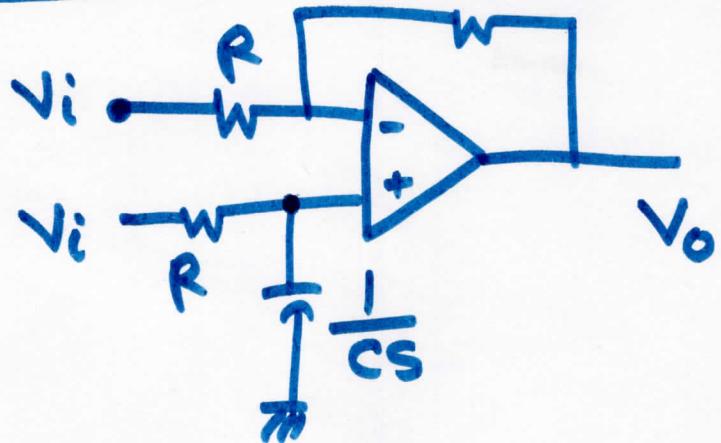


All Pass Filter (APF)



$$V_o = -\frac{R}{R} V_i + \left(1 + \frac{R}{R}\right) \times \frac{\frac{1}{CS}}{R + \frac{1}{CS}} \times V_i$$

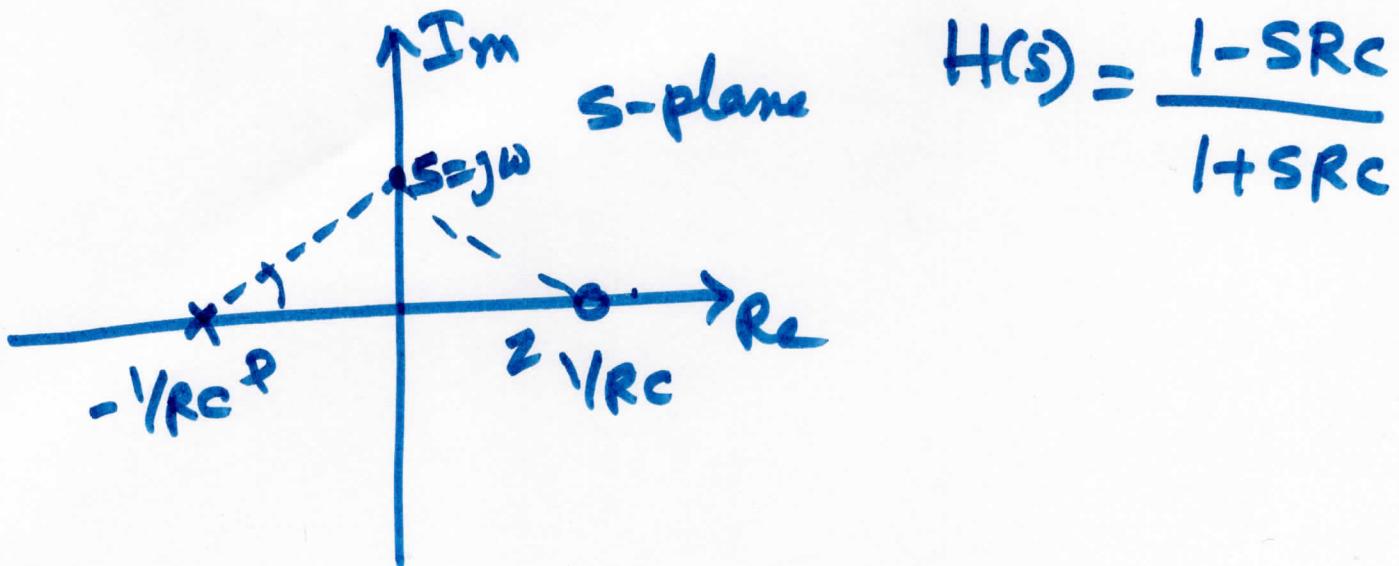
$$= -V_i + 2 \times \frac{1}{1+SRC} \times V_i$$

