University of Puerto Rico - ECE Department
INEL 4202 - Electronics II - Summer 2001 - Exam 2 Solutions - Prof. M. Toledo

1. For a current-mixing feedback amplifier, $R_{if} = 110\Omega$, $R_{of} = 26k\Omega$, $A_f = 20$, and $\omega_{L,f} = 10rad/s$. For the associated non-feedback amplifier, $R_o = 2k\Omega$ and $\omega_H = 10^4 rad/s$.

   (a) Find the non-feedback amplifier R_i, A and ω_L. (10 pts)

   (b) What's the feedback's network β? (10 pts)

   ANSWER

   (a) Since $R_{of} > R_o$, the amplifier must sample current. Thus,

   $$D = 1 + \beta A = \frac{R_{of}}{R_o} = \frac{26k\Omega}{2k\Omega} = 13$$

   Since the feedback is current-mixing, $R_{if} = R_i/D$ and

   $$R_i = D \times R_{if} = 13 \times 110\Omega = 1430\Omega$$

   $$A = D \times A_f = 20 \times 13 = 260A/A$$

   $$\omega_L = D \times \omega_{LF} = 13 \times 10rad/s = 130rad/s$$

   (b)

   $$D = 1 + \beta \times A$$

   $$\beta = \frac{D-1}{A} = \frac{13-1}{260} \approx 0.046$$

2. A feedback amplifier displays a transresistance gain $R_{Mf} = 10^5\Omega$, $R_{if} = 10\Omega$ and $R_{of} = 10\Omega$. The feedback type is voltage-sampling, current-mixing with $\beta = 0.9 \times 10^{-5}$. The source's Thevenin resistance is $R_s = v_s/i_s = 1k\Omega$ and $R_L = v_o/i_o = 2k\Omega$.

   (a) Determine the current and voltage gains, $A_{vf} = v_o/v_s$ and $A_{if} = i_o/i_s$ respectively, of the feedback amplifier. (10 pts)

   (b) Find the transresistance gain $R_M = v_o/i_s$, input resistance R_i and output resistance R_o of the non-feedback amplifier. (10 pts)

   (c) Determine the current and voltage gains of the non-feedback amplifier. (10 pts)

   ANSWER

   (a)

   $$R_{Mf} = \frac{v_o}{i_s} = \frac{i_o R_L}{i_s} = R_L A_{if}$$

   Thus

   $$A_{if} = R_{Mf}/R_L = 10^5\Omega/2k\Omega = 50A/A$$

   Also since

   $$R_{Mf} = \frac{v_o}{i_s} = \frac{v_o}{v_s/R_s} = R_s A_{vf}$$

   then

   $$A_{vf} = \frac{R_{Mf}}{R_s} = 100V/V$$

(b) From $R_{Mf} = \frac{R_M}{1+\beta \times R_M}$,

$$R_M = \frac{R_{Mf}}{1 - \beta \times R_{Mf}} = \frac{10^5}{1 - (0.9 \times 10^{-5})(10^5)} = 10^6\Omega$$

The improvement factor is $D = 1 + \beta R_M = 1 + (0.9 \times 10^{-5})(10^5) = 10$ and

$$R_i = D \times R_{if} = 100\Omega$$

$$R_o = D \times R_{of} = 100\Omega$$

(c) $A_i = R_M / R_L = 500 A/A$; $A_v = R_M / R_s = 1000 V/V$

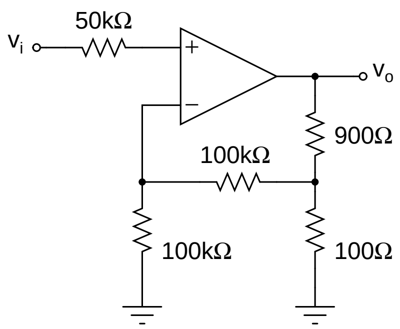
3. In the amplifier shown below, voltage-sampling, voltage-mixing feedback is employed. The active element is an opamp, for which the open-loop gain is 10^5, the output resistance is $R_O = 1k\Omega$, and the input resistance is $R_i = 100k\Omega$.

