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Flat Passband Gain Design Algorithm for 2nd-order RC Polyphase Filter

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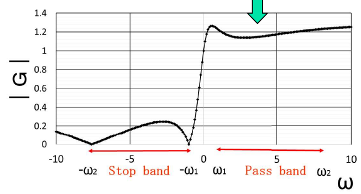
Need for Flat Passband Gain Algorithm of 2nd-order RC Polyphase Filter

Transfer Function

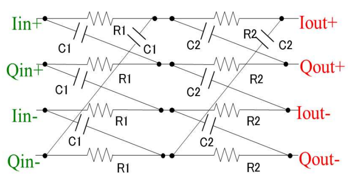
$$G_2(j\omega) = \frac{(1+\omega R_1 C_1)(1+\omega R_2 C_2)}{1-\omega^2 R_1 C_1 R_2 C_2 + j\omega(C_1 R_1 + C_2 R_2 + 2R_1 C_2)}$$

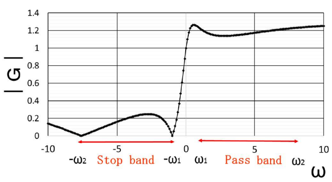
We need flat passband gain

Gain |G2(jω)| characteristics



Four Design Parameters



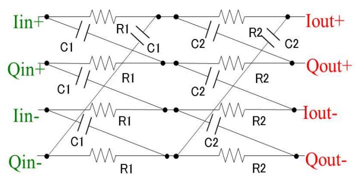


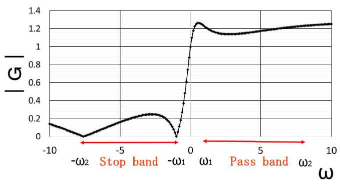
4 parameters : R_1, R_2, C_1, C_2

$$\omega_1 = \frac{1}{R_1 C_1}, \omega_2 = \frac{1}{R_2 C_2}, X = \frac{1}{R_2 C_1}, Y = \frac{1}{R_1 C_2}$$

4 constraints

Two Constraints from Filter Spec.

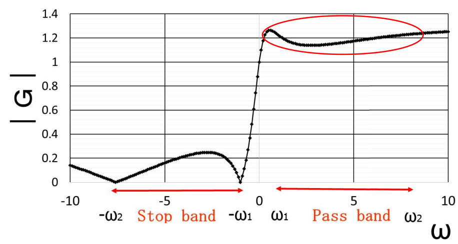




- 2 zeros : $-\omega_1 = \frac{-1}{R_1 C_1}$, $-\omega_2 = \frac{-1}{R_2 C_2}$

are given from the filter specification.

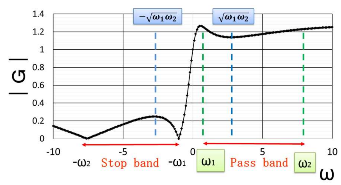
Proposed Algorithm Uses Third Constraint



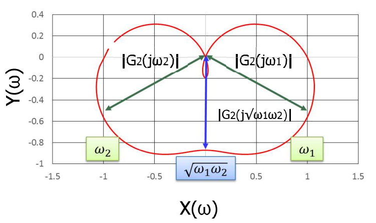
- We use the third constraint $X = \frac{1}{R_2 C_1}$ for passpand gain flattening.
- The fourth constraint is left for ease of IC realization.

Nyquist Chart of G2(jω)

Gain characteristics |G2(jω)|



Nyquist chart of G2(jω)=X(ω)+j Y(ω)

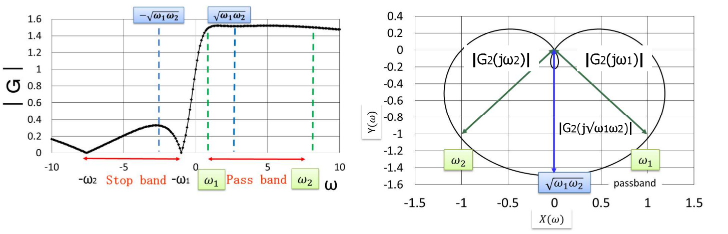


|G2(jω1)|=|G2(jω2)|

But in general |G2(jω1)|=|G2(jω2)|≠|G2(j√ω1ω2)|

Our Idea for Flat Passband Gain Algorithm

Gain characteristics |G2(jω)| Nyquist chart of G2(jω)=X(ω)+j Y(ω)



If we make $|G_2(j\omega_1)| = |G_2(j\omega_2)| = |G_2(j\sqrt{\omega_1\omega_2})|$,
gain would be flat from ω_1 to ω_2.

