

LOW-PASS FILTER

$$G_{LP}(s) = \frac{H_o \omega_o^2}{s^2 + 2\zeta\omega_o s + \omega_o^2}$$

Transfer Function:

$$H(s) = \frac{-R_4/R_1}{s^2 R_3 C_2 R_4 C_5 + s C_5 [R_3(1 + R_4/R_1) + R_4] + 1}$$

Parameters:

$$\omega_o = \frac{1}{(R_3 C_2 R_4 C_5)^{1/2}}$$

$$H_o = -R_4/R_1$$

$$\zeta = \frac{1}{2} (C_5/C_2)^{1/2} [(R_3/R_4)^{1/2}(1 + R_4/R_1) + (R_4/R_3)^{1/2}]$$

Design Equations: Set $C_5 = KC_2$

Given: $\omega_o, \zeta, -H_o$

Choose: C_2, K

Calculate: $C_5 = KC_2$

$$R_1 = R_4/(-H_o)$$

$$R_4 = \frac{\zeta \pm [\zeta^2 - K(1 - H_o)]^{1/2}}{\omega_o C_5} = \frac{F}{\omega_o C_5}$$

$$R_3 = \frac{1}{F\omega_o C_2}$$

Sensitivities:

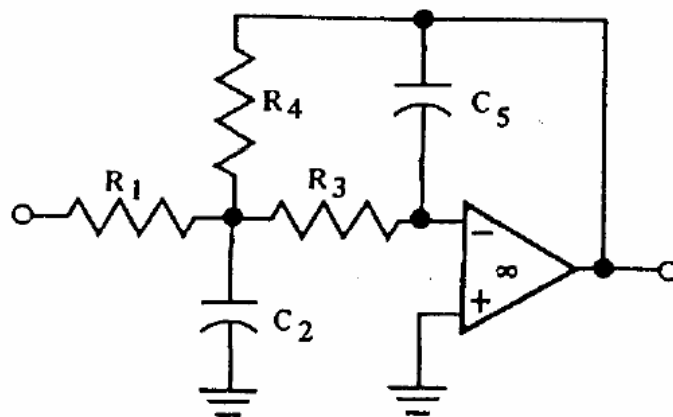
$$S_{R_3}^{\omega_o} = S_{R_4}^{\omega_o} = S_{C_2}^{\omega_o} = S_{C_4}^{\omega_o} = -\frac{1}{2}$$

$$S_{R_4}^{H_o} = -S_{R_1}^{H_o} = 1$$

$$S_{R_1}^{\zeta} = -H_o K / 2\zeta F$$

$$S_{R_3}^{\zeta} = \frac{1}{2} - F/\zeta$$

$$S_{R_4}^{\zeta} = \frac{1}{2} - K/2\zeta F$$



HIGH-PASS FILTER

$$G_{HP}(s) = \frac{H_o s^2}{s^2 + 2\zeta\omega_o s + \omega_o^2}$$

Transfer Function:

$$H(s) = \frac{-s^2 R_2 C_1 R_5 C_3}{s^2 R_2 C_4 R_5 C_3 + s[R_2 C_3 + R_2 C_4(1 + C_1/C_4)] + 1}$$

Parameters:

$$\omega_o = \frac{1}{(R_2 C_4 R_5 C_3)^{1/2}}$$

$$H_o = -C_1/C_4$$

$$\zeta = \frac{1}{2} (R_2/R_5)^{1/2} [(C_3/C_4)^{1/2} + (C_4/C_3)^{1/2} (1 + C_1/C_4)]$$

Design Equations: Set $C_1 = C_3 = C$

Given: $\omega_o, \zeta, -H_o$

Choose: C

Calculate: $C_4 = C/(-H_o)$

$$R_2 = \frac{-H_o \zeta}{(0.5 - H_o)\omega_o C} = \frac{-H_o}{F\omega_o C}$$

$$R_5 = \frac{(0.5 - H_o)}{\zeta\omega_o C} = \frac{F}{\omega_o C}$$

Sensitivities:

$$S_{R_2}^{\omega_o} = S_{R_5}^{\omega_o} = S_{C_3}^{\omega_o} = S_{C_4}^{\omega_o} = -\frac{1}{2}$$

