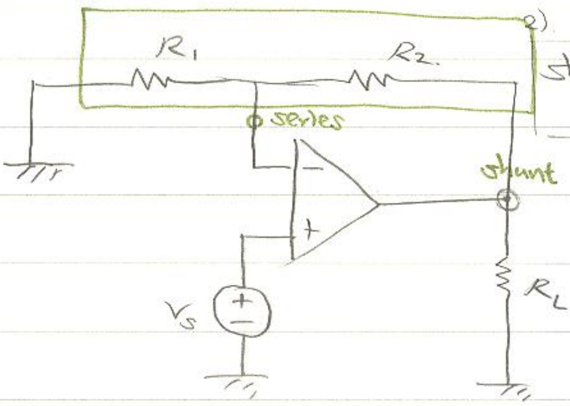
8.26 8

1) Identify the feedback topology
2) Indicate the output variable being sampled and the feedback sign
3) Expression for β and A_f

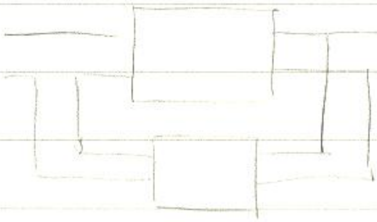
(a)

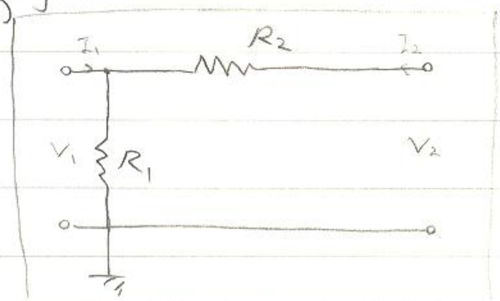


output voltage를 sense하여 series로 voltage를 v_s에 mix해주는 feedback 회로

→ series-shunt

feedback network를 다시 그리면



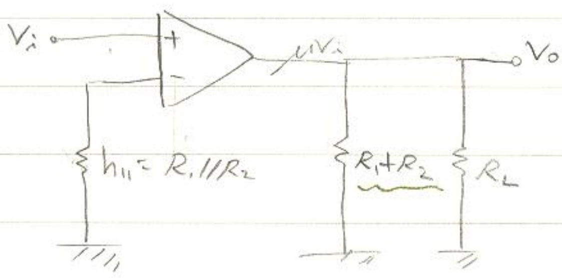


series-shunt 구성이므로 h-parameter two-port network를 이용해 feedforward를 무시한 채 A-circuit과 β circuit을 다시 그리는 과정은 아래와 같다

$$\begin{bmatrix} V_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix} \begin{bmatrix} I_1 \\ V_2 \end{bmatrix} \Rightarrow \begin{matrix} V_1 = h_{11} I_1 + h_{12} V_2 \\ I_2 = h_{21} I_1 + h_{22} V_2 \end{matrix} \Rightarrow h_{11} = \left.\frac{V_1}{I_1}\right|_{V_2=0}, \quad h_{22} = \left.\frac{I_2}{V_2}\right|_{I_1=0}, \quad h_{12} = \left.\frac{V_1}{V_2}\right|_{I_1=0}$$

이때 $h_{11} = R_1 // R_2$, $h_{22} = \frac{1}{R_1+R_2}$, $h_{12} = \frac{R_1}{R_1+R_2}$

A-circuit을 다시 그리면



$$A = \frac{v_o}{v_i}$$

한편 op-amp가 gain을 μ라 하면

$$\boxed{A = \frac{v_o}{v_i}} = \boxed{\mu}$$

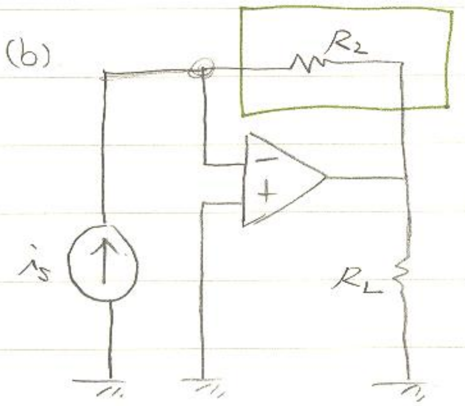
$$\boxed{\beta} = h_{12} = \boxed{\frac{R_1}{R_1+R_2}}$$

$$\Rightarrow A_f = \frac{A}{1+A\beta} = \frac{\mu}{1+\frac{\mu R_1}{R_1+R_2}} = \frac{\mu}{\frac{(1+\mu)R_1+R_2}{R_1+R_2}} = \frac{\mu(R_1+R_2)}{(1+\mu)R_1+R_2}$$

