Minimum-Sensitivity Single-Amplifier Biquadratic Filters

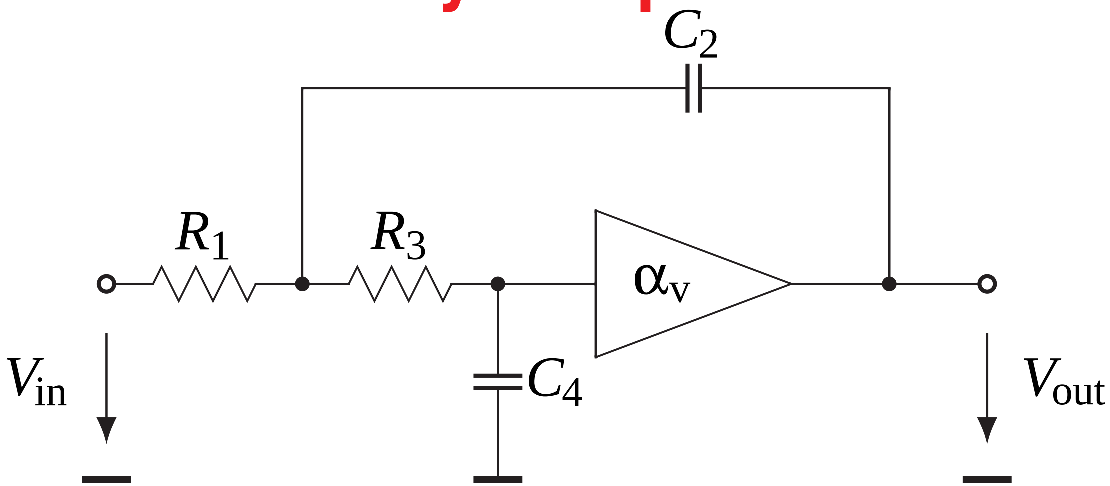
Hanspeter Schmid and George S. Moschytz
Signal and Information Processing Laboratory
Swiss Federal Institute of Technology, Zürich

General case: Gain below two.

Unity-gain: some filters need LOW component spreads.

ECCTD 1999, September 2, Stresa, Italy.

