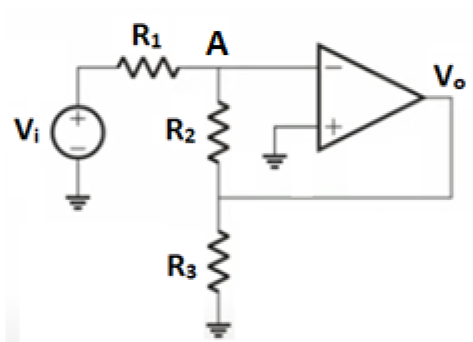
JAYPEE INSTITUTE OF INFORMATION TECHNOLOGY
Electronics and Communication Engineering
Electrical Science-II (15B11EC211)
Solution of Tutorial Sheet: 6

Solution: 01



For Ideal case of Op-Amp, voltage gain (A_V)= $V_o/V_{id} = \infty$

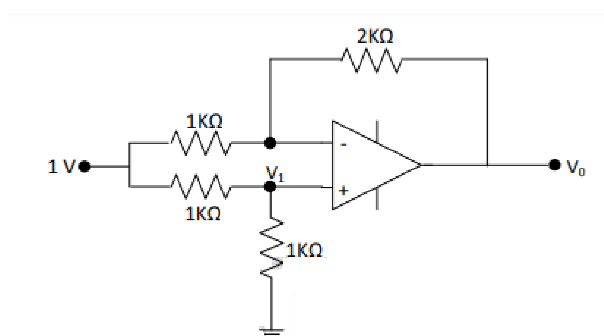
Therefore, $V_{id} = 0$ i.e. $V_+ - V_- = 0$ or $V_+ = V_-$ (**Virtual short concept)**

Apply KCL at node A position in the inverting terminal

$$(0-V_i)/R_1+(0-V_o)/R_2 = 0$$

$$\mathbf{Av = V_0/V_i= -R_2/R_1}$$

Solution-02



Apply superposition in the given Op-Amp

The output voltage (V_{01}) due to inverting input = $(-R_f/R)V_i$ = $(-2k/1K)\times1 = -2$ Volt

and for V_1 = $1k\times1/1k+1k = 0.5$ (Potential divider)

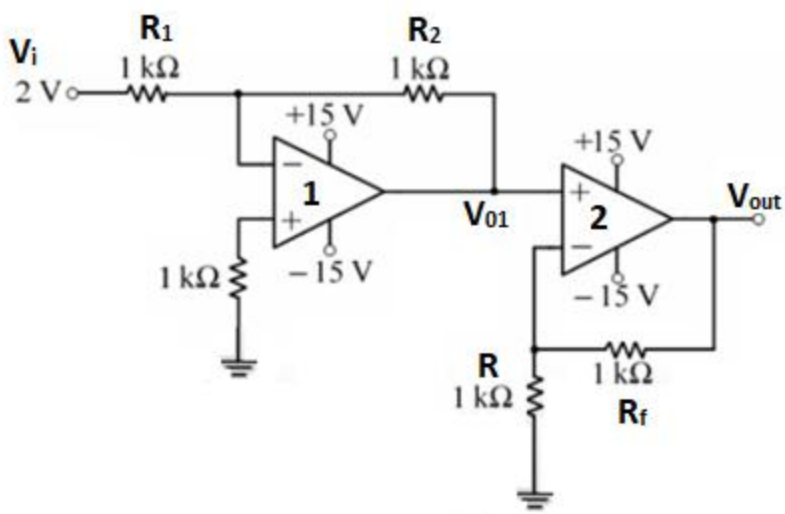
The output voltage (V_{02}) due to non inverting input = $(1+R_f/R)V_1$ = $(1+2/1)\times0.5 = 1.5$ Volt

The total output (V_0) = $V_{01}+V_{02}$ = $-2+1.5 = -0.5$ Volt

<u>Solution:03</u>

For ideal case of Op-Amp, voltage gain (A_V)= $V_0/V_{id} = \infty$

Therefore, $V_{id} = 0$ i.e. $V_+ - V_- = 0$ or $V_+ = V_-$



<u>For OP-AMP -1:</u> It is a inverting Op-Amp.

Therefore,

Apply KCL at inverting terminal

$$(0-V_i)/R_1+(0-V_{01})/R_2 = 0$$

$$\mathbf{V_{01}= (-R_2/R_1)V_i = -(1k/1k)\times2= -2 \text{ Volt} \quad \ldots\ldots(i)}$$

<u>For OP-AMP -2:</u> It is a non inverting Op-Amp.

Therefore,

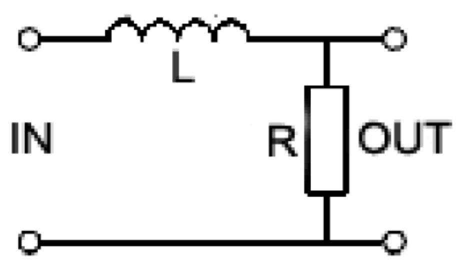
For non-inverting amplifer, apply KCL again at inverting terminal for V_{out}

$$(V_{01}-0)/R+(V_{01}-V_{out})/R_f = 0$$

$$V_{out} = (1+R_f/R)\, V_{01}$$

$$\mathbf{V_{out} = (1+1/1)\times(-2\,) = -4\ Volt}$$

Solution:04



$$\mathbf{H}(\omega) = \frac{\mathbf{V}_o}{\mathbf{V}_i} = \frac{R}{R + j\omega L} = \frac{1}{1 + j\omega L/R}$$

H(0) = 1 and H(∞) = 0 showing that this circuit is a lowpass filter.

