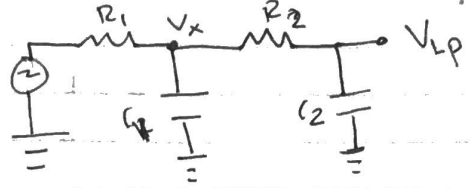
LAB #2

ECEN 325

1) a)



$$V_x = \left(\frac{1}{R_1} + \frac{1}{R_2} + C_1 s\right) = \frac{V_x}{R_2 C_2 s + 1} + \frac{V_i}{R_1}$$

$$H_{LP}(s) = \frac{V_{LP}(s)}{V_i} = \frac{V_o}{V_x} \times \frac{V_x}{V_i}$$

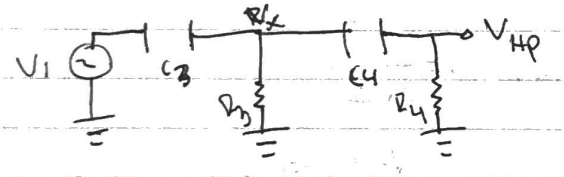
$$V_x = \left(\frac{1}{R_1} + \frac{1}{R_2} + C_1 s - \frac{1}{R_2 C_2 s + 1}\right) = \frac{V_i}{R_1}$$

$$V_o = V_x \frac{\frac{1}{C_2 s}}{\frac{1}{C_2 s} + R_2} = \frac{1}{R_2 C_2 s + 1} V_x$$

$$\frac{V_x}{V_i} = \frac{1}{1 + \frac{R_1}{R_2} + R_1 C_1 s - \frac{R_1}{R_2 C_2 s + 1}} = \frac{1 + R_2 C_2 s}{C_2 s + 1 + R_1 C_2 s + \frac{R_1}{R_2} + R_1 R_2 C_2 s^2 + R_1 C_1 s - R_1}$$

$$H_{LP} = \frac{1}{(R_1 R_1 C_2 C_1) s^2 + (R_1 C_1 + R_2 C_2 + R_1 C_2) s + 1}$$

b)



$$V_o = \frac{R_4}{R_4 + 1/C_4 s} V_x$$

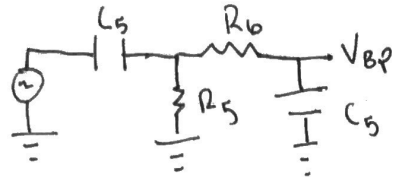
$$V_x (C_4 s + C_3 s + 1/R_3) = C_4 s V_o + C_3 s V_i = \frac{R_4 C_4 C_4 s^2}{R_4 C_4 s + 1} V_x + C_3 s V_i$$

$$V_x \left(C_4 s + C_3 s + 1/R_3 - \frac{R_4 C_4 C_4 s^2}{R_4 C_4 s + 1}\right) = V_i C_3 s$$

$$\frac{V_x}{V_i} = \frac{C_3 s (C_4 R_4 s + 1)}{C_4 s + C_3 C_4 R_4 s^2 + C_3 s + \frac{R_4 C_4 s}{R_3} + 1/R_3}$$

$$\frac{V_o}{V_i} = \frac{R_3 R_4 C_3 C_4 s^2}{s^2 [R_3 R_4 C_3 C_4) + s (R_3 C_3 + R_3 C_4 + R_4 C_4) + 1} = H_{HP}$$

c)



$$V_o = \frac{\frac{1}{C_6 s} V_x}{R_6 + \frac{1}{C_6 s}} = \frac{1 V_x}{R_6 C_6 s + 1}$$

$$V_x = \left(\frac{1}{R_6} + \frac{1}{R_5} + C_5 s\right) = V_o / R_6 + C_5 s V_i = \frac{V_x}{R_6 R_5 C_6 s + R_6} + C_5 s V_i$$

$$\frac{V_x}{V_i} = \frac{C_5 s R_6 R_6 C_6 s + 1}{R_6 C_6 0 + \frac{R_6^2 C_6 s}{R_5} + \frac{R_6}{R_5} + s^2 R_6^2 C_6 C_5 + s R_6 C_5}$$

$$\frac{V_o}{V_{in}} = \boxed{\frac{R_5 C_5 s}{s^2 (R_5 R_6 C_5 C_6) + s(R_5 R_6 C_6 + C_5 + C_6) + 1} = H_{BP}}$$

2)a)

$$H_{LP} = \frac{1}{1 + \frac{s}{2\pi f_1}} \quad \frac{1}{1 + \frac{s}{2\pi f_2}} \qquad f_1 = 4\text{kHz} \quad f_2 = 8\text{kHz}$$

$$= \frac{1}{1 + \frac{s}{2\pi (4\text{k})}} \quad \frac{1}{1 + \frac{s}{2\pi (8\text{k})}}$$

$$4000 = \frac{1}{R_1 C_1 2\pi} \qquad R_1 C_1 = \frac{1}{8000\pi}$$

$$R_2 C_2 = \frac{1}{16000\pi}$$

$R_1 = 1000\ \Omega$
$C_1 = 40\text{nF}$
$R_2 = 1000\ \Omega$
$C_2 = 20\text{nF}$

b) $H_{HP} = \frac{s}{s+2\pi f_3} \cdot \frac{s}{s+2\pi f_4}$ $f_3 = 4k\,Hz$ $f_4 = 8k\,Hz$