Sallen-Key Lowpass Filter

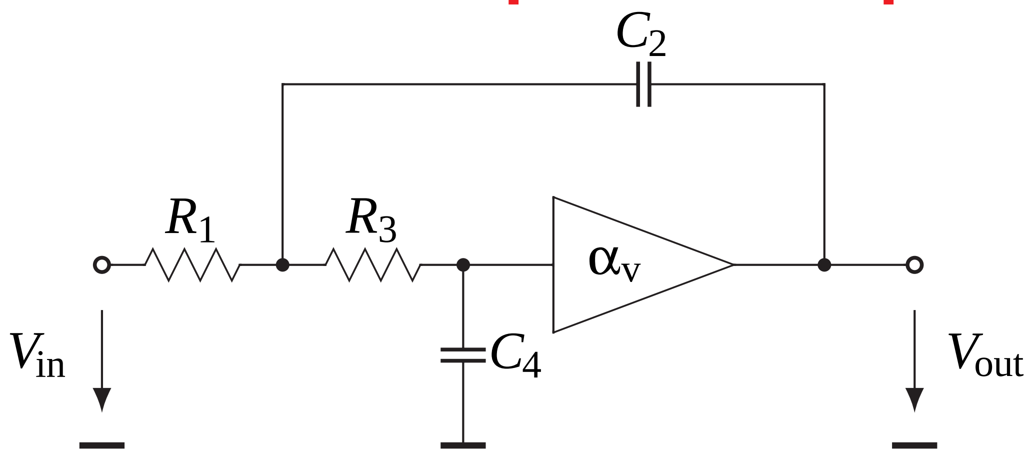


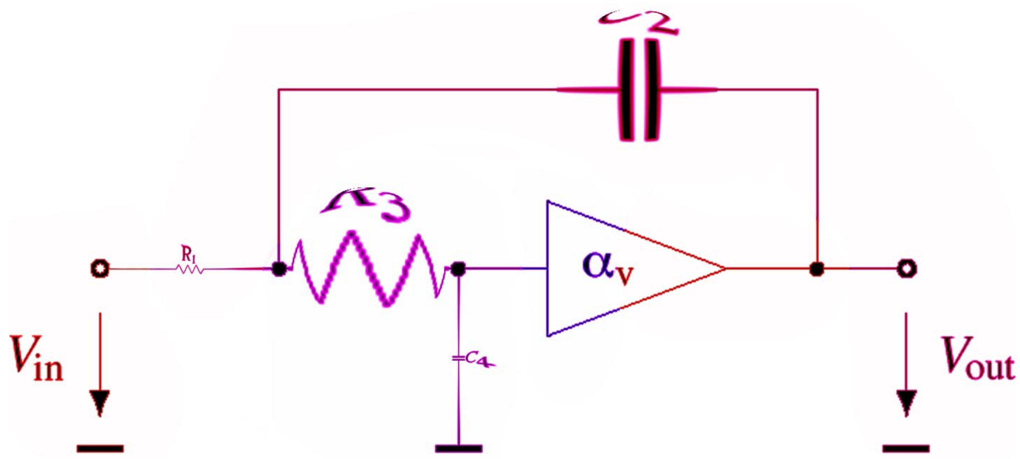
(with $R_1 = R/n$, $R_3 = R \cdot n$, $C_2 = C/m$ and $C_4 = C \cdot m$)

$$T(s) = \alpha_V \frac{\omega_p^2}{s^2 + \frac{\omega_p}{q_p} s + \omega_p^2}$$

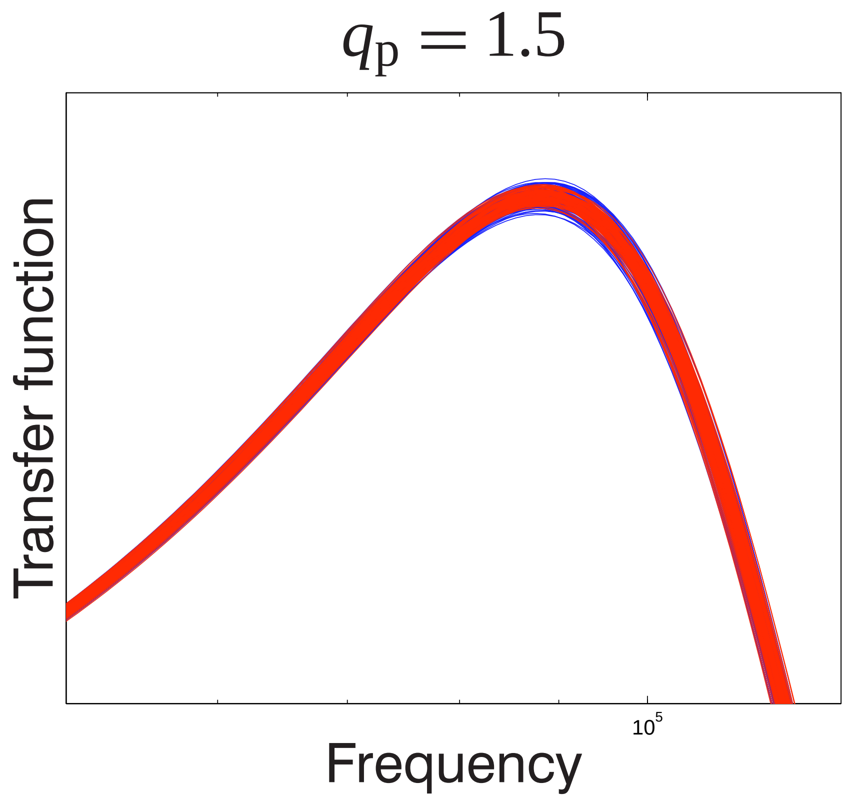
$$\omega_p = \frac{1}{RC}, \qquad \frac{1}{q_p} = mn + \frac{m}{n} + \frac{1 - \alpha_V}{mn}$$

