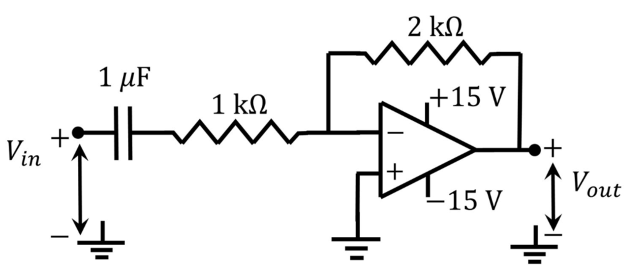
Assignment

EE23BTECH11001 - Aashna Sahu

Q:An ideal OPAMP circuit with a sinusoidal input is shown in the figure. The 3dB frequency is the frequency at which the magnitude of the voltage gain decreases by 3 dB from the maximum value. Which of the options is/are correct?



(A) The circuit is a low pass filter.

(B) The circuit is a high pass filter.

(C) The 3 dB frequency is 1000rad/s.

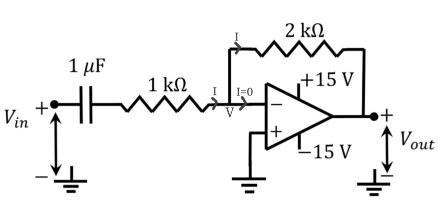
(D) The 3 dB frequency is $\frac{1000}{3}$rad/s.

(GATE EC 2022)

Solution:

Parameter	Description	Value
V_{in}	Input Voltage	–
V_{out}	Output Voltage	–
C	Capacitor	$1\mu F$
R_1	Resistance	$1k\Omega$
R_2	Feedback Resistance	$2k\Omega$

TABLE 4: Input Parameters



$$\frac{V_{in} - V}{\frac{1}{sC} + R_1} = \frac{V - V_{out}}{R_2} \tag{1}$$

As Op-Amp is ideal

$$V = V^+ = 0V \tag{2}$$

$$\left|\frac{V_{out}}{V_{in}}\right| = \frac{sCR_2}{1 + sCR_1} \tag{3}$$

$$H(s) = \frac{sCR_2}{1 + sCR_1} \tag{4}$$

For determining nature of Filter
Put $s = 0$

$$H(s) = 0 \tag{5}$$

Put $s \to \infty$

$$H(s) = \frac{R_2}{R_1} = 2 \quad \text{(Finite)} \tag{6}$$

$\therefore$ It is high pass filter.

On simplifying (4) further

$$H(s) = \frac{R_2}{R_1}\left(\frac{s}{s + \frac{1}{CR_1}}\right) \tag{7}$$

$$|H(s)|_{max} = \frac{R_2}{R_1} \tag{8}$$

$$|H(s)|_{\omega=\omega_c} = \frac{R_2}{R_1}\left|\frac{s}{s + \frac{1}{CR_1}}\right| \tag{9}$$

Given

$$20\log(|H(s)|_{max}) - 20\log(|H(s)|_{\omega=\omega_c}) = 3dB \tag{10}$$

$$\frac{|H(s)|_{max}}{|H(s)|_{\omega=\omega_c}} = \sqrt{2} \tag{11}$$

From (8) and (9)

$$\frac{1}{\sqrt{2}}\frac{R_2}{R_1} = \frac{R_2}{R_1}\left|\frac{s}{s + \frac{1}{CR_1}}\right| \tag{12}$$

Put $s = j\omega_c$

$$\left|\frac{j\omega_c}{j\omega_c + \frac{1}{CR_1}}\right| = \frac{1}{\sqrt{2}} \tag{13}$$

$$\implies \omega_c = \frac{1}{CR_1} \tag{14}$$

From Table 4

$$\omega_c = 1000\text{rad/s} \tag{15}$$

Where ω_c is 3 dB frequency.

Finally, Correct options are (B) and (C).