GATE 2022 IN-56

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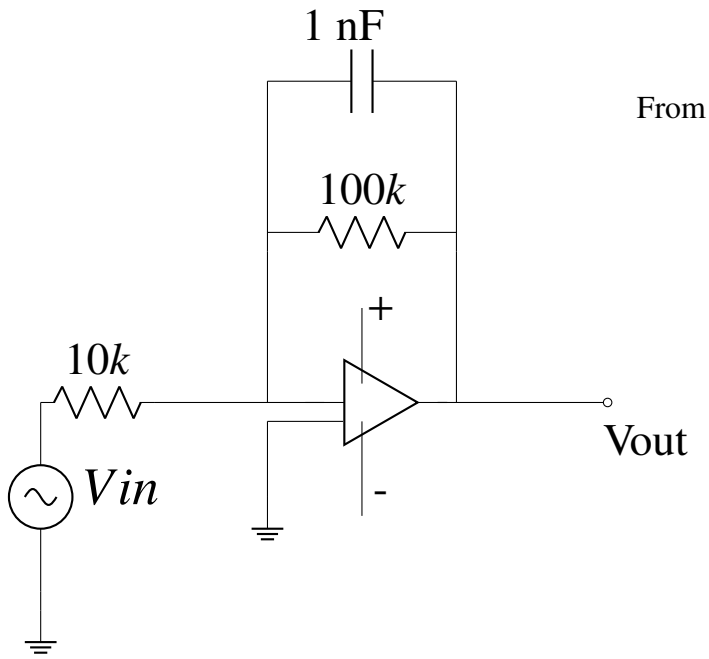
Question: The circuit shown is driven by a sinusoidal input voltage, V_{in}, resulting in the output voltage V_{out}. The frequency (in kilohertz) at which the voltage gain is 0 dB is (rounded off to two decimal places). (GATE IN 2022)



Solution: This circuit is an inverting OP-AMP. The transfer function of an inverting OP-AMP is given by

$$Z_1 = R_1 \tag{1}$$

$$Z_2 = \frac{R_2}{1 + j\omega R_2 C} \tag{2}$$

$$\frac{1}{Z_2} = \frac{1}{R_2} + j\omega C \tag{3}$$

$$\frac{V_{\text{out}}}{V_{\text{in}}} = -\frac{Z_2}{Z_1} \tag{4}$$

$$\frac{|V_{\text{out}}|}{|V_{\text{in}}|} = \frac{|Z_2|}{|Z_1|} \tag{5}$$

From Table 0

$$20\log\left(\frac{V_{\text{out}}}{V_{\text{in}}}\right) = 0 \tag{6}$$

$$\frac{V_{\text{out}}}{V_{\text{in}}} = 1 \tag{7}$$

$$\frac{|V_{\text{out}}|}{|V_{\text{in}}|} = \frac{|R_2|}{|(1 + j\omega R_2 C)R_1|} = 1 \tag{8}$$

$$\frac{R_2}{R_1} = \sqrt{1 + (R_2\omega C)^2} \tag{9}$$

$$10 = \sqrt{1 + (10^5 \cdot \omega 10^{-9})^2} \tag{10}$$

$$99 = \omega^2 \times 10^{-8} \tag{11}$$

$$\omega = \sqrt{99} \times 10^4 \tag{12}$$

$$2\pi f = 99.49 \times 10^3 \tag{13}$$

$$f = 15.84\,\text{kHz} \tag{14}$$

Parameter	Value	Description
$20\log\left(\frac{V_{\text{out}}}{V_{\text{in}}}\right)$	0	Voltage gain
Sinusoidal input voltage	V_{in}	Input voltage applied to the circuit
Output voltage	V_{out}	Voltage across the output of the circuit
R_1	10 kΩ	Resistor connected to the inverting input of the OP-AMP
R_2	100 kΩ	Feedback resistor connected from the output to the inverting input of the OP-AMP
C	1 nF	Capacitor connected in parallel with R_2
Z_1	?	Impedance of resistor R_1
Z_2	?	Impedance of capacitor C in series with resistor R_2

TABLE 0
PARAMETERS

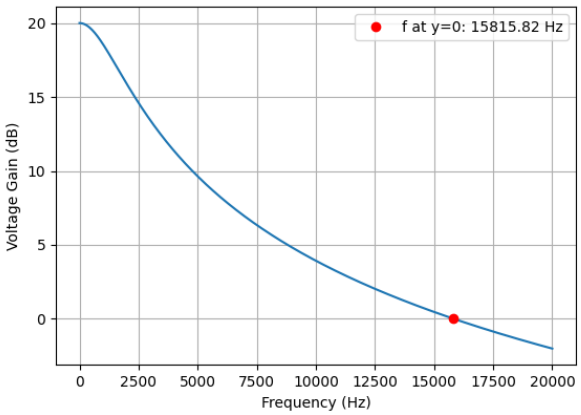


Fig. 0. Frequency vs Voltage gain