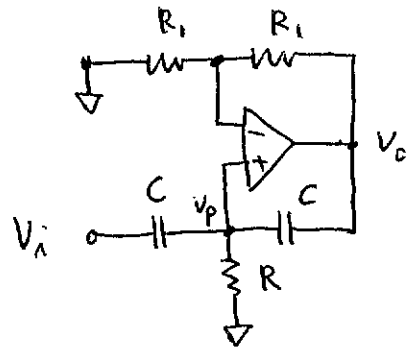
3장 연습문제 해답

3-2



(a) $\begin{cases} \dfrac{V_i - V_p}{1/sC} = \dfrac{V_p}{R} + \dfrac{V_p - V_o}{1/sC} \\ \dfrac{V_p}{R_1} = \dfrac{V_o - V_p}{R_1} \end{cases} \Rightarrow V_p = \frac{1}{2} V_o$

$$sCV_i - sCV_p - \frac{V_p}{R} - sCV_p = -sCV_o$$

$$sCV_i = 2sCV_p + \frac{V_p}{R} - sCV_o$$

$$= \frac{V_o}{2R}$$

$$\therefore H(s) = \frac{V_o}{V_i} = s2RC \quad ; \text{ 비반전 미분기}$$

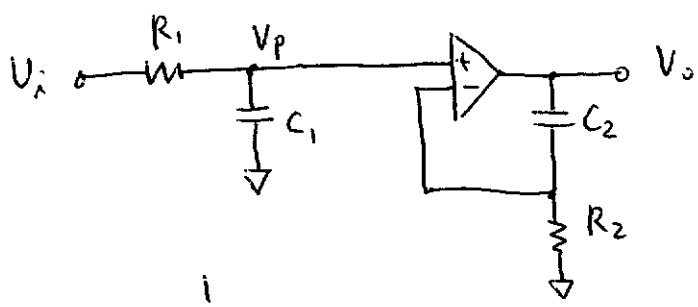
(b) $H(j\omega) = j\omega 2RC$

$\omega = 2\pi \times 100$ 에서 $|H(j\omega)| = 1$ 이므로

$$2\pi \times 100 \times 2RC = 1 \Rightarrow RC = \frac{1}{400\pi} \doteq 8 \times 10^{-4}$$

$C = 0.1\,\mu F$, $R = 800\,k\Omega$

3-3



단, $R_1 C_1 = R_2 C_2$

(a) $V_p = \dfrac{1}{1 + sR_1C_1} V_i$

$$V_o = \left(1 + \frac{1/sC_2}{R_2}\right) V_p = \left(1 + \frac{1}{sR_2C_2}\right) \frac{1}{1 + sR_1C_1} V_i$$

$$= \frac{1}{sR_2C_2} V_i$$

$\therefore H(s) = \frac{V_o}{V_i} = \frac{1}{sR_2C_2}$: 비반전 적분기

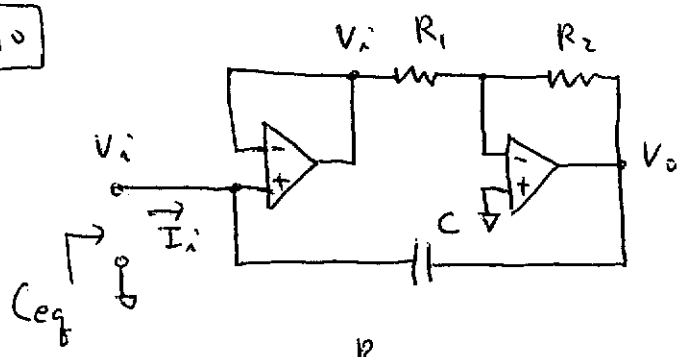
(b) $H(j\omega) = \frac{1}{j\omega R_2 C_2}$

$\omega = 2\pi \times 100$ rad/s $\quad |H|_{dB} = 20\log_{10} \frac{1}{2\pi \times 1\omega R_2 C_2} = 20$

$R_2C_2 = \frac{1}{2000\pi} \fallingdotseq 1.6 \times 10^{-4}$

$C_2 = C_1 = 0.1\,\mu F, \quad R_2 = R_1 = 1.6\,k\Omega$

3-10



(a) $V_o = -\frac{R_2}{R_1} V_i$

$I_i = \frac{V_i - V_o}{1/sC} = \frac{(1+\frac{R_2}{R_1})V_i}{1/sC} = sC\left(1+\frac{R_2}{R_1}\right)V_i$

$\therefore C_{eq} = C\left(1+\frac{R_2}{R_1}\right)$

(b) $C = 0.1\,\mu F$

$R_2 = 1\,M\Omega$ pot.

