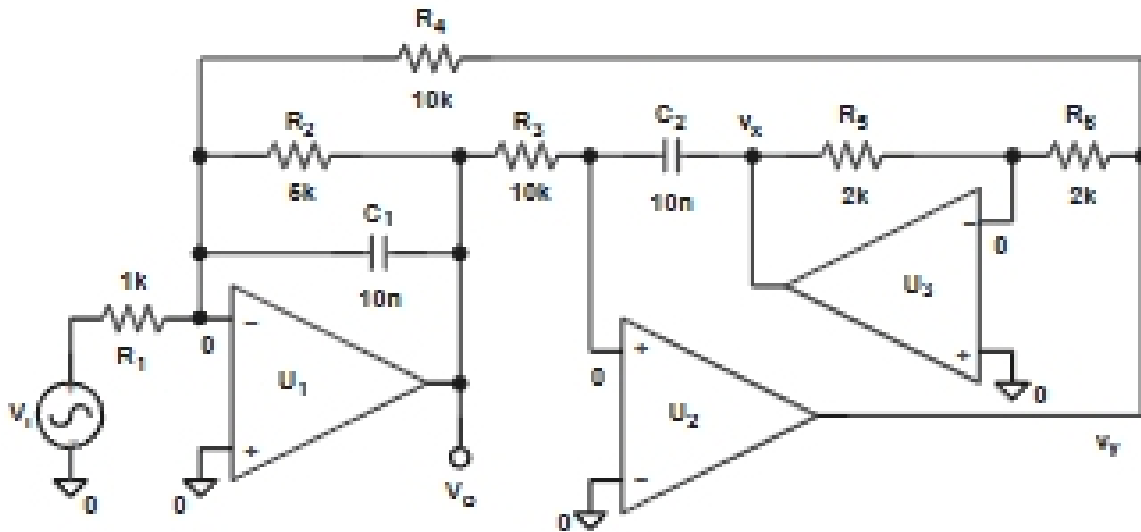


ECEN 325 HOMEWORK #2 SOLUTION

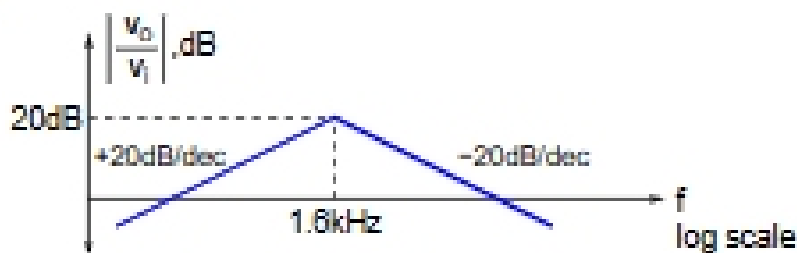
1.



(a)

$$\begin{aligned} \frac{0 - v_o}{R_3} + (0 - v_x)sC_2 &= 0 \Rightarrow \boxed{v_x = -\frac{v_o}{sR_3C_2}} \\ \frac{0 - v_y}{R_6} + \frac{0 - v_x}{R_5} &= 0 \Rightarrow \frac{v_y}{2k} = -\frac{v_x}{2k} \Rightarrow \boxed{v_y = -v_x = \frac{v_o}{sR_3C_2}} \\ \frac{0 - v_i}{R_1} + \frac{0 - v_y}{R_4} + \frac{0 - v_o}{R_2} + sC_1(0 - v_o) &= 0 \Rightarrow \frac{v_i}{R_1} + \frac{v_y}{R_4} + \frac{v_o}{R_2} + sC_1v_o = 0 \\ \Rightarrow \frac{v_i}{R_1} + \frac{v_o}{sR_3R_4C_2} + \frac{v_o}{R_2} + sC_1v_o &= 0 \Rightarrow \frac{v_o}{v_i} = -\frac{\frac{1}{R_1}}{\frac{1}{sR_3R_4C_2} + \frac{1}{R_2} + sC_1} = -\frac{\frac{s}{R_1C_1}}{s^2 + \frac{s}{R_2C_1} + \frac{1}{R_3R_4C_1C_2}} \\ \Rightarrow \frac{v_o}{v_i} &= -\frac{10^5 s}{s^2 + 2 \times 10^4 s + 10^8} = -\frac{10^5 s}{(s + 10000)(s + 10000)} = \boxed{-10 \frac{s}{s + 2\pi 1.6k} \frac{1}{1 + \frac{s}{2\pi 1.6k}}} \end{aligned}$$

(b)