$$= V_i \left[\frac{2}{1+SRC} - 1 \right]$$

$$= V_i \left[\frac{2 - 1 - SRC}{1+SRC} \right]$$

$$= V_i \times \left(\frac{1-SRC}{1+SRC} \right)$$

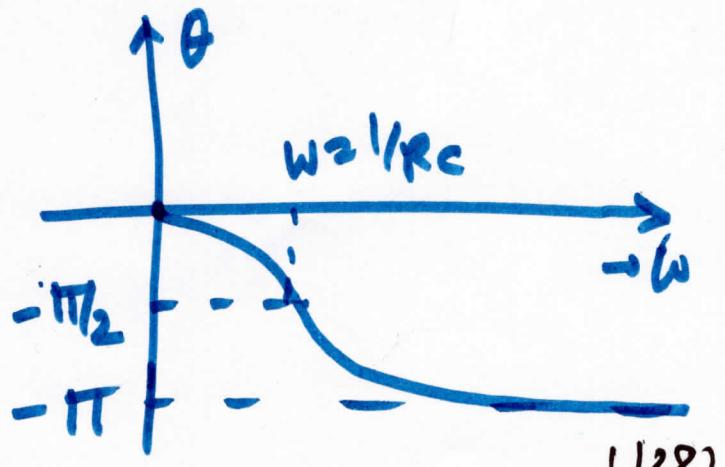
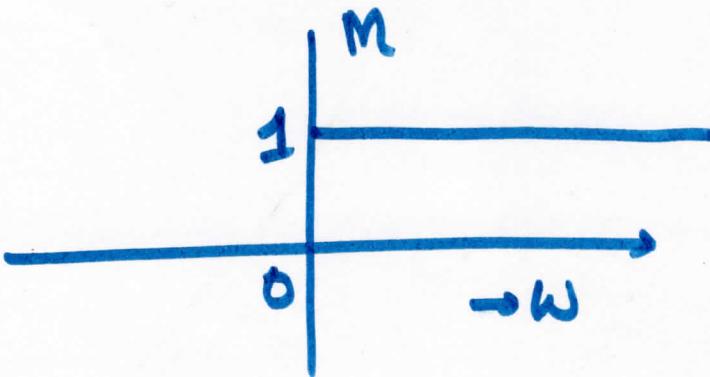
$$\Rightarrow \frac{V_o}{V_i} = H(s) = \frac{1-SRC}{1+SRC}$$



$$H(j\omega) = \frac{1 - j\omega RC}{1 + j\omega RC} = M e^{j\theta}$$

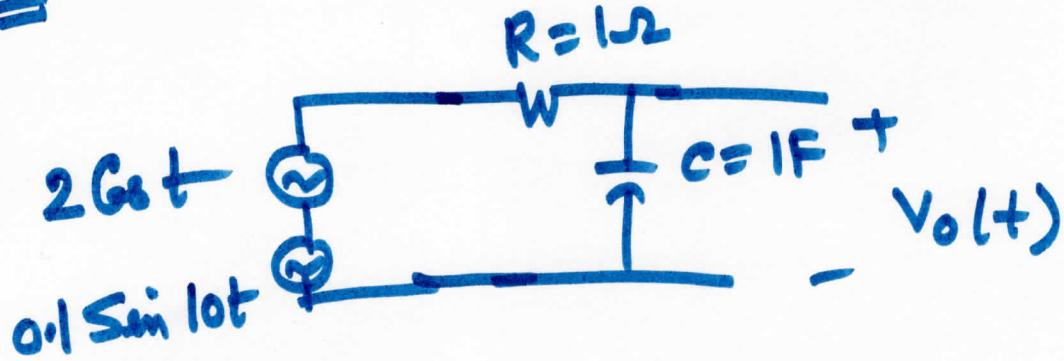
$$\Rightarrow M = \frac{\sqrt{1 + \omega^2 R^2 C^2}}{\sqrt{1 + \omega^2 R^2 C^2}} = 1 = \frac{SE}{SP}$$

$$\begin{aligned} \theta &= -\underline{\tan^{-1}(WR_C)} - \underline{\tan^{-1}(WR_C)} \\ &= -2 \tan^{-1}(WR_C) \end{aligned}$$



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ex



$$V_i = 2\cos t + 0.1\sin 10t$$

For $V_i = 2\cos t \rightarrow \omega = 1$



$$H(s) = \frac{1}{1+sRC}$$

$$= \frac{1}{1+s}$$

$$H(j\omega) = \frac{1}{1+j\omega}$$

$$\omega = 1 \Rightarrow M = \frac{1}{\sqrt{1+1}} = \frac{1}{\sqrt{2}}$$

$$\phi = -\tan^{-1}\left(\frac{1}{1}\right) = -45^\circ$$

for $V_i = 0.1\sin 10t$

$$\omega = 10 \rightarrow M = \frac{1}{\sqrt{1+10^2}} = \frac{1}{\sqrt{101}}$$

$$\phi = -\tan^{-1}\left(\frac{10}{1}\right) = -\tan^{-1}(10)$$

$$\omega = 1, M = \sqrt{2}, \phi = -45^\circ$$

$$\omega = 10, M = \frac{1}{\sqrt{101}}, \phi = -\tan^{-1}(10)$$

$$v_i = 2 \cos t + 0.1 \sin 10t$$

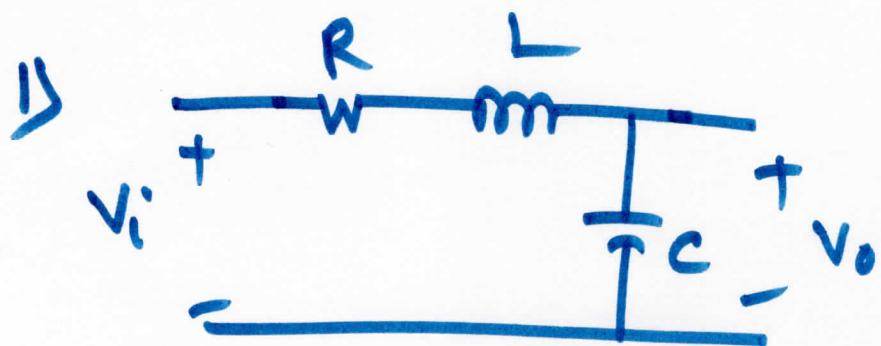
$$\Rightarrow v_o = 2 \times \frac{1}{\sqrt{2}} \cos(t - 45^\circ) +$$

$$0.1 \times \frac{1}{\sqrt{101}} \sin(10t - \tan^{-1}(10))$$

\downarrow neg.

