a filter which must keep all frequencies < 21 kHz (to within ±5%) and reject all frequencies above 38 kHz by at least 60 dB.

• Using a table, design the filter, and for each 2nd-order stage in the filter, calculate ω_c and ζ.

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 \( F_s = \frac{f_s}{f_p} = \frac{38}{21} = 1.81 \)

• Design of stage #1:
  \( \omega_c = 21 \times 0.343 = 7.20 \text{ kHz} \)
  \[ \text{Gain} = 3 - 2\zeta = 3 - 2 \times 0.807 = 1.39 \]

• Design of stage #2:
  \( \omega_c = 21 \times 0.623 = 13.08 \text{ kHz} \)
  \[ \text{Gain} = 3 - 2\zeta = 3 - 2 \times 0.377 = 2.25 \]

• Design of stage #3:
  \( \omega_c = 21 \times 0.878 = 18.44 \text{ kHz} \)
  \[ \text{Gain} = 3 - 2\zeta = 3 - 2 \times 0.179 = 2.64 \]

• Design of stage #4:
  \( \omega_c = 21 \times 1.021 = 21.44 \text{ kHz} \)
  \[ \text{Gain} = 3 - 2\zeta = 3 - 2 \times 0.054 = 2.89 \]
Design a 2nd-order RLC low-pass filter, with $f_c = 21\, \text{kHz}$ and $\zeta = 0.8$. Use $C = 10\, \text{nF}$.

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

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

$$\zeta = \frac{R}{2} \sqrt{\frac{C}{L}}, \quad \rightarrow \quad R = 2\zeta \sqrt{\frac{L}{C}} = 1213\, \Omega$$

![RLC Circuit Diagram]

\[ V_i \quad 1213\, \Omega \quad 5.74\, \text{mH} \quad V_o \]

\[ 10\, \text{nF} \]
• Design a 2nd-order Salen-Key high-pass filter, with $f_c = 2$ kHz and $\zeta = 0.5$. Use $C = 10$ nF and $R_2 = 10$ kΩ.

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

\[
\omega_c = \frac{1}{RC}, \quad \Rightarrow \quad R = \frac{1}{C \times \omega_c} = \frac{1}{12566 \times 10 \text{ nF}} = 7.96 \text{ kΩ}
\]

• Select Gain: $2\zeta = 3 - G$

$G = 3 - 2\zeta = 3 - 2 \times 0.5 = 2.00$

\[G = 1 + \frac{R_1}{R_2}, \quad \Rightarrow \quad R_1 = R_2 \times (G - 1), \quad \Rightarrow \quad 10.00 \text{ kΩ}\]