General case: Impedance tapering





Unity-gain filter: Low component spreads

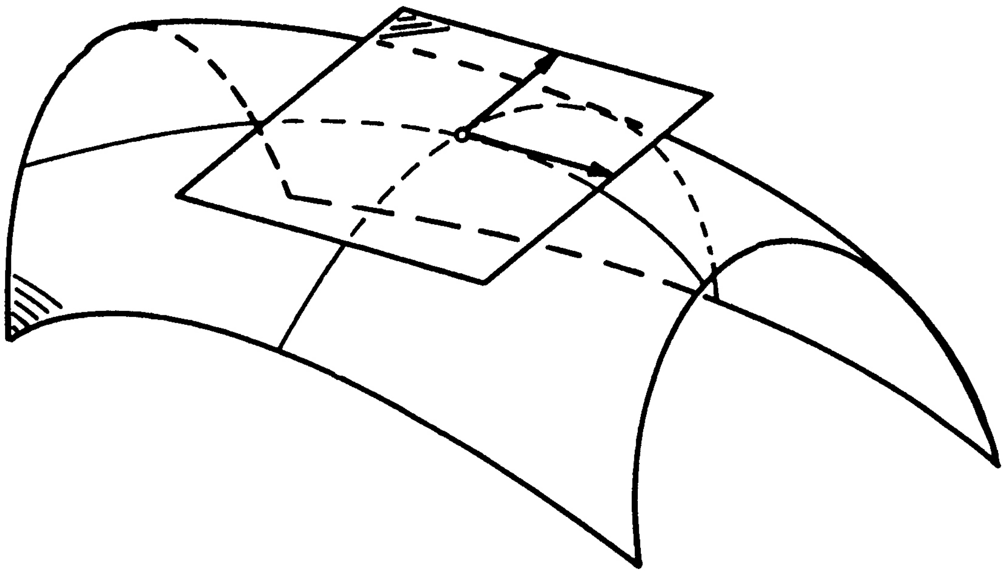


Very large and very low component spreads.

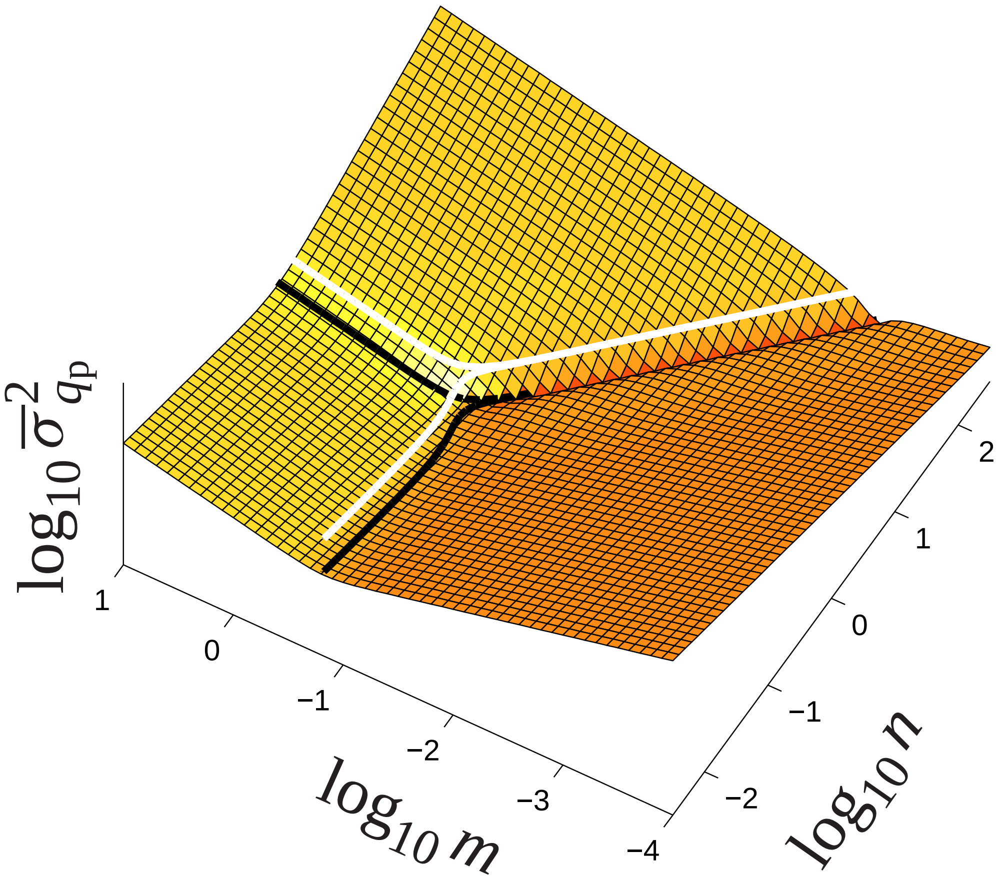
Sensitivity theory: Schöffler criterion

Relative Variances: $\overline{\sigma}^2_{R_1} = \sigma^2_{R_1} / R_1^2$

Schöffler Criterion: $\overline{\sigma}^2_{q_\mathrm{p}} \approx \sum_{x \in X} \left(S_x^{q_\mathrm{p}} \right)^2 \overline{\sigma}^2_x, \quad X = \{ R_i, C_j, \alpha_\mathrm{v} \}$