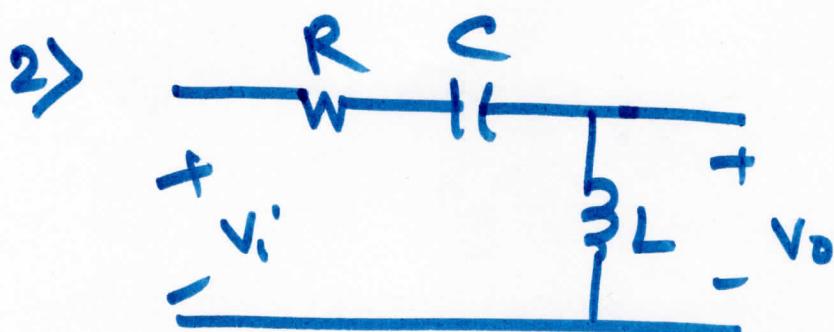
$$\approx \sqrt{2} \cos(t - 45^\circ)$$

Filters with R, L, C



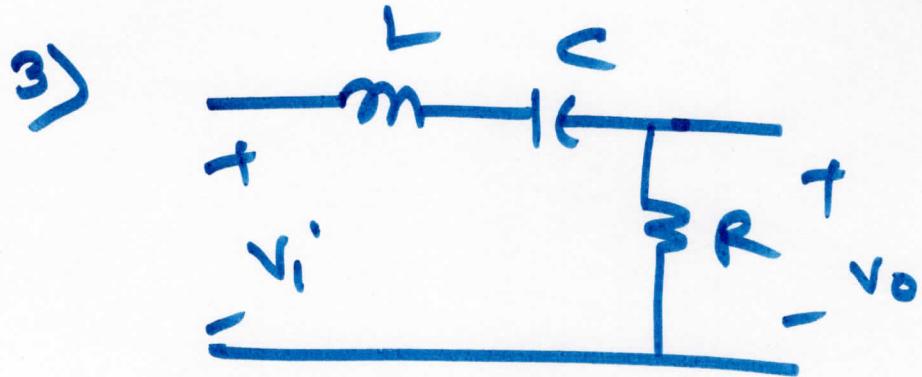
$$\frac{v_o}{v_i} = \frac{\frac{1}{C_s}}{R + Ls + \frac{1}{C_s}} = \frac{1}{Ls^2 + Rcs + 1}$$

(LPF)



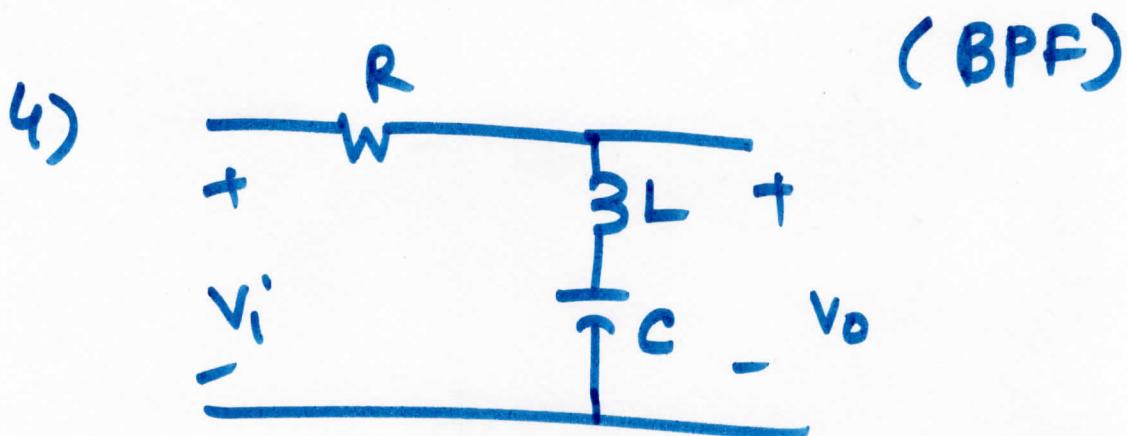
$$\begin{aligned} \frac{v_o}{v_i} &= \frac{Ls}{R + \frac{1}{C_s} + Ls} \\ &= \frac{LC s^2}{LCs^2 + RCS + 1} \end{aligned}$$

(HPF)