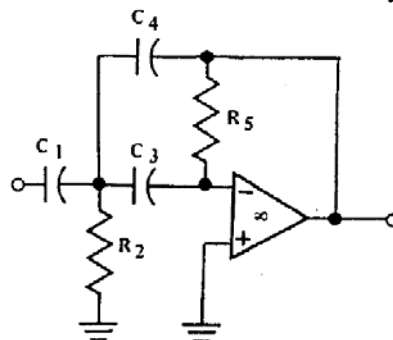
$$S_{C_3}^{\zeta} = -(H_o + 1)/2(3H_o + 1)$$

$$S_{R_2}^{\zeta} = -S_{R_5}^{\zeta} = \frac{1}{2}$$

$$S_{C_4}^{\zeta} = (-2H_o + 1)/2(2H_o + 1)$$

$$S_{C_1}^{\zeta} = H_o/(2H_o - 1)$$

$$S_{C_1}^{H_o} = -S_{C_4}^{H_o} = 1$$



BAND-PASS FILTER

$$G_{BP}(s) = \frac{H_o 2\zeta\omega_o s}{s^2 + 2\zeta\omega_o s + \omega_o^2}$$

Transfer Function:

$$H(s) = \frac{-sR_5C_3}{s^2R_1C_3R_5C_4 + sR_1(C_3 + C_4) + (1 + R_1/R_2)}$$

CLASS 2E: BAND-PASS

Transfer Function:

$$H(s) = \frac{-sR_5C_3}{s^2R_1C_3R_5C_4 + sR_1(C_3 + C_4) + (1 + R_1/R_2)}$$

Parameters:

$$\omega_o = \left[\frac{1 + R_2/R_1}{R_2C_3R_5C_4} \right]^{1/2}$$

$$H_o = \frac{-R_5/R_1}{1 + C_4/C_3}$$

$$Q = \frac{(R_5/R_1 + R_5/R_2)^{1/2}}{(C_3/C_4)^{1/2} + (C_4/C_3)^{1/2}}$$

Design Equations: Set $C_3 = C_4 = C$

Given: ω_o , Q , $-H_o$

Choose: C

Calculate: $R_1 = Q/(-H_o\omega_o C)$

$$R_2 = 1/\left[1 + H_o/2Q^2\right]2Q\omega_o C$$

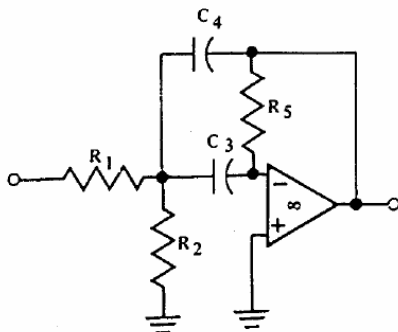
$$R_5 = 2Q/\omega_o C$$

Sensitivities:

$$S_{R_1}^{\omega_o} = S_{R_1}^Q = H_o/4Q^2$$

$$S_{R_2}^{\omega_o} = S_{R_2}^Q = \frac{1}{2} (1 + H_o/2Q^2)$$

$$S_{R_5}^{\omega_o} = S_{C_3}^{\omega_o} = S_{C_4}^{\omega_o} = -S_{R_5}^Q = -\frac{1}{2}$$



BAND-STOP FILTER

$$G_{BS}(s) = \frac{H_o (s^2 + \omega_o^2)}{s^2 + 2\zeta\omega_o s + \omega_o^2}$$

Transfer Function:

$$H(s) = \frac{R_B}{R_A + R_B} \frac{s^2 R_1 C_1 R_2 C_2 + s[R_1(C_1 + C_2) - R_2 C_2 R_A / R_B] + 1}{s^2 R_1 C_1 R_2 C_2 + s R_1(C_1 + C_2) + 1}$$

Parameters:

$$\omega_{op} = \omega_{oz} = \frac{1}{(R_1 C_1 R_2 C_2)^{1/2}}$$

$$H_o = \frac{R_B}{R_A + R_B}$$

$$\zeta_p = \frac{R_1(C_1 + C_2)}{2(R_1 C_1 R_2 C_2)^{1/2}}$$

$$\zeta_z = \frac{R_1(C_1 + C_2) - R_2 C_2 R_A / R_B}{2(R_1 C_1 R_2 C_2)^{1/2}} = 0 \text{ so that}$$

$$\frac{R_A}{R_B} = \frac{R_1(C_1 + C_2)}{R_2 C_1}$$

Design Equations: Set $C_2 = kC_1$ (For Minimum Offset)

Given: ω_o, Q_p

Choose: C_1, k

Calculate: $C_2 = kC_1$

$$R_1 = 1 / [(1+k)Q_p \omega_o C_1]$$

$$R_2 = (1+k)Q_p / \omega_o C_2$$

$$H_o = 1 / [1 + 1 / [(1+k)Q_p^2]]$$

$$R_A = R_2 / H_o$$

$$R_B = [(1+k)Q_p^2] R_A$$