$R_2 = 0$ 일 때 $\quad C_{eq} = 0.1\,\mu F$

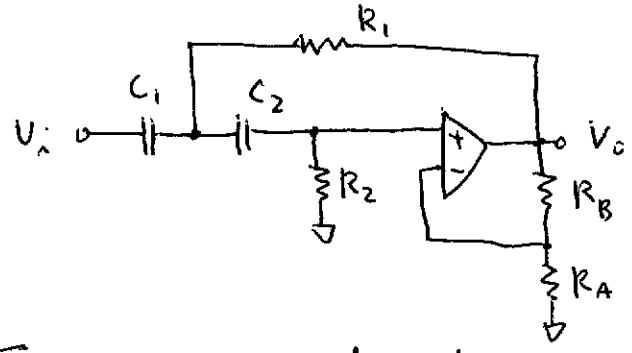
$R_2 = 1\,M\Omega$ 일 때 $\quad C_{eq} = 0.1 \times \left(1+\frac{1000}{R_1}\right) = 100$

$R_1 = \frac{1000}{999} \fallingdotseq 1\,k\Omega$

3-19 HP KRC Filter

$f_o = 100$ Hz, $Q = 0.5 \sim 5$ with $100k\Omega$ pot.

(a)



Equal component design 으로 하면

$R_1 = R_2 = R$, $C_1 = C_2 = C$

$\omega_0 = \frac{1}{RC} = 2\pi \times 100 \Rightarrow RC \doteq 1.6 \times 10^{-3}$

$C = 0.1\,\mu F$, $R = 16\,k\Omega$

$K = 3 - \frac{1}{Q}$ 이므로 $1 \le K \le 2.8$

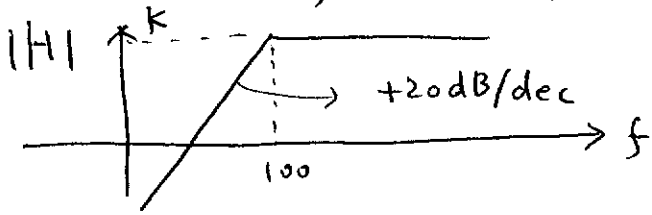
$K = 1 + \frac{R_B}{R_A}$ 이므로 R_B 는 $100\,k\Omega$ pot.

$R_B = 0$ 일 때 $K = 1$

$R_B = 100\,k\Omega$ 일 때 $1 + \frac{100}{R_A} = 2.8$ 이므로

$R_A = 54.8\,k\Omega$

(b) V_i : 60Hz, 5 Vrms, 3V dc offset



주파수가 $\frac{1}{10}$ 이하면 이득이 $\frac{1}{10}$ 이 됨.

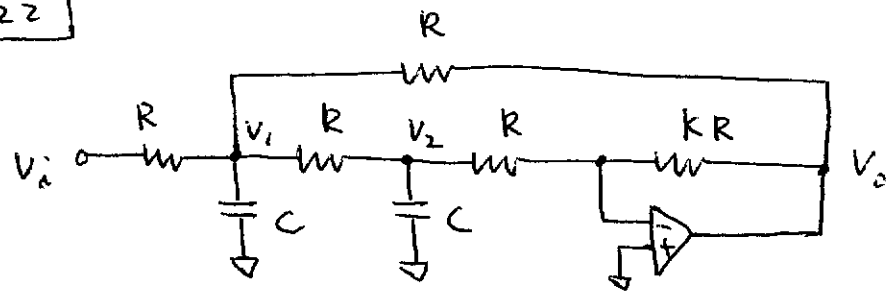
따라서 주파수가 $\frac{60}{100} = \frac{6}{10}$ 이하면 이득이 $\frac{6}{10}K$ 가 됨.

① $K = 1$ 일 때 V_o 는 $\frac{6}{10} \times 5 = 3\ V_{rms}$

② $K = 2.8$ 일 때 V_o 는 $\frac{6}{10} \times 2.8 \times 5 = 8.4\ V_{rms}$

3V dc offset 은 Hpf 에 의해 제거됨.