Solving Third Constraint

Our algorithm

$|G_2(j\omega_1)| = |G_2(j\omega_2)| = |G_2(j\sqrt{\omega_1\omega_2})|$,

$$\alpha\omega_{21}^2 + \beta\omega_{21} + \gamma = 0 \qquad \omega_{21} = \frac{1}{R_2C_1}$$

We need a positive real solution of ω_{21}.

Condition for Solution

Third constraint

$$\omega_{21} = \frac{1}{R_2C_1} = \frac{-\beta + \sqrt{\beta^2 - 4\alpha\gamma}}{2\alpha}$$

$$\alpha = 6\omega_1^2 + 6\omega_2^2 + 4\omega_1\omega_2 - 8\sqrt{\omega_1\omega_2}(\omega_1 + \omega_2)$$

$$\beta = 6\omega_1^3 + 6\omega_2^3 + 10\omega_1\omega_2(\omega_1 + \omega_2) - 8\sqrt{\omega_1\omega_2}(\omega_1 + \omega_2)^2$$

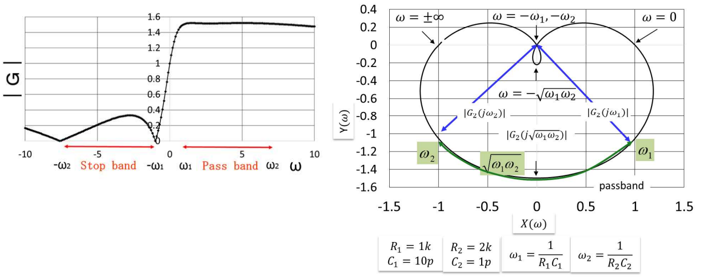
$$\gamma = \omega_1^4 + \omega_2^4 + 2\omega_1\omega_2(\omega_1^2 + \omega_2^2 + 5\omega_1\omega_2) - 4\sqrt{\omega_1\omega_2}(\omega_1^3 + \omega_1^2\omega_2 + \omega_1\omega_2^2)$$

For a positive real ω_{21} ➡ $0.79142 < \frac{\omega_1}{\omega_2} < 12.63556$

This is obtained from numerical calculation.

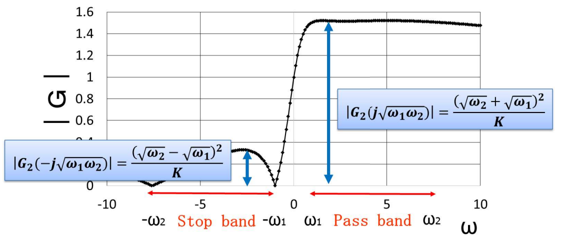
Numerical Simulation Result of Our Algorithm

Gain characteristics |G2(jω)| Nyquist chart of G2(jω)=X(ω)+j Y(ω)



Passband gain becomes flat.

Image Rejection Ratio (IRR)

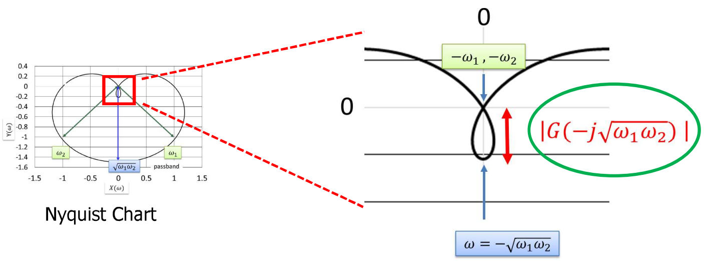


$$|G_2(-j\sqrt{\omega_1\omega_2})| = \frac{(\sqrt{\omega_2} - \sqrt{\omega_1})^2}{K} \qquad |G_2(j\sqrt{\omega_1\omega_2})| = \frac{(\sqrt{\omega_2} + \sqrt{\omega_1})^2}{K}$$

$$K = \sqrt{\frac{\omega_2}{\omega_1}} + \sqrt{\frac{\omega_1}{\omega_2}} + \frac{2\sqrt{\omega_1\omega_2}}{\omega_{12}}$$

● Image Rejection Ratio = $\frac{\textbf{Passband Gain}}{(\textbf{Stopband Gain})_{MAX}} = \left(\frac{\sqrt{\omega_2}+\sqrt{\omega_1}}{\sqrt{\omega_2}-\sqrt{\omega_1}}\right)^2$

Nyquist Chart & Image Rejection Ratio



Nyquist chart visualizes image rejection ratio.