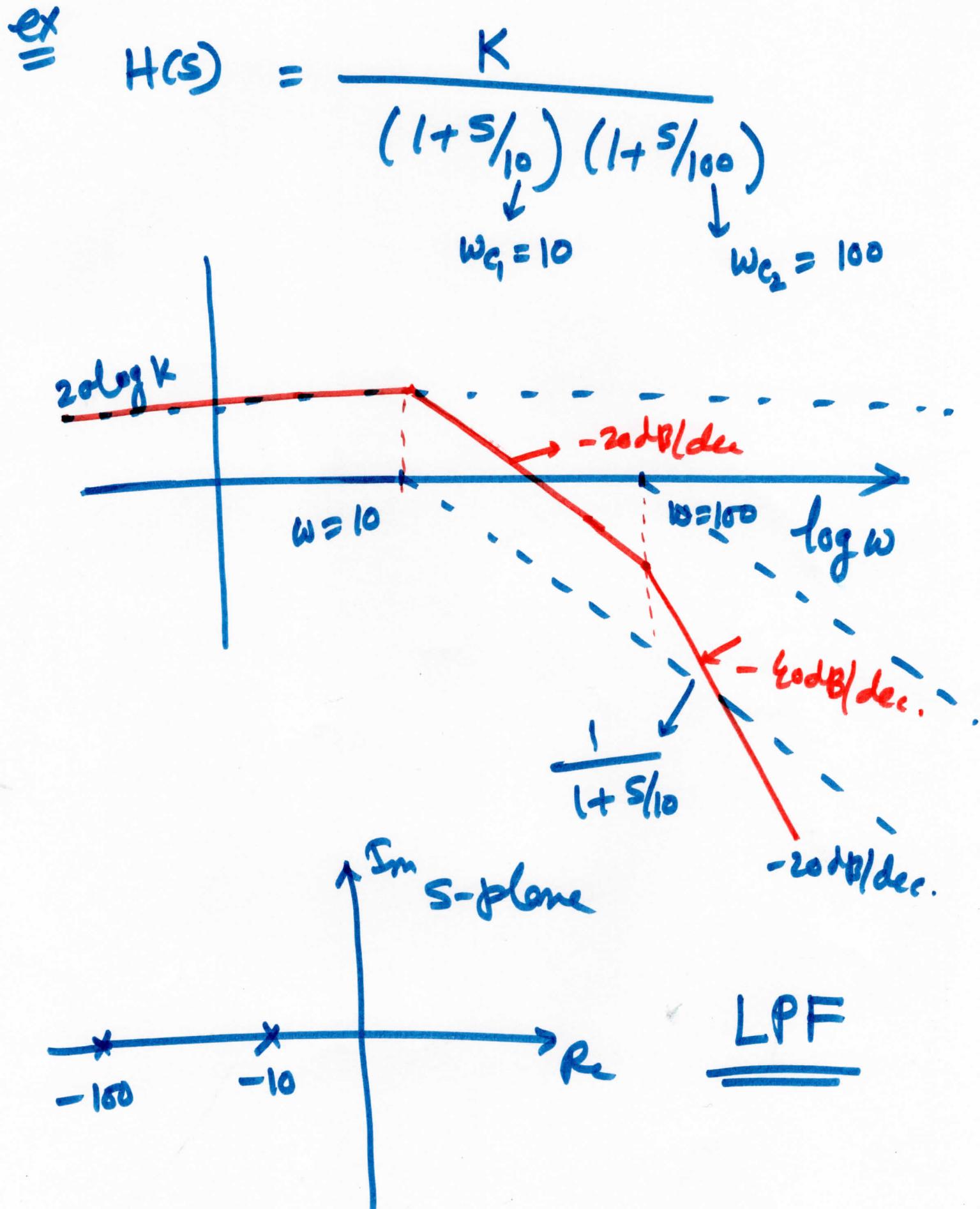
$$\frac{v_o}{v_i} = \frac{R}{Ls + \frac{1}{Cs} + R}$$