At the corner frequency, $|H(\omega_c)| = 1/\sqrt{2}$, i.e.

$$\frac{1}{\sqrt{2}} = \frac{1}{\sqrt{1+\left(\frac{\omega_c L}{R}\right)^2}} \longrightarrow 1 = \frac{\omega_c L}{R}$$

or $\omega_c = R/L$

Hence, $\omega_c = R/L = 2\,\pi f_c$

$$f_c = \frac{1}{2\pi}\cdot\frac{R}{L} = \frac{1}{2\pi}\cdot\frac{10\times10^3}{2\times10^{-3}} = \underline{\mathbf{796\ kHz}}$$

Solution:05

$$\mathbf{H}(\omega) = \frac{R \,||\, \dfrac{1}{j\omega C}}{j\omega L + R \,||\, \dfrac{1}{j\omega C}}$$

$$\mathbf{H}(\omega) = \frac{\dfrac{R/j\omega C}{R + 1/j\omega C}}{j\omega L + \dfrac{R/j\omega C}{R + 1/j\omega C}}$$

$$\mathbf{H}(\omega) = \frac{\mathbf{R}}{\mathbf{R + j\omega L - \omega^2 RLC}}$$

$$H(\omega) = \frac{0.25}{0.25 + j\omega\text{-}0.25\omega^2}$$

H(0) = 1 and H(∞) = 0 showing that this circuit is a lowpass filter.

Solution:06

$$\mathbf{H}(\omega) = \frac{\mathbf{V}_o}{\mathbf{V}_i} = \frac{j\omega L}{R + j\omega L}$$

H(0) = 0 and H(∞) = 1 showing that this circuit is a highpass filter.

$$\mathbf{H}(\omega_c) = \frac{1}{\sqrt{2}} = \frac{1}{\sqrt{1 + \left(\dfrac{R}{\omega_c L}\right)^2}} \longrightarrow 1 = \frac{R}{\omega_c L}$$

or $\boldsymbol{\omega_c = R/L}$

Hence, $\omega_c = R/L = 2\,\pi f_c$

$$f_c = \frac{1}{2\pi}\cdot\frac{R}{L} = \frac{1}{2\pi}\cdot\frac{200}{0.1} = \underline{\mathbf{318.3\ Hz}}$$

Solution: 07

$$\omega_1 = 2\pi f_1 = 20\pi\times10^3$$

$$\omega_2 = 2\pi f_2 = 22\pi\times10^3$$

$$B = \omega_2 - \omega_1 = 2\pi\times10^3$$

$$\omega_0 = \frac{\omega_2+\omega_1}{2} = 21\pi\times10^3$$

$$Q = \frac{\omega_0}{B} = \frac{21\pi}{2\pi} = 10.5$$

$$\omega_0 = \frac{1}{\sqrt{LC}} \quad\rightarrow\quad L = \frac{1}{\omega_0^2 C}$$

$$L = \frac{1}{\left(21\pi\times10^3\right)\left(80\times10^{-12}\right)} = 2.872\text{H}$$

$$B = \frac{R}{L} \quad\rightarrow\quad R = BL$$

$$R = \left(2\pi\times10^3\right)\left(2.872\right) = 18.045\ \text{k}\Omega$$

Solution: 08

$$\mathbf{H}'(\omega) = \frac{j\omega RC}{1 + j\omega RC} = \frac{j\omega}{j\omega + 1/RC}$$

This has a unity passband gain, i.e. H(∞) = 1.

$$\frac{1}{RC} = \omega_c = 50$$

$$\mathbf{H}^{\wedge}(\omega) = 10\,\mathbf{H}'(\omega) = \frac{j10\omega}{50 + j\omega}$$

$$\mathbf{H}(\omega) = \underline{\frac{\mathbf{j10\omega}}{\mathbf{50 + j\omega}}}$$

Solution: 09

(a)

$$\mathbf{V}_{+} = \frac{1/j\omega C}{R + 1/j\omega C}\mathbf{V}_i, \qquad \mathbf{V}_{-} = \mathbf{V}_o$$

Since $\mathbf{V}_{+} = \mathbf{V}_{-}$,

$$\frac{1}{1 + j\omega RC}\mathbf{V}_i = \mathbf{V}_o$$

$$\mathbf{H}(\omega) = \frac{\mathbf{V}_o}{\mathbf{V}_i} = \frac{\mathbf{1}}{\mathbf{1 + j\omega RC}}$$

(b)

$$\mathbf{V}_+ = \frac{R}{R + 1/j\omega C}\mathbf{V}_i, \qquad \mathbf{V}_- = \mathbf{V}_o$$

Since $\mathbf{V}_+ = \mathbf{V}_-$,

$$\frac{j\omega RC}{1 + j\omega RC}\mathbf{V}_i = \mathbf{V}_o$$

$$\mathbf{H}(\omega) = \frac{\mathbf{V}_o}{\mathbf{V}_i} = \frac{\mathbf{j\omega RC}}{\mathbf{1 + j\omega RC}}$$

<u>Solution: 10</u>

$$Z_f = R_f \,||\, \frac{1}{j\omega C_f} = \frac{R_f}{1 + j\omega R_f C_f}$$

$$Z_i = R_i + \frac{1}{j\omega C_i} = \frac{1 + j\omega R_i C_i}{j\omega C_i}$$

Hence,

$$\mathbf{H}(\omega) = \frac{\mathbf{V}_o}{\mathbf{V}_i} = \frac{\mathbf{-Z_f}}{\mathbf{Z_i}}$$

$$= \underline{\frac{\mathbf{-j\omega R_f C_i}}{\mathbf{(1 + j\omega R_f C_f)(1 + j\omega R_i C_i)}}}$$

This is a bandpass filter.

H(ω) is similar to the product of the transfer function of a lowpass filter and a highpass filter.