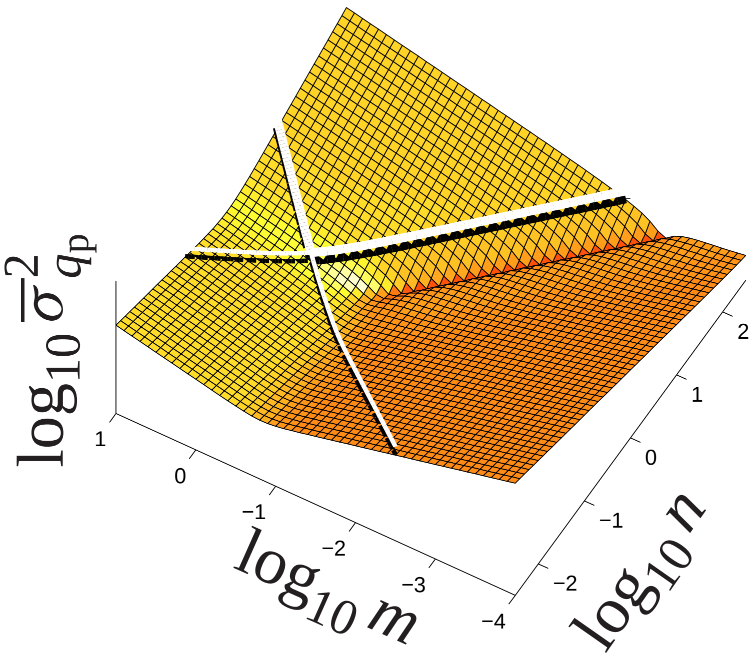
Gradients of the variance surface



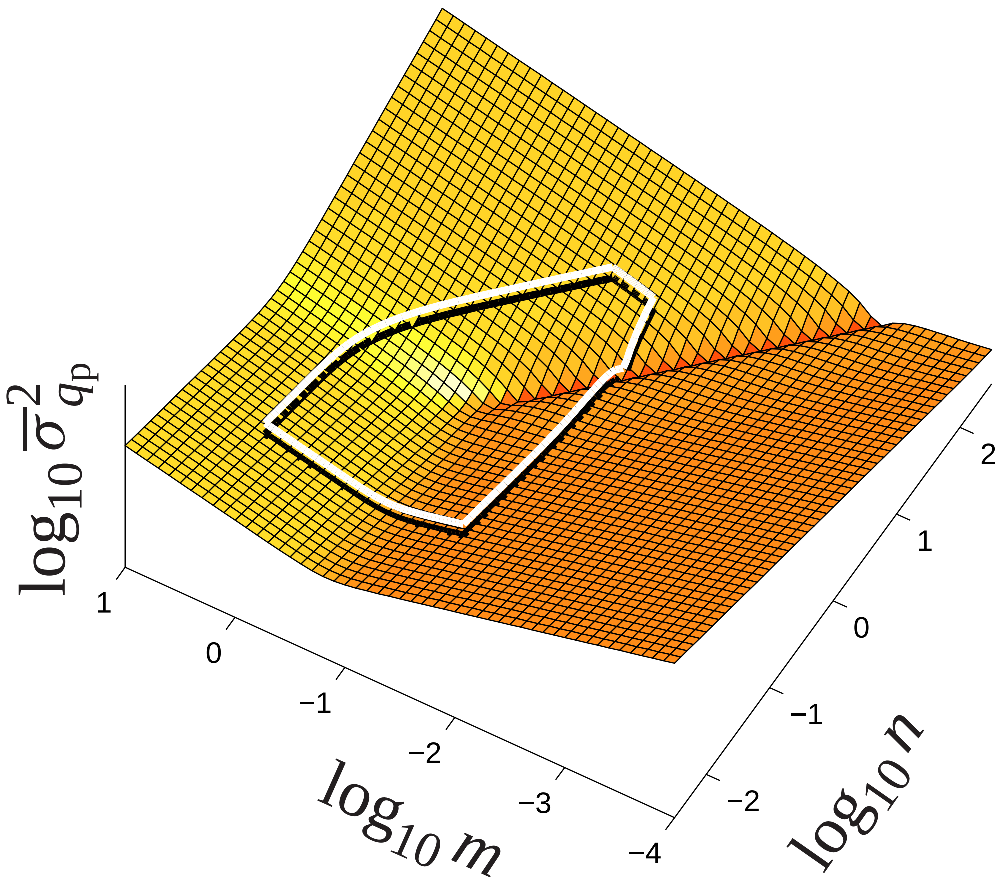
Coordinate transformation

$$\log_{10} x = \log_{10} m + \log_{10} n\,, \quad \log_{10} y = \log_{10} n - \log_{10} m$$