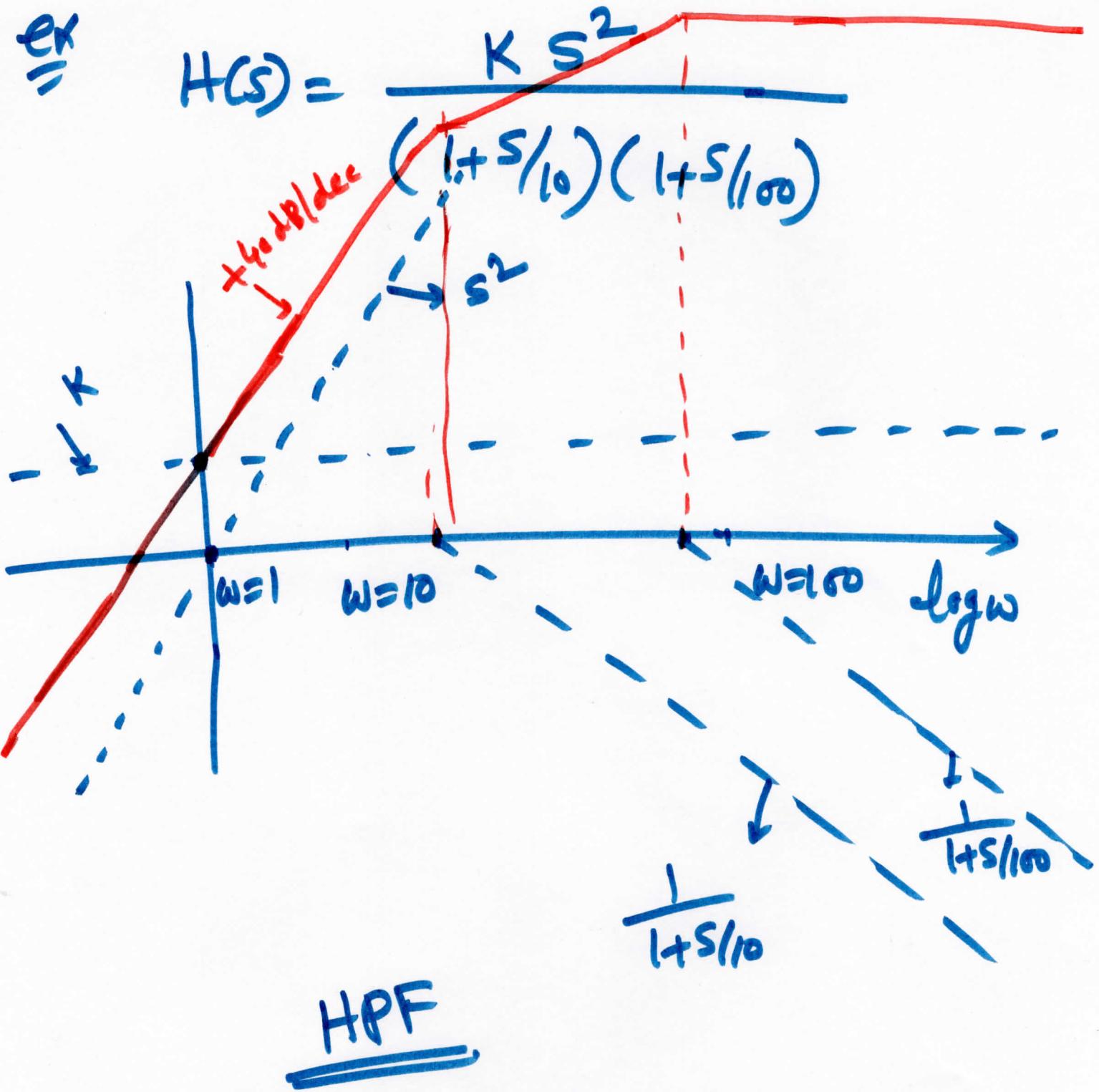
$$= \frac{RCS}{LCS^2 + RCS + 1}$$



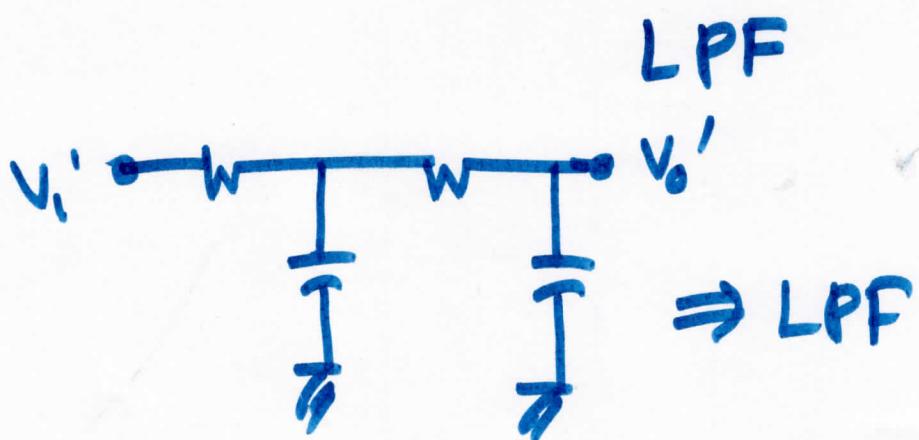
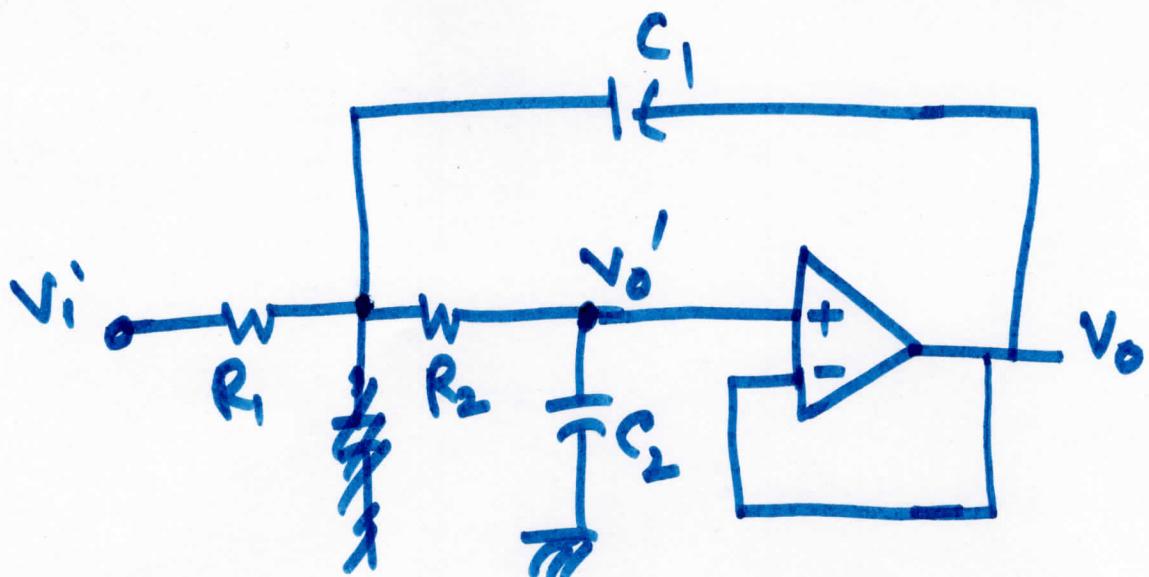