   (a) Find the feedback network's β, R_{11} and R_{22}. (10 pts)

   (b) Replace the opamp with it's two-port network equivalent circuit and draw the resulting non-feedback amplifier diagram, including the loading effects of the feedback network. (10 pts)

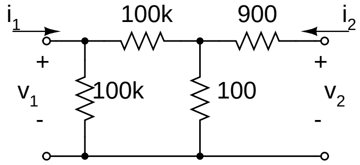
   (c) Find the non-feedback amplifier's voltage gain A_v, input resistance R_i and output resistance R_o that should be used to apply feedback theory. (10 pts)

   (d) Use feedback theory to find the feedback amplifier's voltage gain A_{vf}, input resistance R_{if} and output resistance R_{of}. (10 pts)



ANSWER

(a) The feedback network is



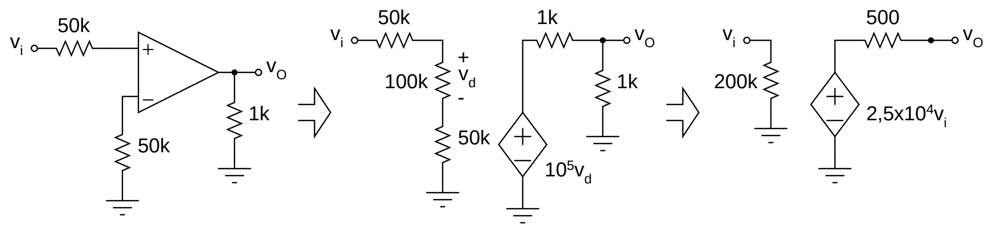
Using formulae for voltage-voltage feedback from the table

$$\beta = \frac{1}{2} \frac{50k \parallel 100}{900 + 50k \parallel 100} \approx 0.05$$

$$R_{11} = (900 \; || \; 100 + 100k) \; || \; 100k = 50k\Omega$$

$$R_{22} = 900 + (100k + 100k) \; || \; 100 \approx 1k\Omega$$

(b) Replacing the feedback network by R_{11} and R_{22} we obtain the non-feedback amplifier, which can be simplified as follows:



(c) From the above schematic,

$$A_v = 2.5 \times 10^4 V/V$$

$$R_i = 200k$$

$$R_o = 500$$

(d) Now we can apply feedback theory to obtain

$$D = 1 + (0.05)(2.5 \times 10^4) = 1251$$

$$A_{vf} = \frac{2.5 \times 10^4}{D} = \approx 20V/V$$

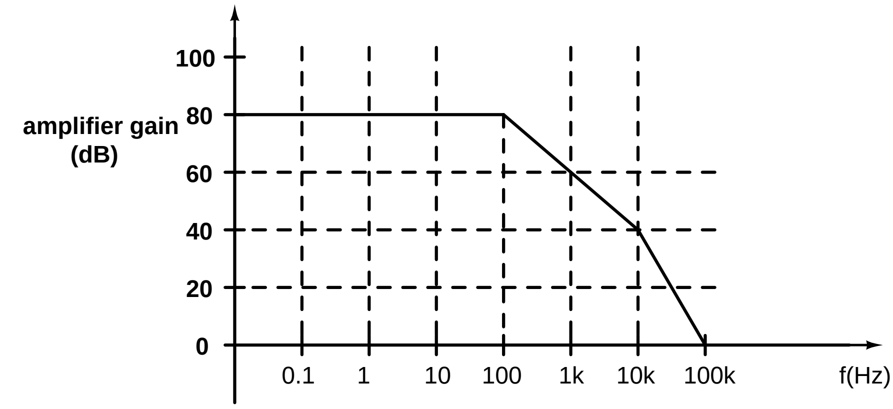
$$R_{if} = D \times R_i = 250.2M\Omega$$

