Sketch the filter requirements for a filter which must keep all frequencies < 29 kHz (to within \( \pm 5\% \)) and reject all frequencies above 52 kHz by at least 60 dB.

Using a table, design the filter, and for each 2\(^{nd}\)-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 FILTER = Chebychev 0.2 dB

Next, calculate \( F_s = f_s/f_p = 52/29 = 1.79 \)

- Design of stage #1:
  \[ \omega_c = 29 \times 0.343 = 9.95 \text{ kHz} \]
  \[ \text{Gain} = 3 - 2\zeta = 3 - 2 \times 0.807 = 1.39 \]

- Design of stage #2:
  \[ \omega_c = 29 \times 0.623 = 18.07 \text{ kHz} \]
  \[ \text{Gain} = 3 - 2\zeta = 3 - 2 \times 0.377 = 2.25 \]

- Design of stage #3:
  \[ \omega_c = 29 \times 0.878 = 25.46 \text{ kHz} \]
  \[ \text{Gain} = 3 - 2\zeta = 3 - 2 \times 0.179 = 2.64 \]

- Design of stage #4:
  \[ \omega_c = 29 \times 1.021 = 29.61 \text{ kHz} \]
  \[ \text{Gain} = 3 - 2\zeta = 3 - 2 \times 0.054 = 2.89 \]
- Design a 2\textsuperscript{nd}-order RLC low-pass filter, with $f_c = 29$ kHz and $\zeta = 0.7$. Use $C = 10$ nF.

Natural frequency: $\omega_c = 2\pi f_c = 2\pi(29 \text{ kHz}) = 182212 \text{ rad/s}$

\[ \omega_c = \frac{1}{\sqrt{LC}}, \quad \rightarrow \quad L = \frac{1}{\omega^2 C} = 3.01 \text{ mH}. \]

\[ \zeta = \frac{R}{2 \sqrt{LC}}, \quad \rightarrow \quad R = 2\zeta \sqrt{\frac{L}{C}} = 768 \Omega \]

![RLC circuit diagram](image-url)
Design a 2\textsuperscript{nd}-order Salen-Key high-pass filter, with $f_c = 2 \text{ kHz}$ and $\zeta = 0.8$. 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: $2\zeta = 3 - G$

$G = 3 - 2\zeta = 3 - 2 \times 0.8 = 1.40$

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