FACULTY OF ENGINEERING
DEPARTMENT OF ELECTRONICS AND COMMUNICATIONS

GEE336
Electronic Circuits II

Lecture #3
Examples on Feedback Amplifier

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SUMMER 2015

EXAMPLE 14.1 Determine the voltage gain, input, and output impedance with feedback for voltage-series feedback having $A = -100$, $R_i = 10\text{ k}\Omega$, and $R_o = 20\text{ k}\Omega$ for feedback of (a) $\beta = -0.1$ and (b) $\beta = -0.5$.

Solution: Using Eqs. (14.2), (14.4), and (14.6), we obtain

a. $$A_f = \frac{A}{1+\beta A} = \frac{-100}{1+(-0.1)(-100)} = \frac{-100}{11} = \mathbf{-9.09}$$

$$Z_{if} = Z_i(1+\beta A) = 10\text{ k}\Omega\,(11) = \mathbf{110\text{ k}\Omega}$$

$$Z_{of} = \frac{Z_o}{1+\beta A} = \frac{20\times 10^3}{11} = \mathbf{1.82\text{ k}\Omega}$$

b. $$A_f = \frac{A}{1+\beta A} = \frac{-100}{1+(-0.5)(-100)} = \frac{-100}{51} = \mathbf{-1.96}$$

$$Z_{if} = Z_i(1+\beta A) = 10\text{ k}\Omega\,(51) = \mathbf{510\text{ k}\Omega}$$

$$Z_{of} = \frac{Z_o}{1+\beta A} = \frac{20\times 10^3}{51} = \mathbf{392.16\ \Omega}$$

EXAMPLE 14.2 If an amplifier with gain of -1000 and feedback of $\beta = -0.1$ has a gain change of 20% due to temperature, calculate the change in gain of the feedback amplifier.

Solution: Using Eq. (14.9), we get

$$\left|\frac{dA_f}{A_f}\right| \cong \left|\frac{1}{\beta A}\right|\left|\frac{dA}{A}\right| = \left|\frac{1}{-0.1(-1000)}(20\%)\right| = \mathbf{0.2\%}$$

The improvement is 100 times. Thus, whereas the amplifier gain changes from $|A| = 1000$ by 20%, the gain with feedback changes from $|A_f| = 100$ by only 0.2%.

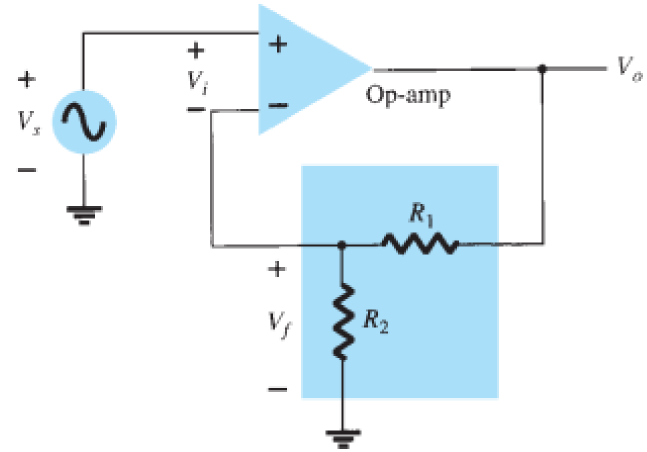


FIG. 14.8

EXAMPLE 14.4 Calculate the amplifier gain of the circuit of Fig. 14.8 for op-amp gain $A = 100{,}000$ and resistances $R_1 = 1.8\ \text{k}\Omega$ and $R_2 = 200\ \Omega$.

Solution:

$$\beta = \frac{R_2}{R_1 + R_2} = \frac{200\ \Omega}{200\ \Omega + 1.8\ \text{k}\Omega} = 0.1$$

$$A_f = \frac{A}{1 + \beta A} = \frac{100{,}000}{1 + (0.1)(100{,}000)}$$

$$= \frac{100{,}000}{10{,}001} = 9.999$$

Note that since $\beta A \gg 1$,

$$A_f \cong \frac{1}{\beta} = \frac{1}{0.1} = \mathbf{10}$$

EXAMPLE 12–1

A certain op-amp has an open-loop differential voltage gain of 100,000 and a common-mode gain of 0.2. Determine the CMRR and express it in decibels.