3-22



(a)
$$\begin{cases} \dfrac{V_i - V_1}{R} = sCV_1 + \dfrac{V_1 - V_2}{R} + \dfrac{V_1 - V_o}{R} \\ \dfrac{V_1 - V_2}{R} = sCV_2 + \dfrac{V_2}{R} \\ \dfrac{V_2}{R} = -\dfrac{V_o}{kR} \end{cases} \Rightarrow V_o = -kV_2$$

$$V_1 - V_2 = sCRV_2 + V_2 \Rightarrow V_1 = (2 + sCR)V_2$$
$$= -\frac{2+sCR}{k} V_o$$

$$V_i - V_1 = sCRV_1 + V_1 - V_2 + V_1 - V_o$$
$$V_i = (3 + sCR)V_1 - V_2 - V_o$$
$$= -\left[\frac{(3+sCR)(2+sCR) - 1 + k}{k}\right] V_o$$

$$H(s) = \frac{V_o}{V_i} = \frac{-k}{(5+k) + 5sCR + s^2C^2R^2}$$

$$H(j\omega) = \frac{-k}{5+k} \cdot \frac{1}{1 + j\omega \frac{5}{5+k} RC - \omega^2 \frac{R^2C^2}{5+k}}$$

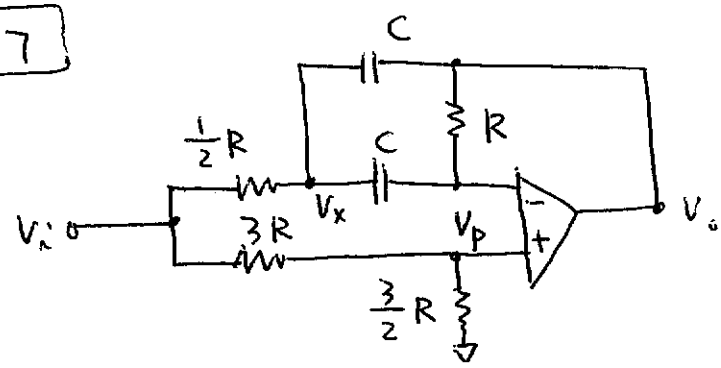
$$\therefore Q = \frac{\sqrt{5+k}}{5}, \quad \omega_o = \frac{\sqrt{5+k}}{RC}, \quad H_{olp} = \frac{-k}{5+k}$$

(b) $Q = 5$ 이면 $k = \sqrt{620} \doteq 24.9$

$$\omega_o = \frac{25}{RC} = 2\pi \times 2 \times 10^3 \text{ 이면 } RC = 1.99 \times 10^{-3}$$

$C = 0.1\,\mu F$, $R = 19.9\,k\Omega$

3-27



$$\begin{cases} V_p = \frac{1}{3} V_i \\ \frac{V_i - V_x}{R/2} = sC(V_x - V_p) + sC(V_x - V_o) \\ sC(V_x - V_p) = \frac{V_p - V_o}{R} \end{cases}$$

$$sRC V_x = (sRC+1) V_p - V_o$$

$$= \frac{1}{3}(1+sRC) V_i - V_o$$

$$V_x = \frac{1+sRC}{3sRC} V_i - \frac{V_o}{sRC}$$

$$2V_i - 2V_x = sRC V_x - sRC V_p + sRC V_x - sRC V_o$$

$$\left(2 + \frac{sRC}{3}\right) V_i = (2 + 2sRC) V_x - sRC V_o$$

$$= \frac{2(1+sRC)^2}{3sRC} V_i - \frac{2(1+sRC)}{sRC} V_o - sRC V_o$$

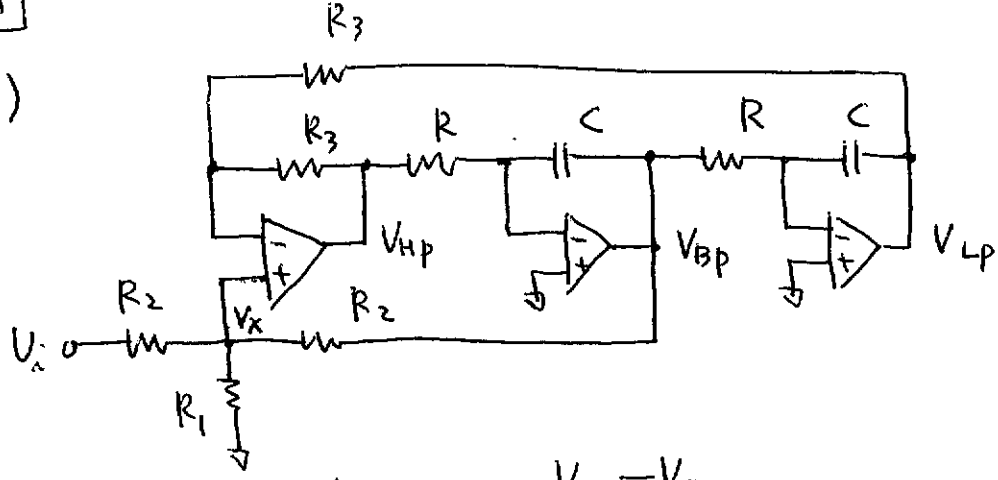
$$H(s) = \frac{V_o}{V_i} = \frac{1}{3} \frac{2 - 2sRC + s^2R^2C^2}{2 + 2sRC + s^2R^2C^2}$$