$= \frac{s}{s+8k\pi} \cdot \frac{s}{s+16k\pi}$

$R_3 C_3 = \frac{1}{8000\pi}$ $R_4 C_4 = \frac{1}{16000\pi}$

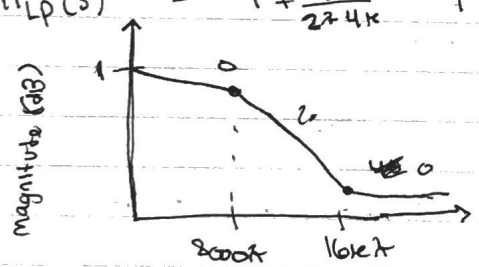
$R_3 = 1000\,\Omega$ $C_3 = 40nF$ $R_4 = 1000\,\Omega$ $C_4 = 20nF$

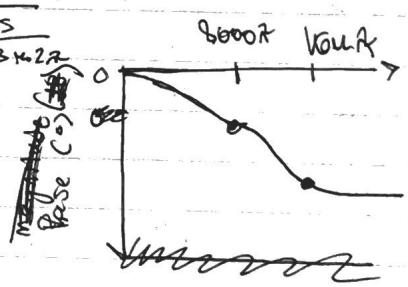
c) $H_{BP} = \frac{s}{s+2\pi f_5} \cdot \frac{1}{1+\frac{s}{2\pi f_6}}$, $f_5 = 4k\,Hz$ $f_6 = 8k\,Hz$

$R_5 C_3 = \frac{1}{8k\pi}$ $R_4 C_4 = \frac{1}{16k\pi}$

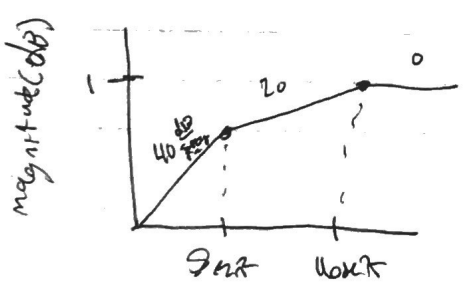
$R_5 = 1000\,\Omega$ $C_5 = 40nF$ $R_6 = 100k\,\Omega$ $C_6 = 20nF$

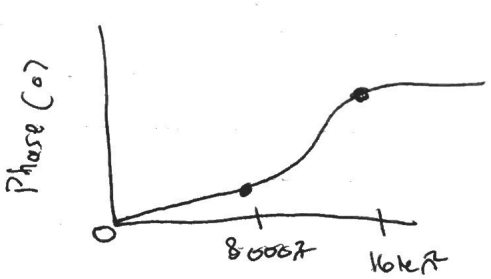
d) $H_{LP}(s) = \frac{1}{1+\frac{s}{2\pi 4k}} \cdot \frac{1}{1+\frac{s}{8k2\pi}}$



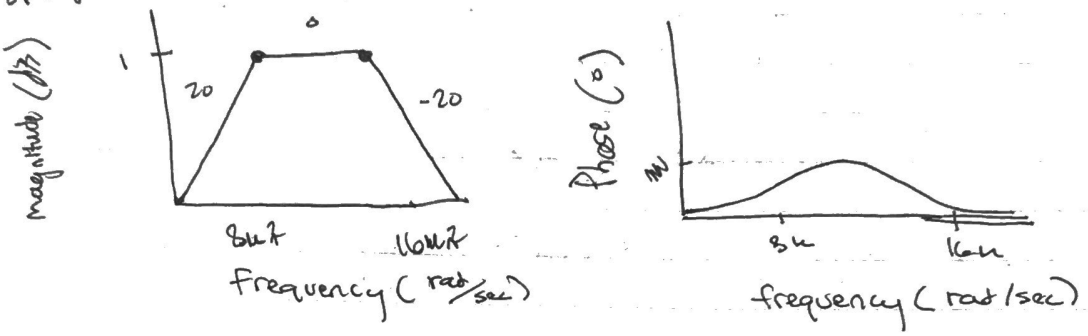


$H_{HP}(s)$





$H_{BP}(s)$



4)

$$|H(j\omega)|_{LP} = \frac{1}{\sqrt{1^2 + (6/4)^2}} = .554 \quad @\ 4kHz$$

$$= \frac{1}{\sqrt{1^2 + (6/8)^2}} = .8 \quad @\ 8kHz$$

$.554 \cdot .8 = .4432$

$$\phi_{LP} = -\tan^{-1}\left(\frac{6}{4}\right) + -\tan^{-1}(6/8) = -1.162 \text{ rad}$$

$$V_{LP}(t) = .2216 \sin(2\pi 6000t - 1.62 \text{ rad})$$

$$H(j\omega)_{HP} = \frac{6/4}{\sqrt{1^2 + (6/4)^2}} \times \frac{6/8}{\sqrt{1^2 + (6/8)^2}} = .499$$

$$\phi_{HP} = -\tan^{-1}(6/4) + -\tan^{-1}(6/8) = -.93 + -.64$$

$$V_{HP} = .2495 \sin(2\pi 6000t - 1.62 \text{ rads})$$

$$|H(j\omega)| = \frac{6/4}{\sqrt{1 + (6/4)^2}} \times \frac{1}{\sqrt{1 + (6/8)^2}} = .6656$$

$$V_{BP} = .3328 \sin(2\pi 6000t - 1.62 \text{ rads})$$