Electrical Engineering Practice Problems

for the Power, Electrical and Electronics, and Computer PE Exams

Eighth Edition

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45 Amplifiers

PRACTICE PROBLEMS

1. An operational amplifier has a gain of 10^5. The frequencies at the half-power points are $f_L = 500$ Hz and $f_H = 1000$ Hz. What is the figure of merit?

(A) 1×10^6 rad/s
(B) 5×10^7 rad/s
(C) 3×10^8 rad/s
(D) 6×10^8 rad/s

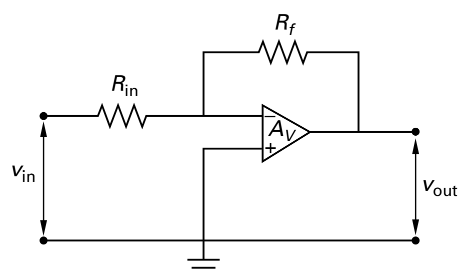
2. During testing of an operational amplifier, a signal of equal magnitude is applied to the two terminals. That is, $v^+ = -v^-$. What gain is being measured?

(A) A_{cm}
(B) A_{dm}
(C) A_V
(D) G_P

3. An operational amplifier data sheet indicates a voltage gain of 10^5 and a power supply voltage of 12 V. What is the maximum voltage difference between the input terminals that will ensure linear operation?

(A) 60 μV
(B) 90 μV
(C) 120 μV
(D) 150 μV

4. Consider the circuit shown. The feedback resistance is 10 kΩ, and the input resistance is 100 Ω. If the op amp gain is 10^5, what is the gain of the circuit?

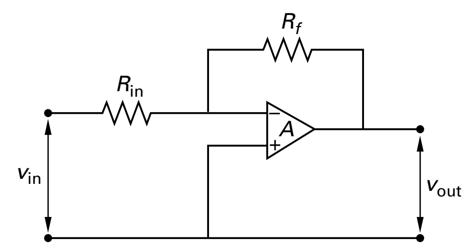


(A) -100
(B) -99.9
(C) $+100$
(D) 10^5

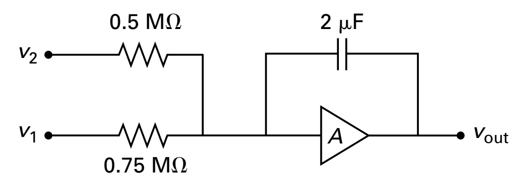
5. An operational amplifier has an input resistance of 10^5 Ω and a bandwidth of 1000 Hz, and is at a room temperature of 300K. If 10 dB above the noise is required for proper operation, what is the required signal power?

(A) 0.10 μV
(C) 2.0 μV
(C) 4.0 μV
(D) 16 μV

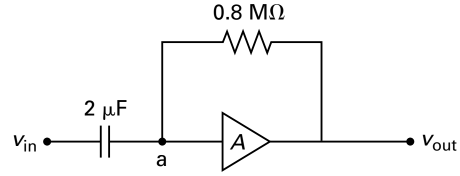
6. Consider the circuit shown. (a) If $R_f = 1$ MΩ and $R_{\text{in}} = 50$ Ω, what is the gain? (b) If $v_{\text{in}} = 1$ mV, what is v_{out}?



7. For the circuit shown, $v_1 = 10 \sin 200t$ and $v_2 = 15 \sin 200t$. What is v_{out}? The op amp is ideal and has infinite gain.



8. In the circuit shown, if v_{in} is $\sin 30t$, what is v_{out}? The op amp is ideal and has infinite gain.



Electronics

SOLUTIONS

1. The figure of merit is

$$F_m = A_{\text{ref}}(\text{BW}) = A_{\text{ref}}\,(2\pi f_H - 2\pi f_L)$$
$$= \left(10^5\right)(2\pi)(1000\text{ Hz} - 500\text{ Hz})$$
$$= \boxed{3.14 \times 10^8 \text{ rad/s} \quad (3 \times 10^8 \text{ rad/s})}$$

The answer is (C).

2. The differential-mode voltage is

$$v_{\text{dm}} = v^+ - v^-$$

Thus, with $v^+ = -v^-$,

$$v_{\text{dm}} = v^+ + v^+ = 2v^+$$

The common-mode voltage is

$$v_{\text{cm}} = \tfrac{1}{2}(v^+ + v^-) = \tfrac{1}{2}\left(v^+ + (-v^-)\right) = 0 \text{ V}$$

Therefore, only the difference is being amplified, and the gain so determined is A_{dm}.

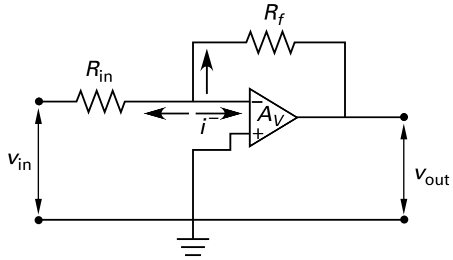
The answer is (B).

