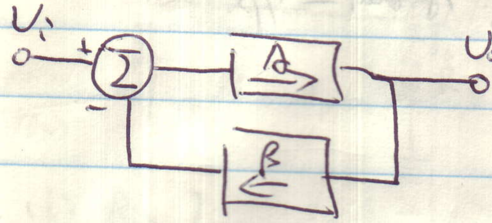
EE105 Discussion Session #2 Week Sept. 15.

1. Feedback System.



$A_o(v_i - \beta v_o) = v_o$

$\rightarrow A_v = v_o/v_i = \frac{1}{\beta}\frac{A_o\beta}{1+A_o\beta}$

Define: $T = A\beta$, loop gain

A_o, open-loop gain

A_v, closed-loop gain

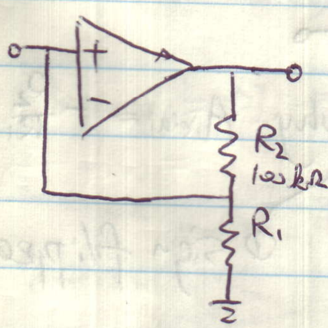
$A_{ideal} = 1/\beta$, ideal gain

β, feedback coefficient

$GE = A_{ideal} - A_v = \frac{1}{\beta}\frac{1}{1+T}$

$FGE = GE/A_{ideal} = 1/(1+T)$

$\boxed{\text{Q1.}}$



$A_o = 86dB$.

? A_v, FGE

(i). $R_1 = 10k\Omega$. (ii) $R_1 = 1k\Omega$

(i) $\beta = \frac{R_1}{R_1+R_2} = \frac{10}{110} = \frac{1}{11}$. $A_o = 86dB = 2\times10^4$

$T = A_o\beta = \frac{2\times10^4}{11} \simeq 2000$

$\begin{cases} A_v = \frac{1}{\beta}\frac{T}{1+T} \simeq \frac{1}{\beta} = 11 \\ FGE = \frac{1}{1+T} \simeq \frac{1}{2000} = 0.05\% \end{cases}$

(ii). $\beta = \frac{1}{1+100} = \frac{1}{101}$, $T = A_o\beta \simeq 200$

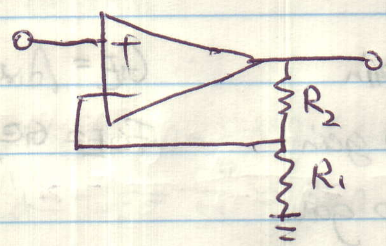
$A_v = \frac{1}{\beta}\frac{T}{1+T} \simeq 101$, $FGE = \frac{1}{1+T} = \frac{1}{1+200} \simeq 0.5\%$

Non-ideal gain

For the feedback system in the diagram.

$$A = A_{ideal}\frac{T}{1+T}, \quad A_{ideal} = 1/\beta.$$

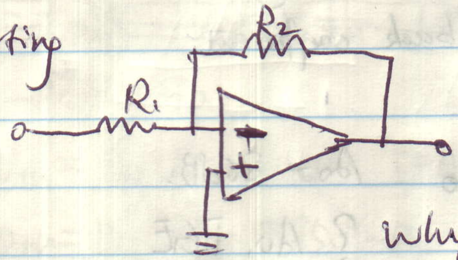
① For non-inverting amplifier



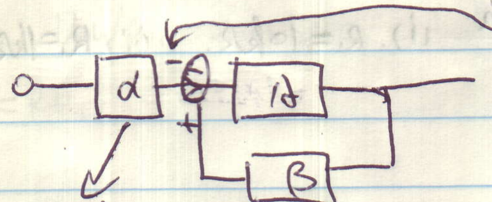
$\beta = \frac{R_1}{R_1+R_2}$

$A_{ideal} = 1/\beta = \frac{R_1+R_2}{R_1}$

② For inverting



why $A_{ideal} = -\frac{R_2}{R_1}$?

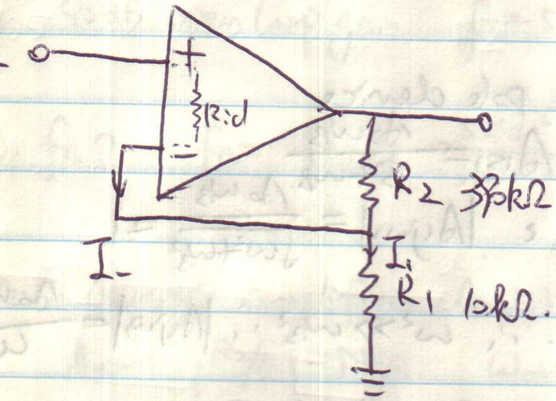


① sign flipped

② $\alpha = \frac{R_2}{R_1+R_2}$

$$A_{ideal} = -\frac{1}{\beta}\cdot\alpha = -\frac{R_1+R_2}{R_1}\cdot\frac{R_2}{R_1+R_2} = -\frac{R_2}{R_1}$$

Q2



$R_{id} = 1M\Omega$

$A_o = 80dB$

(i). R_{in}?