Solution $A_{ol} = 100{,}000$, and $A_{cm} = 0.2$. Therefore,

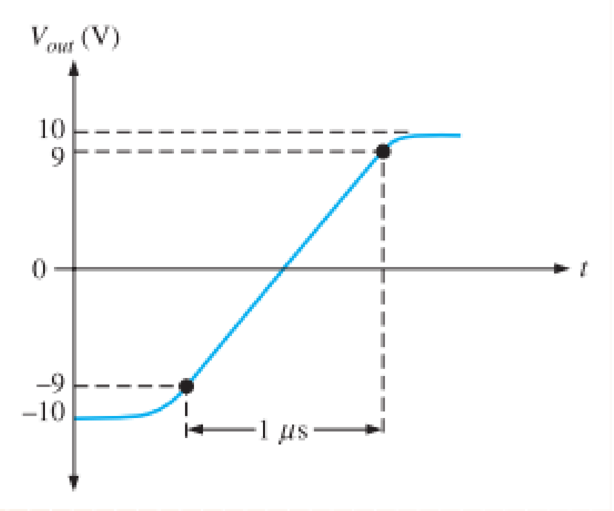
$$\text{CMRR} = \frac{A_{ol}}{A_{cm}} = \frac{100{,}000}{0.2} = \mathbf{500{,}000}$$

Expressed in decibels,

$$\text{CMRR} = 20 \log (500{,}000) = \mathbf{114\ dB}$$

EXAMPLE 12–2 The output voltage of a certain op-amp appears as shown in Figure 12–12 in response to a step input. Determine the slew rate.

▶ FIGURE 12–12



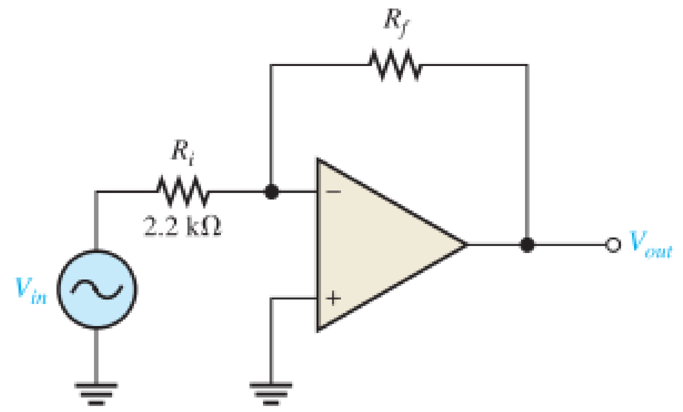
Solution The output goes from the lower to the upper limit in 1 μs. Since this response is not ideal, the limits are taken at the 90% points, as indicated. So, the upper limit is +9 V and the lower limit is −9 V. The slew rate is

$$\text{Slew rate} = \frac{\Delta V_{out}}{\Delta t} = \frac{+9\text{ V} - (-9\text{ V})}{1\ \mu\text{s}} = \mathbf{18\ V/\mu s}$$

EXAMPLE 12–4

Given the op-amp configuration in Figure 12–22, determine the value of R_f required to produce a closed-loop voltage gain of -100.

FIGURE 12–22



Solution Knowing that $R_i = 2.2\ \text{k}\Omega$ and the absolute value of the closed-loop gain is $|A_{cl(I)}| = 100$, calculate R_f as follows:

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

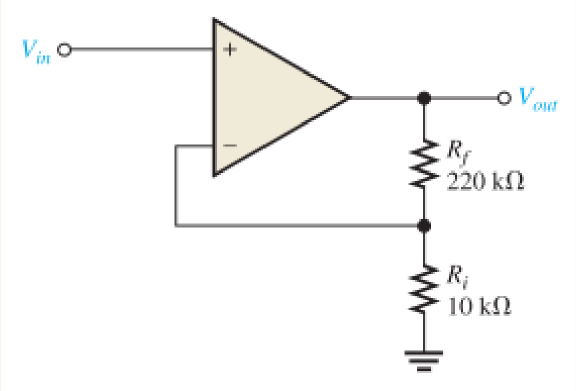
$$R_f = |A_{cl(I)}|R_i = (100)(2.2\ \text{k}\Omega) = \mathbf{220\ k\Omega}$$

EXAMPLE 12–5

(a) Determine the input and output impedances of the amplifier in Figure 12–25. The op-amp datasheet gives $Z_{in} = 2\ \text{M}\Omega$, $Z_{out} = 75\ \Omega$, and $A_{ol} = 200{,}000$.

(b) Find the closed-loop voltage gain.