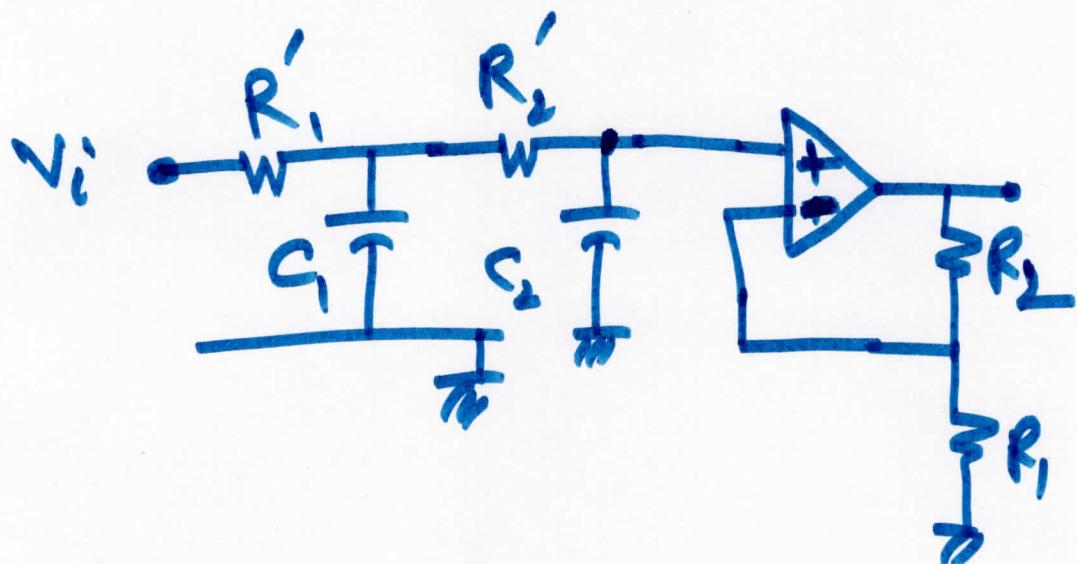
$$\frac{v_o}{v_i} = \frac{Ls + \frac{1}{Cs}}{R + Ls + \frac{1}{Cs}} = \frac{LCS + 1}{LCS + RCS + 1}$$

(Notch Filter)

