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

• Using a table, design the filter, and for each 2\textsuperscript{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 $F_s = \frac{f_s}{f_p} = \frac{52}{29} = 1.79$

• 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 2nd-order RLC low-pass filter, with $f_c = 29$ kHz and $\zeta = 0.7$. Use $C = 10 \text{ nF}$.

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

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

$$\zeta = \frac{R}{2} \sqrt{\frac{C}{L}}, \quad \rightarrow \quad R = 2\zeta \sqrt{\frac{L}{C}} = 768 \Omega$$
• 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: $2\zeta = 3 - G$

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

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

![Diagram of the high-pass filter circuit with annotated components and connections.](image-url)