$$H(j\omega) = \frac{1}{3} \frac{1 - j\omega RC - \omega^2 \frac{R^2C^2}{2}}{1 + j\omega RC - \omega^2 \frac{R^2C^2}{2}}$$

$$\therefore H_{OAP} = \frac{1}{3}, \quad \omega_0 = \frac{\sqrt{2}}{RC}, \quad Q = \frac{1}{\sqrt{2}}$$

3-31

(a)



$$\frac{V_i - V_x}{R_2} = \frac{V_x}{R_1} + \frac{V_x - V_{BP}}{R_2}$$

$$\frac{V_x - V_{HP}}{R_3} = \frac{V_{HP}}{R} \Rightarrow V_x = \left(1 + \frac{R_3}{R}\right) V_{HP}$$

$$\frac{V_x - V_{HP}}{R_3} = \frac{V_{LP} - V_x}{R_3} \Rightarrow V_x = \frac{1}{2}\left(V_{HP} + V_{LP}\right)$$

$$\frac{V_{HP}}{R} = -sC V_{BP} \Rightarrow V_{HP} = -sRC\, V_{BP}$$

$$\frac{V_{BP}}{R} = -sC V_{LP} \Rightarrow V_{BP} = -sRC\, V_{LP}$$

$R_1 V_i - R_1 V_x = R_2 V_x + R_1 V_x - R_1 V_{BP}$ 이므로

$$V_i = \left(2 + \frac{R_2}{R_1}\right) V_x - V_{BP} \text{ 또는}$$

$$V_{BP} = \left(2 + \frac{R_2}{R_1}\right) V_x - V_i$$

$$V_x = \frac{1}{2}\left(V_{HP} + V_{LP}\right) = \frac{1}{2}\left[-sRC\, V_{BP} - \frac{1}{sRC} V_{BP}\right]$$

$$= -\frac{1}{2}\,\frac{1 + s^2R^2C^2}{sRC}\, V_{BP}$$

$$V_{BP} = -\frac{1}{2}\left(2 + \frac{R_2}{R_1}\right)\frac{1 + s^2R^2C^2}{sRC} V_{BP} - V_i$$

$$\therefore V_i = -\left[\frac{sRC + \left(1 + \frac{R_2}{2R_1}\right) + \left(1 + \frac{R_2}{2R_1}\right) s^2R^2C^2}{sRC}\right] V_{BP}$$

$$H_{Bp}(s) = \frac{V_{BP}}{V_i} = -\frac{sRC}{\left(1+\frac{R_2}{2R_1}\right) + sRC + \left(1+\frac{R_2}{2R_1}\right)s^2R^2C^2}$$

$$= -\frac{1}{1+\frac{R_2}{2R_1}} \cdot \frac{sRC}{1 + s\frac{RC}{1+\frac{R_2}{2R_1}} + s^2R^2C^2}$$

$$H_{Bp}(j\omega) = -\frac{1}{1+\frac{R_2}{2R_1}} \cdot \frac{j\omega RC}{1 + j\omega\frac{RC}{1+\frac{R_2}{2R_1}} - \omega^2R^2C^2}$$

$\therefore \omega_0 = \frac{1}{RC}$, $Q = 1+\frac{R_2}{2R_1}$, $H_{oBp} = -1$

$H_{Lp}(s) = -\frac{1}{sRC} H_{Bp}(s)$ 이므로 $H_{oLp} = \frac{1}{Q}$

$H_{Hp}(s) = -sRC\, H_{Bp}(s)$ 이므로 $H_{oHp} = \frac{1}{Q}$

(b) $f_L = 594\ Hz$, $f_H = 606\ Hz$

$f_o = \sqrt{f_L f_H} \doteq 600\ Hz$

$RC = \frac{1}{2\pi \times 600} = 2.65 \times 10^{-4}$

$C = 0.1\ \mu F$, $R = 2.65\ k\Omega$

$Q = \frac{\omega_0}{BW} = \frac{600}{606-594} = 50 = 1+\frac{R_2}{2R_1}$

$\frac{R_2}{R_1} = 98 \Rightarrow R_2 = 98\ k\Omega$, $R_1 = 1\ k\Omega$

$R_3 \doteq 10\ k\Omega$ 사용

(c) $H_{oLp} = \frac{1}{Q} = \frac{1}{50}$.