KHN Filter

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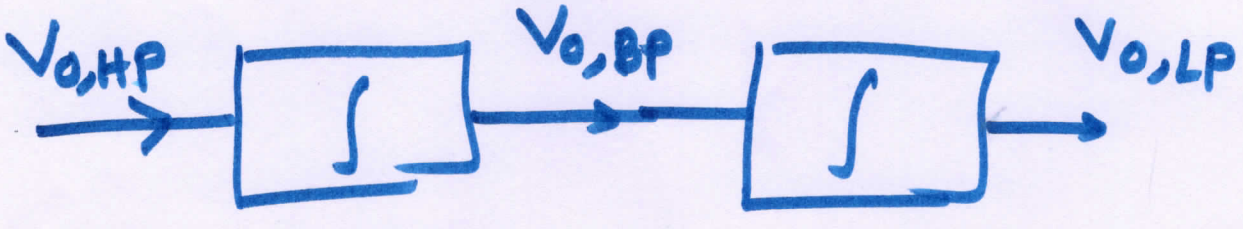
or

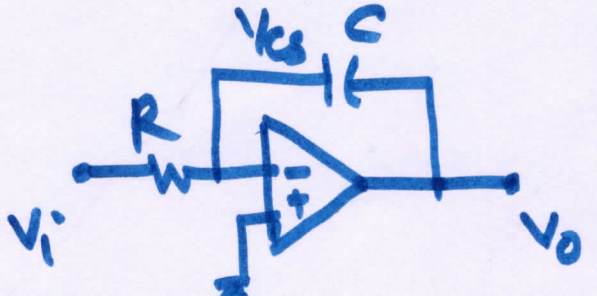
State-Variable Filter

$$\frac{V_{o,HP}}{V_i} = \frac{s^2}{s^2 + 2\zeta\omega_n s + \omega_n^2} \longrightarrow \text{HPF}$$

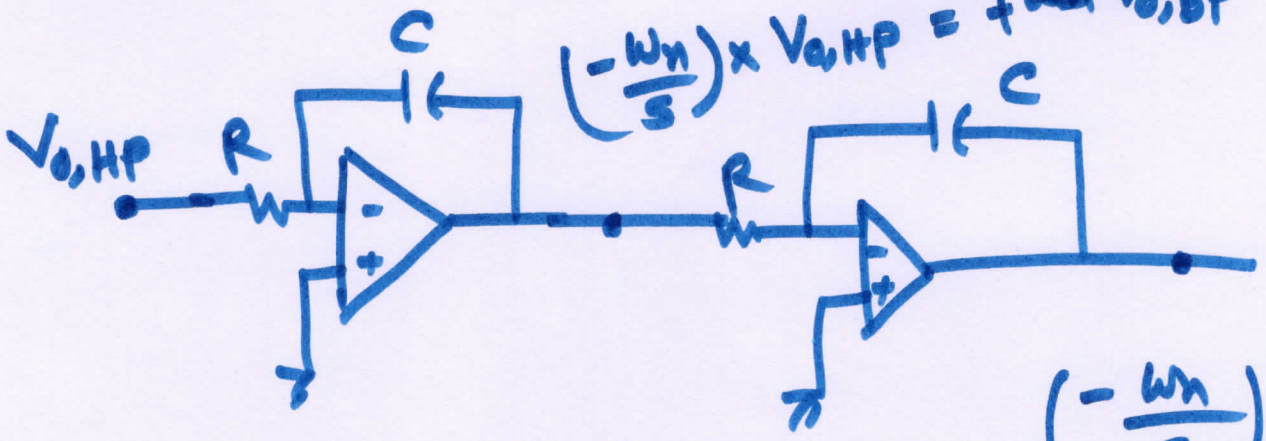
$$\frac{V_{o,BP}}{V_i} = \frac{\omega_n s}{s^2 + 2\zeta\omega_n s + \omega_n^2} \longrightarrow \text{BPF}$$

$$\frac{V_{o,LP}}{V_i} = \frac{\omega_n^2}{s^2 + 2\zeta\omega_n s + \omega_n^2} \longrightarrow \text{LPF}$$





