
Sheet (2) - Solution

1. A non-inverting amplifier has Ri of 1KΩ and R_f of 100 KΩ. Determine V_f and B if V_{out} = 5V.

$$B = \frac{R_i}{R_i + R_f} = \frac{1.0\,\text{k}\Omega}{101\,\text{k}\Omega} = \mathbf{9.90 \times 10^{-3}}$$

$$V_f = BV_{out} = (9.90 \times 10^{-3})5\text{ V} = 0.0495\text{ V} = \mathbf{49.5\text{ mV}}$$

2. For the non-inverting amplifier shown in figure (1). Determine $A_{cl(NI)}$, V_{out}, and V_f.

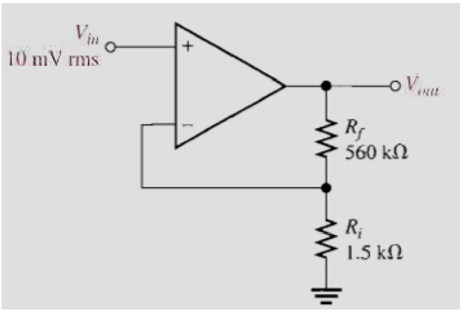

Figure (1)

(a) $A_{cl(NI)} = \frac{1}{B} = \frac{1}{1.5\,\text{k}\Omega / 561.5\,\text{k}\Omega} = \mathbf{374}$

(b) $V_{out} = A_{cl(NI)}V_{in} = (374)(10\text{ mV}) = \mathbf{3.74\text{ V rms}}$

(c) $V_f = \left(\frac{1.5\,\text{k}\Omega}{561.5\,\text{k}\Omega}\right)3.74\text{ V} = \mathbf{9.99\text{ mV rms}}$

3. Calculate the closed loop gain for non-inverting amplifier has R_1=4.7KΩ, R_F=47KΩ, and A_{OL}=150,000.

$$A_{cl(NI)} = \frac{1}{B} = \frac{1}{4.7\,\text{k}\Omega / 51.7\,\text{k}\Omega} = \mathbf{11}$$

4. For an inverting amplifier with closed loop gain of -300, and R_1 of 10KΩ, calculated the value required to R_f to satisfy this gain.

$$\frac{R_f}{R_i} = A_{cl(I)}$$

$$R_f = -R_i(A_{cl(I)}) = -10\ \text{k}\Omega(-300) = \mathbf{3\ M\Omega}$$

5. Determine the approximate values for I_{in}, I_f, Vout, A_{cl} in figure (2).

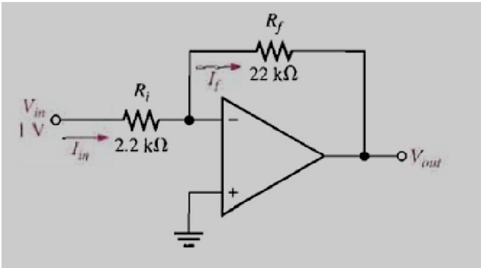

Figure (2)

(a) $I_{in} = \dfrac{V_{in}}{R_{in}} = \dfrac{1\text{V}}{2.2\ \text{k}\Omega} = \mathbf{455\ \mu A}$

(b) $I_f \cong I_{in} = \mathbf{455\ \mu A}$

(c) $V_{out} = -I_f R_f = -(455\ \mu\text{A})(22\ \text{k}\Omega) = \mathbf{-10\ V}$

(d) $A_{cl(I)} = -\left(\dfrac{R_f}{R_i}\right) = -\left(\dfrac{22\ \text{k}\Omega}{2.2\ \text{k}\Omega}\right) = \mathbf{-10}$

6. Determine the input and output impedances for the following amplifiers of fig.3

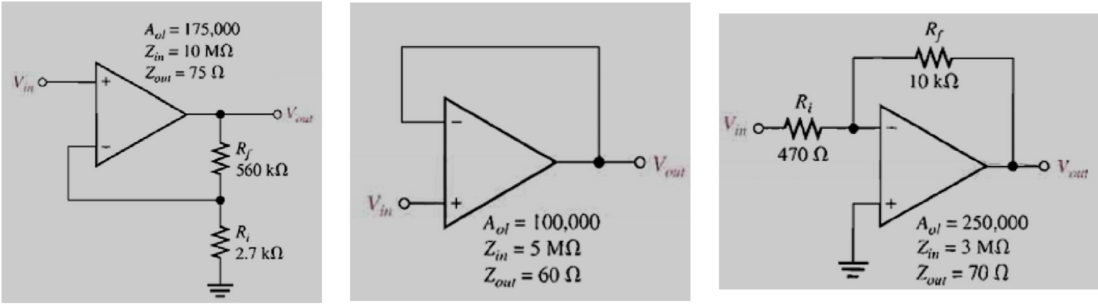

Figure (3)