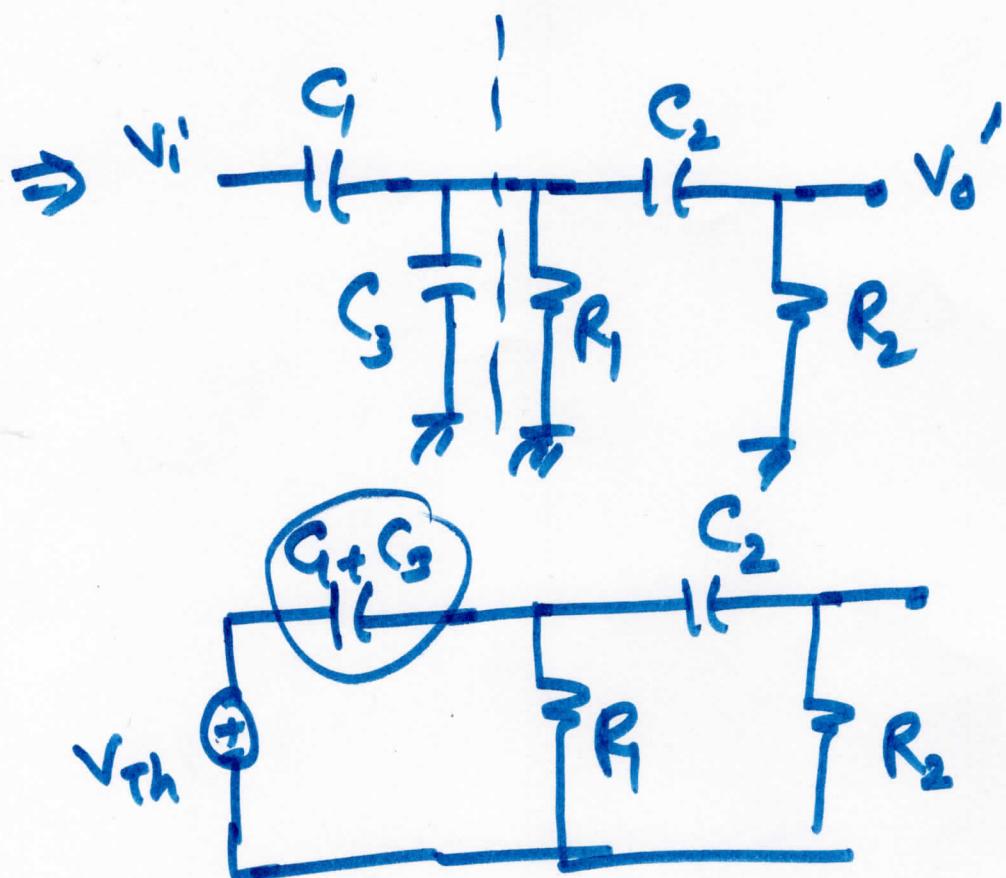
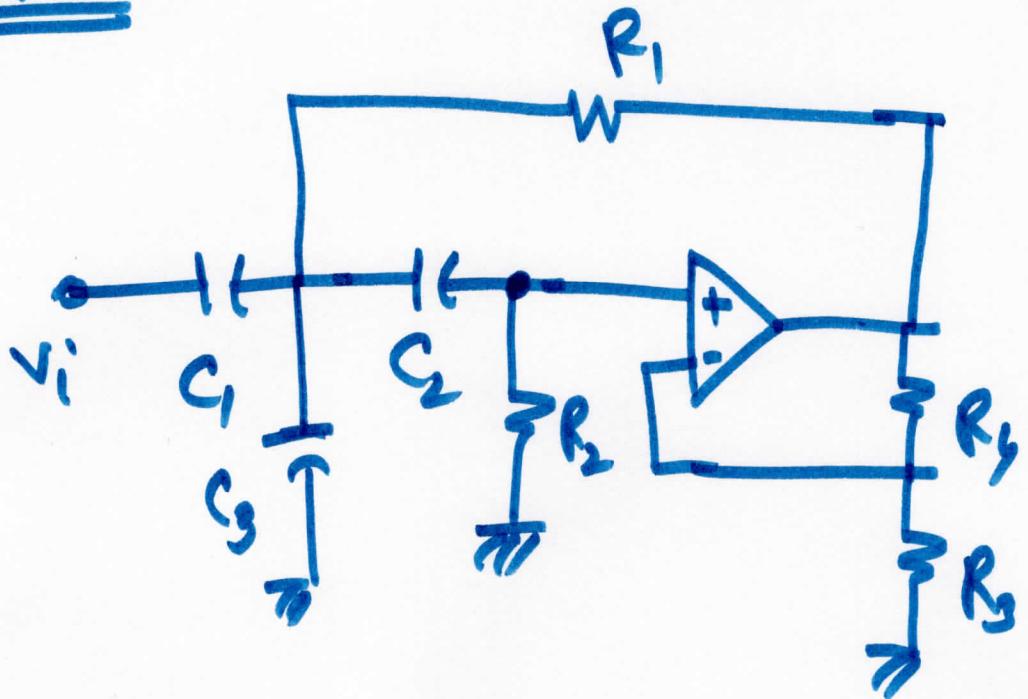