$$\frac{V_o}{V_i} = -\frac{1/Cs}{R} = -\frac{1}{RC}\times\frac{1}{s}$$



$= V_{o,LP}$

$$\frac{V_{o,HP}}{V_i} = \frac{s^2}{s^2 + 2\zeta\omega_n s + \omega_n^2}$$

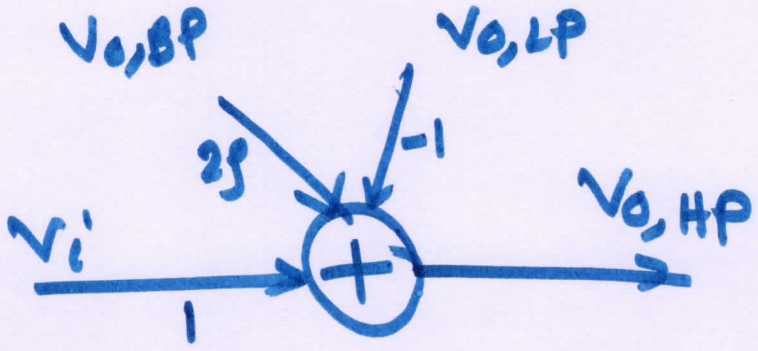
$$= \frac{1}{1 + 2\zeta\left(\frac{\omega_n}{s}\right) + \left(\frac{\omega_n}{s}\right)^2}$$

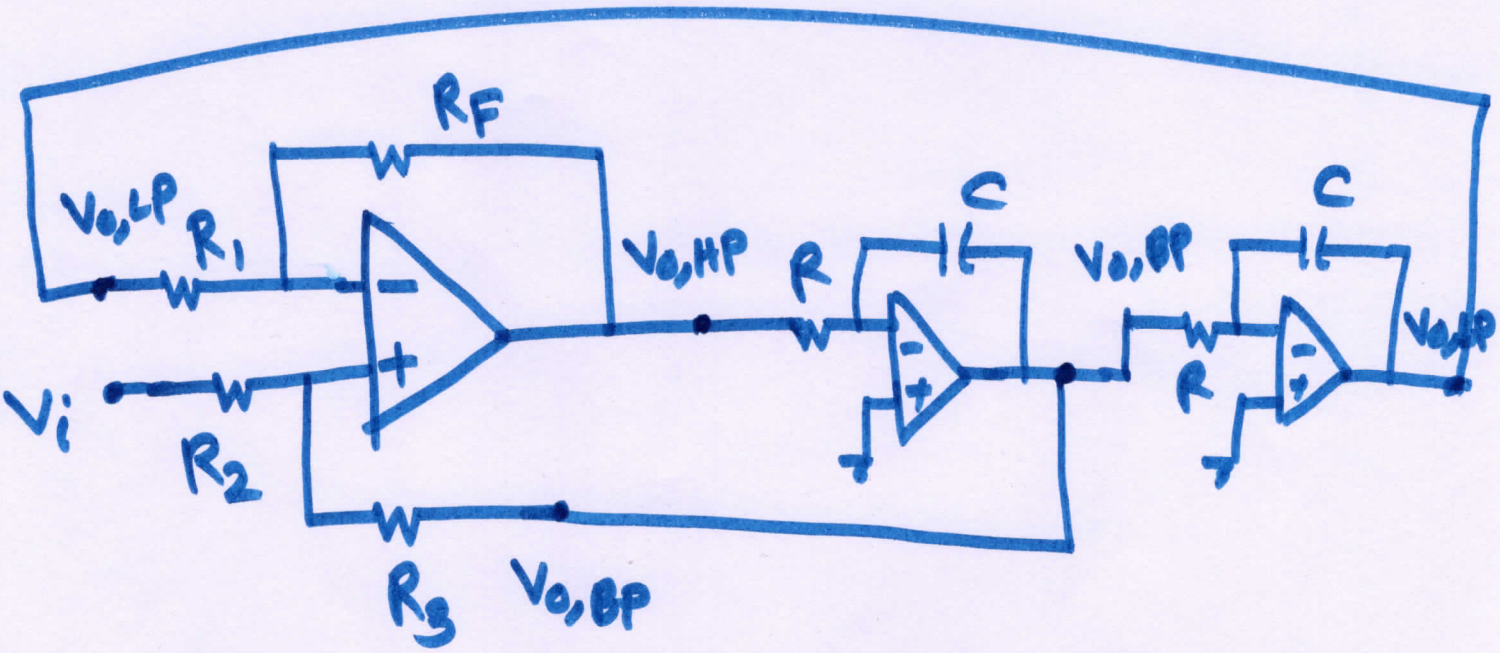
$$\Rightarrow \quad V_{o,HP} + 2\zeta\left(\frac{\omega_n}{s}\right)V_{o,HP} + \left(\frac{\omega_n}{s}\right)^2 V_{o,HP}$$