3. The maximum voltage difference is

$$\left|v^+ - v^-\right| < \frac{V_{\text{DC}} - 3\text{ V}}{A_V}$$
$$|\Delta V| < \frac{12\text{ V} - 3\text{ V}}{10^5} = \frac{9\text{ V}}{10^5}$$
$$= \boxed{90 \times 10^{-6}\text{ V} \quad (90\ \mu\text{V})}$$

The answer is (B).

4. Consider the circuit shown, assuming the indicated current directions at the negative terminal.



Writing Kirchoff's current law (KCL) at the inverting terminal node gives

$$\frac{V^- - v_{\text{in}}}{R_{\text{in}}} + \frac{V^- - v_{\text{out}}}{R_f} + i^- = 0 \text{ A}$$

Applying the ideal op amp assumptions means $i^- = 0$ A and $v^- = 0$ V. Substituting and solving for the gain gives

$$\frac{0 - v_{\text{in}}}{R_{\text{in}}} + \frac{0 - v_{\text{out}}}{R_f} + 0 = 0 \text{ A}$$
$$\frac{v_{\text{out}}}{v_{\text{in}}} = \frac{-R_f}{R_{\text{in}}} = A_{V,\text{ideal}}$$
$$= \frac{-10 \times 10^3\ \Omega}{100\ \Omega} = -100$$

But this op amp is real and has a finite gain. The constraint equation (that is, the fundamental op amp equation) rearranged is

$$V^- - V^+ = \Delta = \frac{-v_{\text{out}}}{A_V}$$

Since V^+ is at 0 V,

$$V^- = \frac{-v_{\text{out}}}{A_V}$$

Substituting into the original equation gives

$$\frac{\dfrac{-v_{\text{out}}}{A_V} - v_{\text{in}}}{R_{\text{in}}} + \frac{\dfrac{-v_{\text{out}}}{A_V} - v_{\text{out}}}{R_f} + 0 = 0$$

The input current is still small enough to be ignored. Rearranging gives

$$\frac{v_{\text{out}}}{v_{\text{in}}} = -A_V\left(\frac{R_f}{R_f + R_{\text{in}} + A_V R_{\text{in}}}\right)$$

Note that when the gain is large, this expression reduces to the expression for gain in the ideal case.

Substituting the given values gives the following result.

$$\frac{v_{\text{out}}}{v_{\text{in}}} = \left(-10^5\right)\left(\frac{10 \times 10^3\ \Omega}{\begin{array}{c}10 \times 10^3\ \Omega + 100\ \Omega\\ +\ (10^5)(100\ \Omega)\end{array}}\right)$$
$$= \boxed{-99.9}$$

The answer is (B).

58 Antenna Theory

PRACTICE PROBLEMS

1. What is the term for a group of components arranged to vary the transmission or reception of electromagnetic waves?

(A) array
(B) Huygens' source
(C) waveguide
(D) dish antenna

2. For an antenna with a bandwidth of 1 GHz at its maximum design temperature of 65°C, what is the noise power?

(A) 9×10^{-13} W
(B) 2×10^{-12} W
(C) 5×10^{-12} W
(D) 5×10^{-9} W

3. What is the phase constant for a 500 MHz signal?

(A) 1.05 rad/m
(B) 10.5 rad/m
(C) 32.0 rad/m
(D) 38.0 rad/m

4. The peak electric field of a plane electromagnetic wave 10 km south of a vertical antenna is 0.2×10^{-2} V/cm. What is the magnitude of the magnetic field at that point?

(A) 10.0 nA/m
(B) 1.00 μA/m
(C) 0.50 mA/m
(D) 0.05 mA/m

5. A radio station's assigned frequency is 107 MHz. What is the free-space basic transmission loss 50 km from the transmitting antenna?

(A) 3.5 dB
(B) 47 dB
(C) 83 dB
(D) 110 dB

SOLUTIONS

1. An array is used to manipulate the direction of an antenna with respect to incoming or outgoing electromagnetic waves.

The answer is (A).

2. The noise power is

$$P_n = \kappa TB$$

The design temperature of 65°C equates to 338K. Substituting gives

$$\begin{aligned} P_n &= \left(1.3805 \times 10^{-23}\ \frac{\text{J}}{\text{K}}\right)(338\text{K})(10^9\ \text{Hz}) \\ &= \boxed{4.67 \times 10^{-12}\ \text{W} \quad (5 \times 10^{-12}\ \text{W})} \end{aligned}$$

The answer is (C).

3. The phase constant, β, is

$$\beta = \frac{2\pi}{\lambda}$$

The wavelength of a 500 MHz wave is

$$\begin{aligned} \lambda &= \frac{c}{f} = \frac{3 \times 10^8\ \frac{\text{m}}{\text{s}}}{500 \times 10^6\ \frac{1}{\text{s}}} \\ &= 0.6\ \text{m} \end{aligned}$$

Substituting gives

$$\beta = \frac{2\pi}{\lambda} = \frac{2\pi}{0.6\ \text{m}} = \boxed{10.5\ \text{rad/m}}$$

The answer is (B).

Communications