Note: You need to show zoom-in plots of your filter response around the passband and stopband corners, for both MATLAB and SPICE results, to demonstrate that you meet the specs.

Design a 2\textsuperscript{nd} order (i.e. single biquad) bandpass filter with 1MHz center frequency and 250kHz 3dB-bandwidth.

a) Calculate $\omega_P$ and $Q_P$.
b) Plot a 3D perspective view of the magnitude response of the filter.
c) Implement the filter with a 2\textsuperscript{nd} order Sallen-Key section (see next page). Calculate all element values and the amplifier gain $K$. For simplicity make all capacitors 1pF and choose all resistors equal size. Calculate also the resulting filter gain $G$.
d) Verify the transfer function with SPICE for nominal values and with a 5\% variation of $K$. By how much are $\omega_P$ and $Q_P$ changing?
e) Calculate the sensitivity $S_K^{Q_P}$ and compare the analytical and simulation results.
f) Return to nominal component values but add two 5\% shunt capacitors from both terminals of $C_2$ to ground. By how much are $\omega_P$ and $Q_P$ changing?

(The Sallen-Key bandpass filter design equations are shown on the next page)
Second-order Sallen-Key bandpass section:

![Circuit Diagram]

Design equations:

Transfer function

$$H_{BP}(s) = \frac{G \frac{\omega_0}{Q} s}{s^2 + \frac{\omega_0}{Q} s + \omega_0^2}$$

Center frequency

$$\omega_0 = \sqrt{\frac{R_1 + R_2}{R_1R_2R_3C_1C_2}}$$

Quality factor

$$Q = \frac{\omega_0}{\frac{1}{R_1C_1} + \frac{1}{R_3C_2} + \frac{1}{R_3C_1} + \frac{1}{R_2C_1} + \frac{1-K}{R_1C_1}}$$

Gain

$$G = \frac{K}{\frac{1}{R_1C_1} + \frac{1}{R_3C_2} + \frac{1}{R_3C_1} + \frac{1}{R_2C_1} + \frac{1-K}{R_1C_1}}$$