Sallen-Key Filter



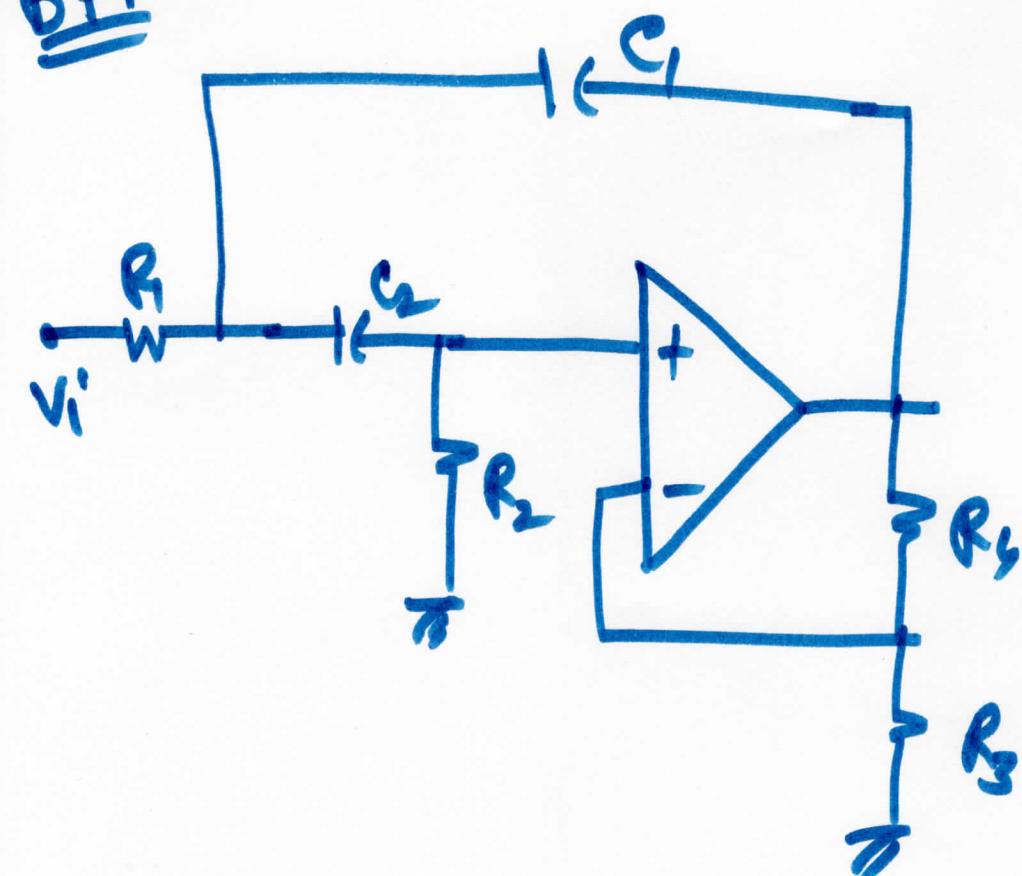
HPF

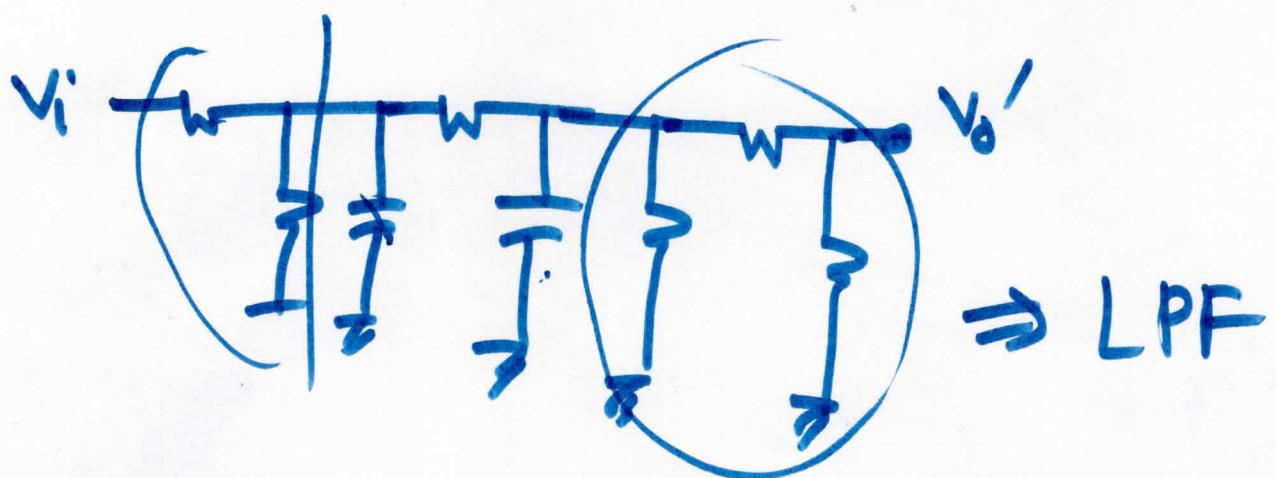
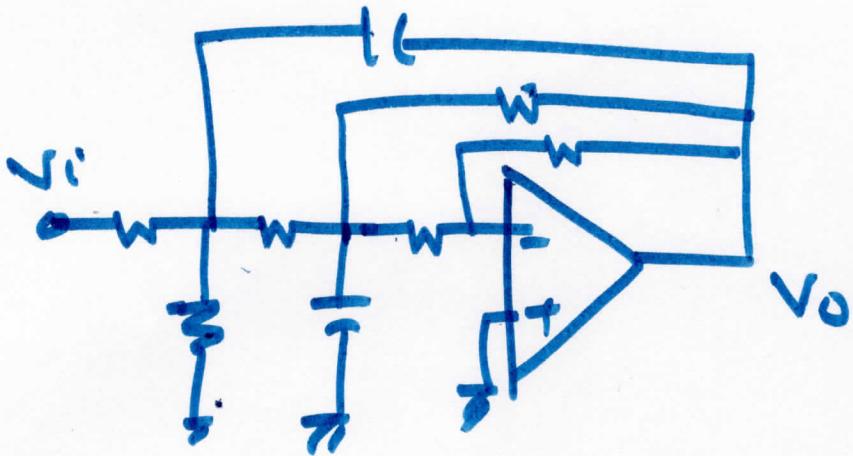


$$V_{in} = \frac{Y_{GS}}{\frac{1}{GS} + \frac{1}{GS}s} \times V_i = \frac{C_1}{C_1 + G} V_i$$

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BPF





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