▶ FIGURE 12–25



Solution

(a) The attenuation, B, of the feedback circuit is

$$B = \frac{R_i}{R_i + R_f} = \frac{10\ \text{k}\Omega}{230\ \text{k}\Omega} = 0.0435$$

$$Z_{in(NI)} = (1 + A_{ol}B)Z_{in} = [1 + (200{,}000)(0.0435)](2\ \text{M}\Omega)$$
$$= (1 + 8700)(2\ \text{M}\Omega) = \mathbf{17.4\ G\Omega}$$

This is such a large number that, for all practical purposes, it can be assumed to be infinite as in the ideal case.

$$Z_{out(NI)} = \frac{Z_{out}}{1 + A_{ol}B} = \frac{75\ \Omega}{1 + 8700} = \mathbf{8.6\ m\Omega}$$

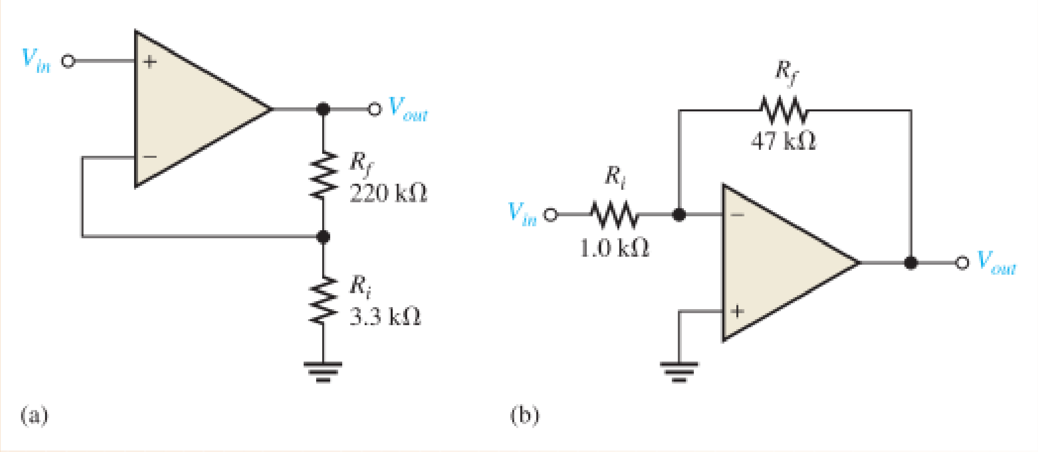
This is such a small number that, for all practical purposes, it can be assumed to be zero as in the ideal case.

(b) $A_{cl(NI)} = 1 + \dfrac{R_f}{R_i} = 1 + \dfrac{220\ \text{k}\Omega}{10\ \text{k}\Omega} = \mathbf{23.0}$

EXAMPLE 12–12

Determine the bandwidth of each of the amplifiers in Figure 12–43. Both op-amps have an open-loop gain of 100 dB and a unity-gain bandwidth (f_T) of 3 MHz.

▶ FIGURE 12–43



Solution

(a) For the noninverting amplifier in Figure 12–43(a), the closed-loop gain is

$$A_{cl} = 1 + \frac{R_f}{R_i} = 1 + \frac{220\text{ k}\Omega}{3.3\text{ k}\Omega} = 67.7$$

Use Equation 12–23 and solve for $f_{c(cl)}$ (where $f_{c(cl)} = BW_{cl}$).

$$f_{c(cl)} = BW_{cl} = \frac{f_T}{A_{cl}}$$

$$BW_{cl} = \frac{3\text{ MHz}}{67.7} = \mathbf{44.3\text{ kHz}}$$

(b) For the inverting amplifier in Figure 12–43(b), the closed-loop gain is

$$A_{cl} = -\frac{R_f}{R_i} = -\frac{47\text{ k}\Omega}{1.0\text{ k}\Omega} = -47$$

Using the absolute value of A_{cl}, the closed-loop bandwidth is

$$BW_{cl} = \frac{3\text{ MHz}}{47} = \mathbf{63.8\text{ kHz}}$$

- For more details, refer to:
  - Chapter 12, T. Floyd, **Electronic Devices**, 9th edition.
  - Chapter 14, **Boylestad, Electronic Devices and Circuit theory**, 11th edition.
- The lecture is available online at:
  - http://bu.edu.eg/staff/ahmad.elbanna-courses/12884
- For inquires, send to:
  - ahmad.elbanna@feng.bu.edu.eg