(a) $B = \dfrac{2.7\text{ k}\Omega}{562.5\text{ k}\Omega} = 0.0048$

$Z_{in(\mathrm{NI})} = (1 + A_{ol})Z_{in} = [1 + (175{,}000)(0.0048)]10\text{ M}\Omega = \mathbf{8.41\ G\Omega}$

$Z_{out(\mathrm{NI})} = \dfrac{Z_{out}}{1 + A_{ol}B} = \dfrac{75\ \Omega}{1 + (175{,}000)(0.0048)} = \mathbf{89.2\ m\Omega}$

(b) $Z_{in(\mathrm{VF})} = (1 + A_{ol})Z_{in} = (1 + 100{,}000)5\text{ M}\Omega = 5 \times 10^{11}\ \Omega = \mathbf{500\ G\Omega}$

$Z_{out(\mathrm{VF})} = \dfrac{Z_{out}}{1 + A_{ol}} = \dfrac{60\ \Omega}{1 + 100{,}000} = \mathbf{600\ \mu\Omega}$

(c) $Z_{in(\mathrm{I})} \cong R_i = \mathbf{470\ \Omega}$

$B = \dfrac{470\ \Omega}{10{,}470\ \Omega} = 0.045$

$Z_{out(\mathrm{I})} = \dfrac{Z_{out}}{1 + A_{ol}B} = \dfrac{70\ \Omega}{1 + (250{,}000)(0.045)} = \mathbf{6.22\ m\Omega}$

7. A voltage follower is driven by a voltage source resistance of 75Ω.

(a) What value of compensating resistor is required for bias current and where should the resistor be placed?

(b) If the two input currents after compensation are 42μA and 40μA. What is the output error voltage?

(a) $R_{comp} = R_{in} = \mathbf{75\ \Omega}$ **placed in the feedback path.**

$I_{OS} = |42\ \mu A - 40\ \mu A| = 2\mu A$

(b) $V_{OUT(error)} = A_v I_{OS} R_{in} = (1)(2\ \mu A)(75\ \Omega) = \mathbf{150\ \mu V}$

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8. A particular voltage follower has an input offset voltage of 2nV. What is the output error voltage?

$$V_{\text{OUT(error)}} = A_v V_{\text{IO}} = (1)(2\text{ nV}) = \mathbf{2\text{ nV}}$$

9. What is the input offset voltage of an op-amp if a dc voltage of 35mV is measured when the input voltage is zero? The opamp's open loop gain is specified to be 200,000.

$$V_{\text{IO}} = \frac{V_{\text{OUT(error)}}}{A_{ol}} = \frac{35\text{ mV}}{200{,}000} = \mathbf{175\text{ nV}}$$

10. The midrange open-loop gain of a certain op-amp is 120dB. Negative feedback reduces this gain by 50dB. What is the closed-loop gain?

$$A_{cl} = 120\text{ dB} - 50\text{ dB} = \mathbf{70\text{ dB}}$$

11. The upper critical frequency of an op-amp's open loop response is 200Hz. If the midrange gain is 175,000, what is the ideal gain at 200Hz? What is the actual gain? What is the op-amp's open-loop bandwidth?

The gain is ideally **175,000 at 200 Hz.** The midrange dB gain is
20 log(175,000) = 105 dB
The actual gain at 200 Hz is

$$A_v(\text{dB}) = 105\text{ dB} - 3\text{ dB} = 102\text{ dB}$$

$$A_v = \log^{-1}\left(\frac{102}{20}\right) = \mathbf{125{,}892}$$

$$BW_{ol} = \mathbf{200\text{ Hz}}$$

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12. An RC lag circuit has a critical frequency of 8.5 KHz. Determine the phase shift for each frequency and plot a graph of its phase angle versus frequency. (i) 100Hz (ii) 400Hz (iii) 850Hz (IV) 8.5 KHz (v) 25 KHz.

