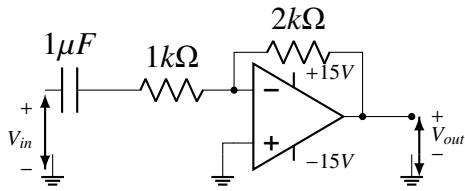


Assignment

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?



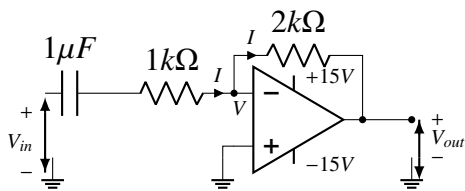
- (A) The circuit is a low pass filter.
- (B) The circuit is a high pass filter.
- (C) The 3 dB frequency is 1000rad/s.
- (D) The 3 dB frequency is $\frac{1000}{3}$ rad/s.

(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	$2k\Omega$
V	Voltage at Negative terminal	–
V^+	Voltage at positive terminal	0

TABLE 4: Input Parameters



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

As Op-Amp is ideal

$$V = V^+ = 0V \quad (2)$$

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

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

Keeping $s = j\omega$

For determining nature of Filter

Put $j\omega = 0$

$$H(j\omega) = 0 \quad (5)$$

Put $j\omega \rightarrow \infty$

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

\therefore It is high pass filter.

On simplifying (4) further

$$H(j\omega) = \frac{R_2}{R_1} \left(\frac{j\omega}{j\omega + \frac{1}{CR_1}} \right) \quad (7)$$

$$|H(j\omega)|_{max} = \frac{R_2}{R_1} \quad (8)$$

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

Given:

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

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

From (8) and (9)

$$\frac{R_2}{R_1} \left| \frac{j\omega_c}{j\omega_c + \frac{1}{CR_1}} \right| = \frac{1}{\sqrt{2}} \frac{R_2}{R_1} \quad (12)$$

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

$$\Rightarrow \omega_c = \frac{1}{CR_1} \quad (14)$$

From Table 4

$$\omega_c = 1000\text{rad/s} \quad (15)$$

Where ω_c is 3 dB frequency.

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

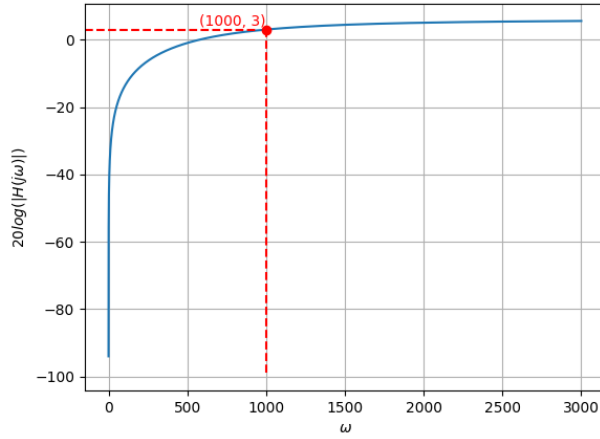


Fig. 4: Frequency response plot