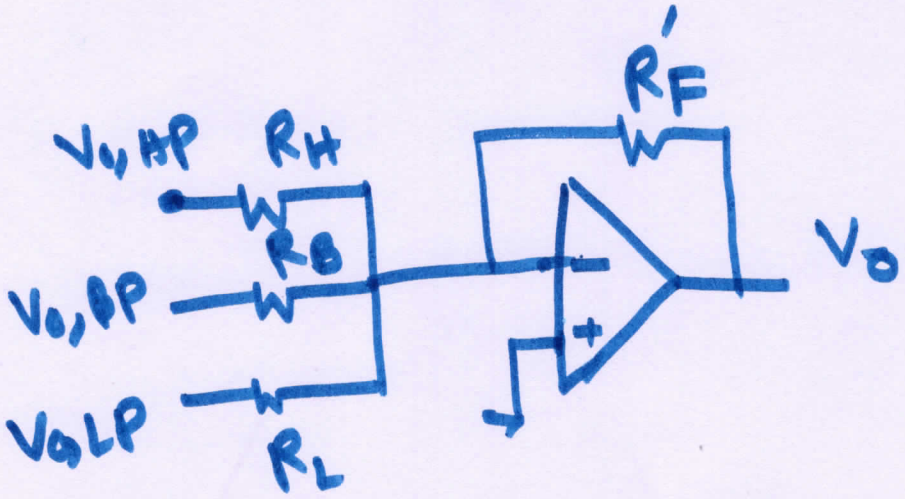
$$= V_i$$

$$\Rightarrow \quad V_{o,HP} = V_i - 2\zeta\left(\frac{\omega_n}{s}\right)V_{o,HP} - \left(\frac{\omega_n}{s}\right)^2 V_{o,HP}$$

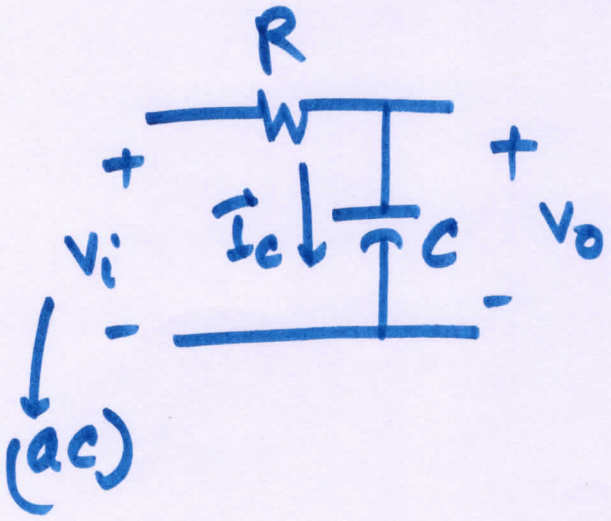
$$= V_i + 2\zeta\, V_{o,BP} - V_{o,LP}$$