$$(a)\quad \theta = \tan^{-1}\left(\frac{f}{f_c}\right) = \tan^{-1}\left(\frac{100\text{ Hz}}{8.5\text{ kHz}}\right) = \mathbf{-0.674^\circ}$$

$$(b)\quad \theta = \tan^{-1}\left(\frac{f}{f_c}\right) = \tan^{-1}\left(\frac{400\text{ Hz}}{8.5\text{ kHz}}\right) = \mathbf{-2.69^\circ}$$

$$(c)\quad \theta = \tan^{-1}\left(\frac{f}{f_c}\right) = \tan^{-1}\left(\frac{850\text{ Hz}}{8.5\text{ kHz}}\right) = \mathbf{-5.71^\circ}$$

$$(d)\quad \theta = \tan^{-1}\left(\frac{f}{f_c}\right) = \tan^{-1}\left(\frac{8.5\text{ kHz}}{8.5\text{ kHz}}\right) = \mathbf{-45.0^\circ}$$

$$(e)\quad \theta = \tan^{-1}\left(\frac{f}{f_c}\right) = \tan^{-1}\left(\frac{25\text{ kHz}}{8.5\text{ kHz}}\right) = \mathbf{-71.2^\circ}$$

13. An RC lag circuit has a critical frequency of 5 KHz. If the resistance value is 1KΩ. What is Xc when f=3KHz.

$$\frac{f_c}{f} = \frac{X_C}{R}$$

$$X_C = \frac{Rf_c}{f} = \frac{(1.0\text{ k}\Omega)(5\text{ kHz})}{3\text{ kHz}} = \mathbf{1.67\text{ k}\Omega}$$

14. Determine the attenuation of an RC lag circuit with f_c=12 KHz for 1 KHz and 100 KHz.

$$\frac{V_{out}}{V_{in}} = \frac{1}{\sqrt{1+\left(\frac{f}{f_c}\right)^2}} = \frac{1}{\sqrt{1+\left(\frac{1\text{ kHz}}{12\text{ kHz}}\right)^2}} = \mathbf{0.997}$$

$$\frac{V_{out}}{V_{in}} = \frac{1}{\sqrt{1+\left(\frac{f}{f_c}\right)^2}} = \frac{1}{\sqrt{1+\left(\frac{100\text{ kHz}}{12\text{ kHz}}\right)^2}} = \mathbf{0.119}$$

15. A certain amplifier has an open-loop gain in midrange of 180,000 and an open-loop critical frequency of 1500Hz. If the attenuation of the path is 0.015, what is the closed-loop bandwidth?

$$BW_{cl} = BW_{ol}(1 + BA_{ol(mid)}) = 1500\text{ Hz}[1 + (0.015)(180{,}000)] = \mathbf{4.05\ MH}$$

16. Given that $f_{c(ol)}$=750Hz, A_{ol}=89dB, and $f_{c(cl)}$=5.5KHz, determine the closed loop gain in decibels.

$$A_{ol}(\text{dB}) = 89\text{ dB}$$
$$A_{ol} = 28{,}184$$
$$A_{cl}f_{c(cl)} = A_{ol}f_{c(ol)}$$
$$A_{cl} = \frac{A_{ol}\,f_{c(ol)}}{f_{c(cl)}} = \frac{(28{,}184)(750\text{ Hz})}{5.5\text{ kHz}} = 3843$$
$$A_{cl}(\text{dB}) = 20\log(3843) = \mathbf{71.7\ dB}$$

17. Which of the amplifiers shown in figure (4) has the smaller Bandwidth?

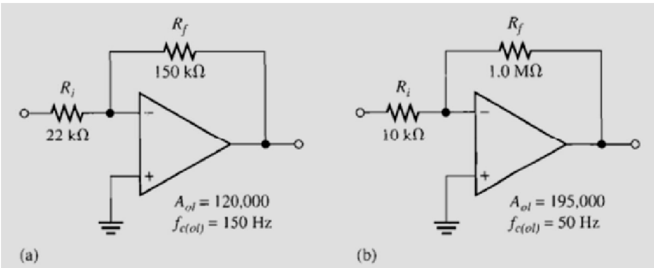

Figure (4)

(a) $$A_{cl} = \frac{150\text{ k}\Omega}{22\text{ k}\Omega} = 6.8$$
$$f_{c(cl)} = \frac{A_{ol}\,f_{c(ol)}}{A_{cl}} = \frac{(120{,}000)(150\text{ Hz})}{6.8} = 2.65\text{ MHz}$$
$$BW = f_{c(cl)} = \mathbf{2.65\ MHz}$$

(b) $$A_{cl} = \frac{1.0\text{ M}\Omega}{10\text{ k}\Omega} = 100$$
$$f_{c(cl)} = \frac{A_{ol}\,f_{c(ol)}}{A_{cl}} = \frac{(195{,}000)(50\text{ Hz})}{100} = 97.5\text{ kHz}$$
$$BW = f_{c(cl)} = \mathbf{97.5\ kHz}$$

Good Luck

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