• 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 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 $F_s = f_s/f_p = 52/29 = 1.79$

• Design of stage #1:
  $\omega_c = 29 \times 0.343 = 9.95$ kHz
  Gain = $3 - 2\zeta = 3 - 2 \times 0.807 = 1.39$

• Design of stage #2:
  $\omega_c = 29 \times 0.623 = 18.07$ kHz
  Gain = $3 - 2\zeta = 3 - 2 \times 0.377 = 2.25$

• Design of stage #3:
  $\omega_c = 29 \times 0.878 = 25.46$ kHz
  Gain = $3 - 2\zeta = 3 - 2 \times 0.179 = 2.64$

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

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

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

\[
\zeta = \frac{R}{2\sqrt{L}}, \quad \rightarrow \quad R = 2\zeta\sqrt{\frac{L}{C}} = 768 \Omega
\]
Design a 2\textsuperscript{nd}-order Salen-Key high-pass filter, with \( f_c = 2 \text{ kHz} \) and \( \zeta = 0.7 \). 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: \( 2\zeta = 3 - G \)
  
  \[ G = 3 - 2\zeta = 3 - 2 \times 0.7 = 1.60 \]
  
  \[ G = 1 + \frac{R_1}{R_2}, \quad \Rightarrow \quad R_1 = R_2 \times (G - 1), \quad \rightarrow \quad 6.00 \text{ k}\Omega \]