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Homework 2: Due 1/29/2020

1. Given an op amp with the following characteristics:

$$\begin{aligned} A_O &= 80k \\ r_d &= 400k\Omega \\ r_o &= 50\Omega \\ R_i &= 3k\Omega \\ R_f &= 47k\Omega \end{aligned} \tag{1}$$

   1. Find the feedback factor

$$\beta = \frac{R_i}{R_i + R_f} = \frac{3}{50} = 0.06 \tag{2}$$

   2. loop gain (A_{CL})

$$A_{CL} \approx \frac{1}{\beta} = 16.\overline{6} \tag{3}$$

   3. exact closed loop gain (A_{CL})

$$A_{CL} = \frac{A_O}{1 + A_O\beta} = \frac{80k}{1 + (80k)(0.06)} \tag{4}$$

$$\underline{\overline{|A_{CL} = 16.663|}}$$

   4. Closed loop input resistance (Z_i)

$$Z_i = (1 + A_O\beta)r_d = (1 + (80k)(0.06))(400k\Omega) \tag{5}$$

$$\underline{\overline{|Z_i = 2G\Omega|}}$$

   5. output resistance (Z_o)

$$Z_o = \frac{r_o}{1 + A_O\beta} = \frac{50}{1 + (80k)(0.06)} \tag{6}$$

$$\underline{\overline{|Z_o = 10m\Omega|}}$$

   6. Compare with question 3-8

      The gain changes are comparable.

3. Repeat question 1(a-e) with the following changes:

$$\begin{aligned} R_i &= \cancel{3k\Omega} = 30k\Omega \\ R_f &= \cancel{47k\Omega} = 270k\Omega \end{aligned} \tag{7}$$

   1. Find the feedback factor

$$\beta = \frac{R_i}{R_i + R_f} = \frac{1}{10} = 0.1 \tag{8}$$

   2. loop gain (A_{CL})

$$A_{CL} \approx \frac{1}{\beta} = 10 \tag{9}$$

3. exact closed loop gain (A_{CL})

$$A_{CL} = \frac{A_O}{1 + A_O\beta} = \frac{80k}{1 + (80k)(0.1)} \tag{10}$$
$$\underline{\overline{|A_{CL} = 9.99875|}}$$

4. Closed loop input resistance (Z_i)

$$Z_i = (1 + A_O\beta)r_d = (1 + (80k)(0.1))(400k\Omega) \tag{11}$$
$$\underline{\overline{|Z_i \approx 3G\Omega|}}$$

5. output resistance (Z_o)

$$Z_o = \frac{r_o}{1 + A_O\beta} = \frac{50}{1 + (80k)(0.1)} \tag{12}$$
$$\underline{\overline{|Z_o = 6m\Omega|}}$$

5. Find A_{CL} given

$$\begin{aligned} R_i &= 1k\Omega \\ R_f &= 99k\Omega \end{aligned} \tag{13}$$

1. $A_O = \infty$

$$\beta = \frac{1}{100} \tag{14}$$
$$A_{CL} = \frac{A_O}{1 + A_O\beta};\ A_O >> 0$$
$$A_{CL} = \frac{1}{\beta}$$
$$\underline{\overline{|A_{CL} = 100|}}$$

2. $A_O = 10^5$

$$A_{CL} = \frac{10^5}{1 + (10^5)(\frac{1}{100})} \tag{15}$$
$$\underline{\overline{|A_{CL} = 99.\overline{900099}|}}$$

3. $A_O = 10^4$

$$A_{CL} = \frac{10^4}{1 + (10^4)(\frac{1}{100})} \tag{16}$$
$$\underline{\overline{|A_{CL} = 99.\overline{0099}|}}$$

4. $A_O = 10^3$

$$A_{CL} = \frac{10^3}{1 + (10^3)(\frac{1}{100})} \tag{17}$$
$$\underline{\overline{|A_{CL} = 90.\overline{90}|}}$$

5. $A_O = 10^2$

$$A_{CL} = \frac{10^2}{1 + (10^2)(\frac{1}{100})} \tag{18}$$
$$\underline{\overline{|A_{CL} = 50|}}$$

7. Find A_{CL} given

$$R_i = 10k\Omega \tag{19}$$
$$R_f = 510k\Omega$$

1. $A_O = \infty$

$$\beta = \frac{1}{52} \tag{20}$$
$$A_{CL} = \frac{A_O}{1 + A_O\beta};\ A_O >> 0$$
$$A_{CL} = \frac{1}{\beta}$$
$$\underline{\overline{|A_{CL} = 52|}}$$

2. $A_O = 10^5$

$$A_{CL} = \frac{10^5}{1 + (10^5)(\frac{1}{52})} \tag{21}$$
$$\underline{\overline{|A_{CL} = 51.97|}}$$

3. $A_O = 10^4$

$$A_{CL} = \frac{10^4}{1 + (10^4)(\frac{1}{52})} \tag{22}$$
$$\underline{\overline{|A_{CL} = 51.73|}}$$

4. $A_O = 10^3$

$$A_{CL} = \frac{10^3}{1 + (10^3)(\frac{1}{52})} \tag{23}$$
$$\underline{\overline{|A_{CL} = 49.50|}}$$

5. $A_O = 10^2$

$$A_{CL} = \frac{10^2}{1 + (10^2)(\frac{1}{52})} \tag{24}$$
$$\underline{\overline{|A_{CL} = 34.11|}}$$