$V_{o,BP}$
$V_{o,LP}$
2
-1
V_i'
1
$V_{o,HP}$


R_F
$V_{o,LP}$
R_1
$V_{o,HP}$
R
C
$V_{o,BP}$
C
V_i
R_2
R
R_3
$V_{o,BP}$


R_F'
$V_{o,HP}$
R_H
R_B
V_o
$V_{o,BP}$
V_{oLP}
R_L

phasor- Diagram



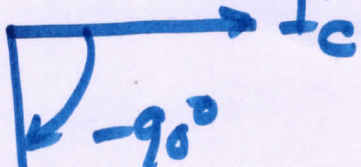
$$V_i = V \sin(\omega t)$$

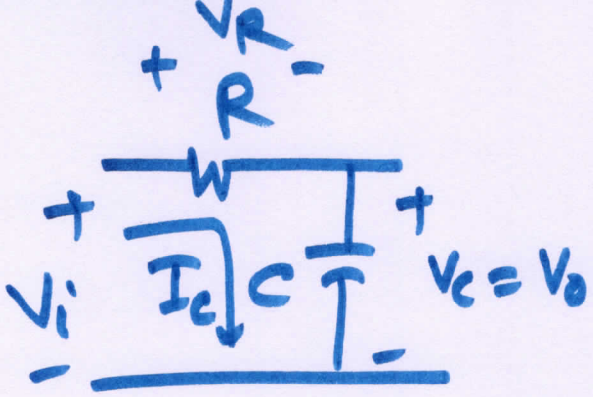
$$X_c(s) = \frac{1}{sC}$$

$$\frac{V_c}{I_c} = X_c(j\omega) = \frac{1}{j\omega C} = \frac{1}{\omega C} e^{-j\pi/2}$$

$$j = e^{j\pi/2} = \cos\pi/2 + j \sin\pi/2$$

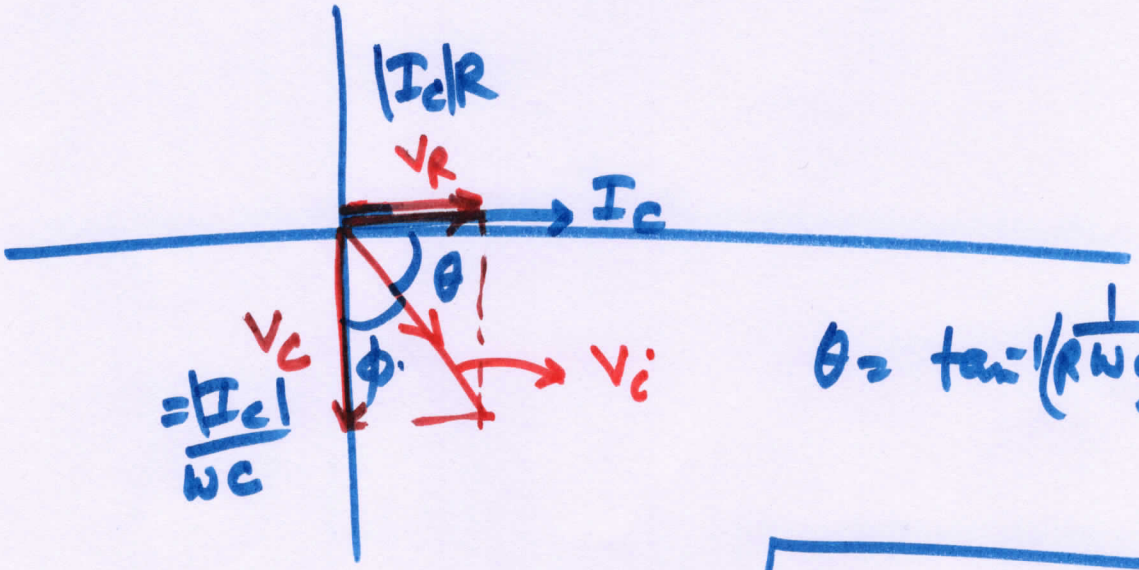
$$\Rightarrow V_c = \frac{I_c}{\omega C} \angle -90^\circ$$





$$V_R = I_c R$$

$$V_i = V_R + V_c$$



$$\theta = \tan^{-1}\left(\frac{1}{R\omega C}\right)$$

$$|V_i| = \sqrt{|V_R|^2 + |V_c|^2}$$

$$= |I_c| \sqrt{R^2 + \left(\frac{1}{\omega C}\right)^2}$$

$$\Rightarrow |I_c| = \frac{|V_i|}{\sqrt{R^2 + \left(\frac{1}{\omega C}\right)^2}}$$

$$I_c = \frac{V_i \angle +\theta}{\sqrt{R^2 + \left(\frac{1}{\omega C}\right)^2}} \quad \therefore V_c = ? \; \frac{I_c}{\omega C} \angle -90^\circ$$