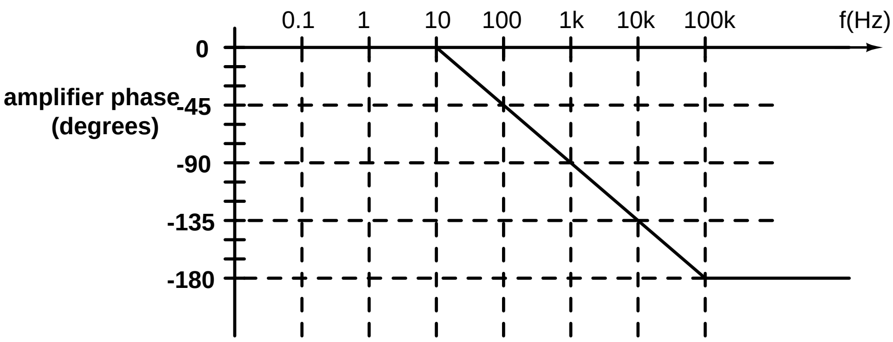
$$R_{of} = R_o/D = 0.4\Omega$$

4. Shown below is the frequency response for the voltage gain of a non-feedback amplifier. The response shows poles at 100Hz and 10kHz.

   (a) Determine the approximate value of the feedback network's β that will yield a phase margin of 60 degrees. (10 pts)

   (b) Use the pole shifting technique to find the position of the lowest frequency pole that would compensate the amplifier to have a $45°$ phase margin when $\beta = .1$. (10 pts)



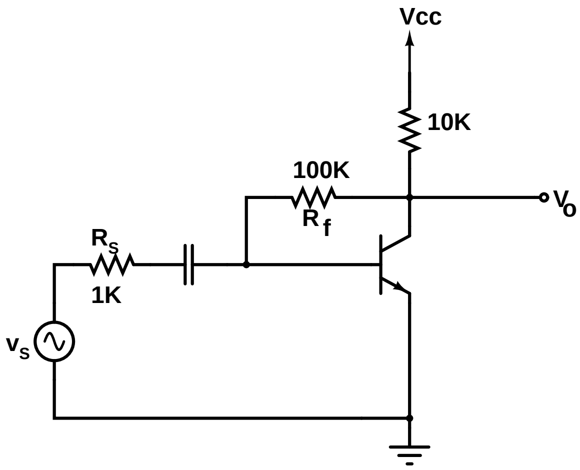


<u>ANSWER</u>

(a) About $20log1/\beta = 45dB$, or $\beta \approx 0.0056$.

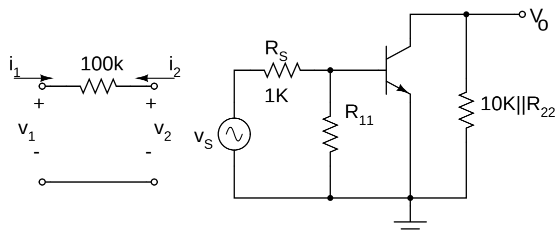
(b) The phase is about $135°$ at $10kHz$. At this frequency, the gain is $40dB$. We must reduce this gain to $20log1/\beta = 20log10 = 20dB$, i.e. by $20dB$. Thus, we need to move the first pole down by one decade, to $10Hz$.

5. In the following amplifier, voltage-sampling, current-mixing feedback is used. Find the feedback amplifier transresistance, R_{mf}. Assume that the capacitor is a short circuit at the operating frequency. Use $\beta = 100$ and $r_\pi = 2k\Omega$. (15 pts)



ANSWER

To solve the problem, we must first find the non-feedback amplifier that incorporates the feedback's network resistive loads. The feedback network is shown on the left of the following figure:



feedback network non-feedback amplifier

From the table's formulae,

$$R_{11} = \frac{v_1}{i_1}\,|_{v_2=0} = 100k\Omega$$

$$R_{22} = \frac{v_2}{i_2}\,|_{v_1=0} = 100k\Omega$$

and

$$\beta = \frac{i_1}{v_2}\,|_{v_1=0} = -\frac{1}{100k\Omega}$$

Now we can calculate the gain from the schematic shown on the right in the above figure. Using the formulae included in the exam's formula sheet,

$$A_v = -g_m R_c \frac{R_{in}}{R_{in} + R_s} = -\frac{100}{2k\Omega}(10k \mid\mid 100k)\frac{100k \mid\mid 2k}{100k \mid\mid 2k + 1k} = -301$$

Using this result, we can find the transresistance

$$R_M = \frac{v_o}{i_s} = \frac{v_o}{v_s/R_s} = R_s A_v = -301k\Omega$$

Finally,

$$R_{Mf} = \frac{R_M}{1 + \beta \times R_M} = \frac{-301k\Omega}{4.01} = -75k\Omega$$