$A_o = 80dB = 10^4$

$R_{in} = R_{id}(1+T)$. $T = A_o\beta = 10^4 \cdot \frac{10}{10+390} = 250$

$R_{in} = 251\ M\Omega$

(ii) I_-? I_1?

$I_- = V_i / R_{in} = 4nA$

Or: $V_o = A_v V_i \simeq \frac{1}{\beta} V_i = 40V$

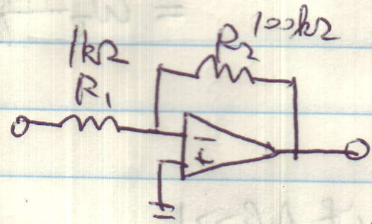
$V_{id} = V_o / A_o = 4m\cancel{A}$

$I_- = V_{id}/R_{id} = 4nA$

$I_1 \simeq V_o/(R_1+R_2) = 100\mu A$

Because $I_1 >> I_- \rightarrow I_1/I_- = 25000$ here.

Q3:



$R_{id} = 1M\Omega$

$A = 100dB$

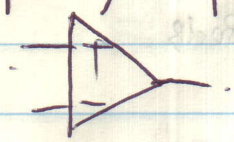
? $\Delta R = R_{in} - R_{in\text{-ideal}}$?

$R_{in\text{-ideal}} = R_1 = 1k\Omega$

$R_{in} = R_1 + R_{id} \| \frac{R_2}{1+A} \simeq R_1 + \frac{R_2}{1+A}$

$\therefore \Delta R \simeq \frac{R_2}{1+A} \simeq \frac{R_2}{A} = \frac{100k\Omega}{10^5} = 1\Omega$

2. Frequency Response



Single pole device

$$A(s) = \frac{A_0 \omega_B}{s + \omega_B}$$

unity gain frequency : $|A(j\omega)| = \dfrac{A_0 \omega_B}{\sqrt{\omega^2 + \omega_B^2}} = 1$.

Because $A_0 \gg 1$. $\therefore$ $\omega^2 \gg \omega_B^2$ $\therefore$ $|A(j\omega)| = \dfrac{A_0 \omega_B}{\omega} = 1$

$\therefore \omega_T = A_0 \omega_B$ $\quad$ $GBW \simeq \omega_T$.

① non-inverting.

$$A_v(s) = \frac{1}{\beta} \cdot \frac{A(s)\beta}{1 + A(s)\beta} = \frac{\dfrac{A_0 \omega_B}{s + \omega_B}}{1 + \dfrac{A_0 \omega_B}{s + \omega_B}\beta} = \frac{A_0 \omega_B}{s + \omega_B(1 + A_0\beta)}$$

$$= \frac{A_0/(1 + A_0\beta)}{\dfrac{s}{\omega_B(1 + A_0\beta)} + 1}.$$

$$\begin{cases} A_v(0) = \dfrac{A_0}{1 + A_0\beta} \simeq \dfrac{1}{\beta} \\ \omega_H = \omega_B(1 + A_0\beta) \\ \quad = \omega_T \dfrac{1 + A_0\beta}{A_0} = \dfrac{\omega_T}{A_v(0)} \end{cases}$$

$\Rightarrow \cancel{GBW = \omega_H}$

② Inverting:

if $A_0\beta \gg 1$

$$A_v(s) = -\frac{R_2}{R_1} \cdot \frac{A_0 \beta \omega_B}{s + \omega_B(1 + A_0\beta)} \simeq -\frac{R_2}{R_1} \frac{1}{\dfrac{s}{\omega_H} + 1}. \quad \omega_H = \frac{\omega_T}{A_0/(1 + A_0\beta)} \simeq \beta\,\omega_T.$$

$\boxed{Q4}$ 90 dB open loop gain. $f_T = 5MHz$.

①. f_B? $f_B = f_T / A_0 = \frac{5 \times 10^6}{31623} = 158 Hz$.

②. in inverting amplifier. $A_v = 50 dB$. BW?

$A_{v(0)} = |R_2/R_1| = 50 dB$. $\omega_H = \beta \omega_T$. , $\beta = \frac{1}{1 + A_{v(0)}} =$

$f_H = 15.8 kHz$