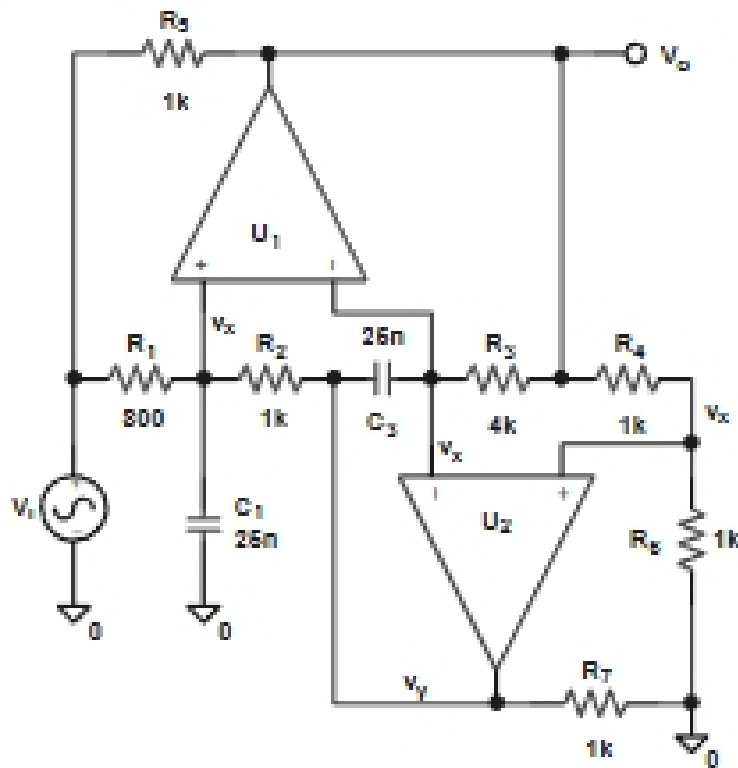
(c) $v_i(t) = 0.1 \sin(2\pi 3 \times 10^3 t)$

$$\left| \frac{v_o}{v_i}(j2\pi 3000) \right| = 10 \frac{1}{\sqrt{1 + \left(\frac{1.6}{3}\right)^2}} \frac{1}{\sqrt{1 + \left(\frac{3}{1.6}\right)^2}} = 4.15$$

$$\angle \frac{v_o}{v_i}(j2\pi 3000) = -180^\circ + \tan^{-1} \frac{1.6}{3} - \tan^{-1} \frac{3}{1.6} = -214^\circ$$

$$v_o(t) = 4.15 \times 0.1 \sin\left(2\pi 3000t - \frac{214}{180}\pi\right) = 0.415 \sin(2\pi 3000t - 3.73)$$

2.



(a)

$$\frac{v_x}{R_6} + \frac{v_x - v_o}{R_4} = 0 \Rightarrow \frac{v_x}{1k} + \frac{v_x - v_o}{1k} = 0 \Rightarrow v_x = \frac{v_o}{2}$$

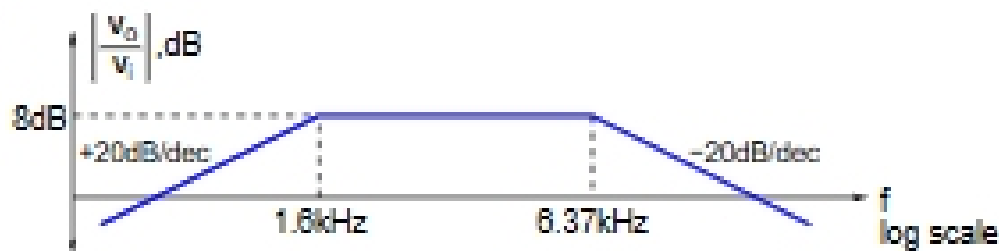
$$\frac{v_x - v_o}{R_3} + (v_x - v_y)sC_3 = 0 \Rightarrow -\frac{v_o}{2} + \left(\frac{v_o}{2} - v_y\right)sR_3C_3 = 0 \Rightarrow v_y = \frac{sR_3C_3 - 1}{2sR_3C_3}v_o$$

$$\frac{v_x - v_i}{R_1} + \frac{v_x - v_y}{R_2} + sC_1v_x = 0 \Rightarrow \frac{v_o}{R_1} = \frac{v_o}{2} \left(\frac{1}{R_1} + \frac{1}{R_2} + sC_1\right) - \frac{sR_3C_3 - 1}{2sR_2R_3C_3}v_o$$

$$\Rightarrow \frac{v_o}{v_i} = \frac{\frac{1}{R_1}}{\frac{1}{2} \left(\frac{1}{R_1} + \frac{1}{R_2} + sC_1\right) - \frac{sR_3C_3 - 1}{2sR_2R_3C_3}} = \frac{\frac{2}{R_1C_1}s}{s^2 + s \left(\frac{1}{R_1C_1} + \frac{1}{R_2C_1} - \frac{1}{R_2C_1}\right) + \frac{1}{R_2R_3C_1C_3}}$$

$$\Rightarrow \frac{v_o}{v_i} = \frac{10^5 s}{s^2 + 5 \times 10^4 s + 4 \times 10^8} = \frac{10^5 s}{(s + 10000)(s + 40000)} = \boxed{2.5 \frac{s}{s + 2\pi 1.6k} \frac{1}{1 + \frac{s}{2\pi 6.37k}}}$$

(b)



(c) $v_i(t) = 0.1 \sin(2\pi 3 \times 10^3 t)$

$$\left| \frac{v_o}{v_i}(j2\pi 3000) \right| = 2.5 \frac{1}{\sqrt{1 + \left(\frac{1.6}{3}\right)^2}} \frac{1}{\sqrt{1 + \left(\frac{3}{6.37}\right)^2}} = 2$$

$$\angle \frac{v_o}{v_i}(j2\pi 3000) = \tan^{-1} \frac{1.6}{3} - \tan^{-1} \frac{3}{6.37} = 2.7^\circ$$

$$v_o(t) = 2 \times 0.1 \sin\left(2\pi 3000t + \frac{2.7}{180}\pi\right) = 0.2 \sin(2\pi 3000t + 0.05)$$