$$x = mn, \quad y = \frac{n}{m} \qquad \text{with } m, n, x, y > 0$$

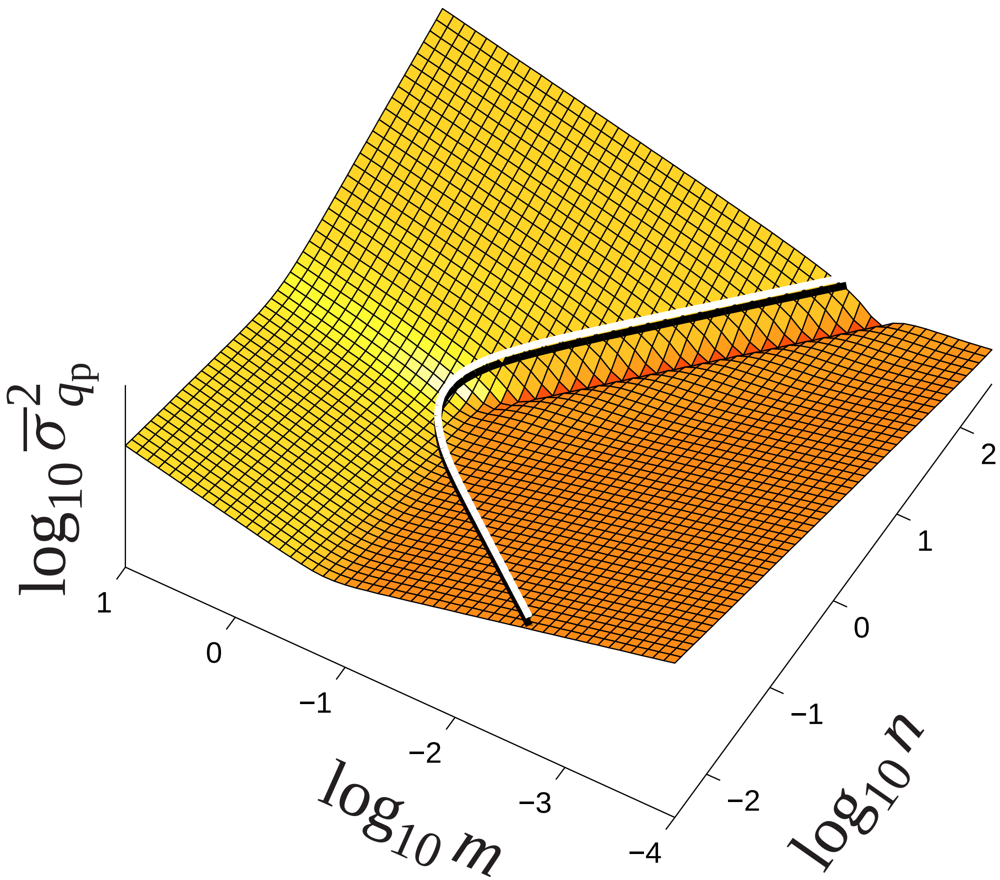


Boundary conditions

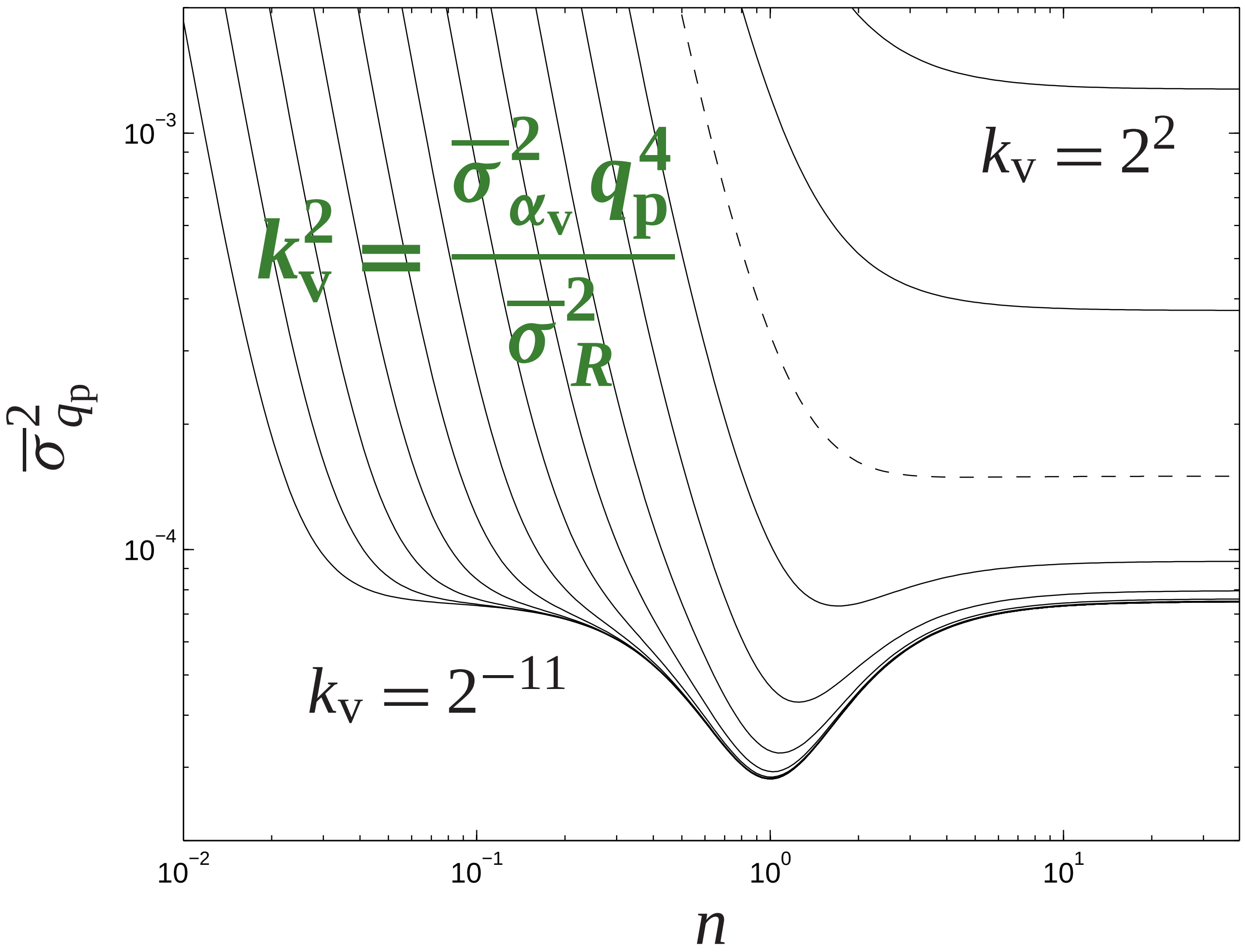


Hanspeter Schmid

Unity-gain



Optimum resistor spread



Conclusion

Results: Limit on the ideal gain in the general case;

possible existence of a low-component-spread optimum

in the unity-gain case.

This allows us to build less expensive filters.

Paper: Design equations to find optimum m and n;

mathematical proofs using root locus theory.

Alterations for Analogue IC Design:

$$\overline{\sigma}^2_{q_\mathrm{p}} \approx \sum_{x \in X} \left(S_x^{q_\mathrm{p}} \right)^2 \overline{\sigma}^2_x, \quad X = \{R, C, m, n, \alpha_\mathrm{v}\}$$