한편 op-amp를 ideal $(\mu=\infty)$로 가정했으므로

3) $$\boxed{\lim_{\mu\to\infty} A_f} = \lim_{\mu\to\infty} \frac{\mu(R_1+R_2)}{(1+\mu)R_1+R_2} = \frac{R_1+R_2}{R_1} = \boxed{\frac{1}{\beta}}$$

(b)

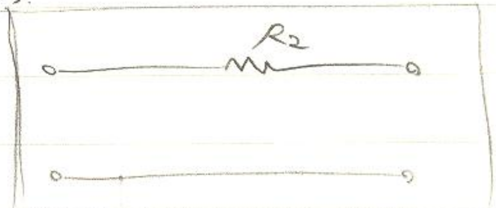


2) output voltage를 shunt로 sense해서 signal current와 shunt로 current를 mix해주고 있다

→ $\boxed{\text{shunt-shunt 구성}}$

1)

feedback network는

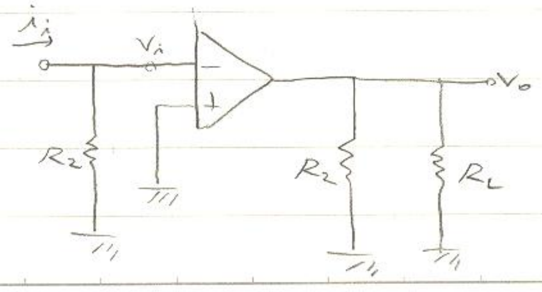


이때 y-parameter two-port network로 feedback 회로를 대체 → A-circuit과 β-circuit의 수정.

$$\begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} y_{11} & y_{12} \\ y_{21} & y_{22} \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \end{bmatrix} \Rightarrow \begin{aligned} I_1 &= y_{11}V_1 + y_{12}V_2 \\ I_2 &= y_{21}V_1 + y_{22}V_2 \end{aligned} \Rightarrow y_{11} = \left.\frac{I_1}{V_1}\right|_{V_2=0},\ y_{22} = \left.\frac{I_2}{V_2}\right|_{V_1=0},\ y_{12} = \left.\frac{I_1}{V_2}\right|_{V_1=0}$$

$$\Rightarrow y_{11} = \frac{1}{R_2},\ y_{22} = \frac{1}{R_2},\ y_{12} = -\frac{1}{R_2}$$

A-circuit을 다시 그리면



$$A = \frac{v_o}{i_i},$$

$v_i = i_i R_2$ (∵ideal op-amp로 가정)

$v_o = -\mu v_i$ (∵ op-amp의 gain을 μ로 가정)

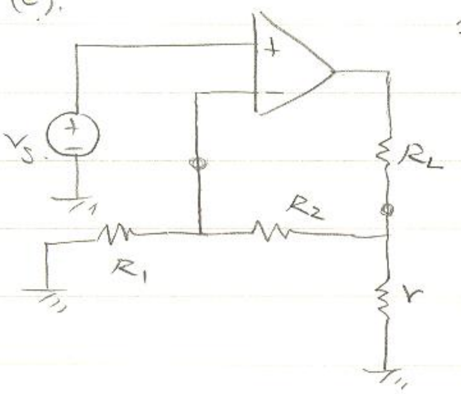
$$\Rightarrow \boxed{A} = \frac{v_o}{i_i} = \frac{v_i}{i_i}\cdot\frac{v_o}{v_i} = R_2(-\mu) = \boxed{-R_2\mu}$$

$$\boxed{\beta} = y_{12} = \boxed{-\frac{1}{R_2}} \qquad \Rightarrow A_f = \frac{A}{1+A\beta} = \frac{-R_2\mu}{1+\left(R_2\mu\cdot\frac{1}{R_2}\right)} = \frac{-R_2\mu}{1+\mu}$$

3)

$$\boxed{\lim_{\mu\to\infty} A_f} = \lim_{\mu\to\infty}\frac{-R_2\mu}{1+\mu} = -R_2 = \boxed{\frac{1}{\beta}}$$

(c).

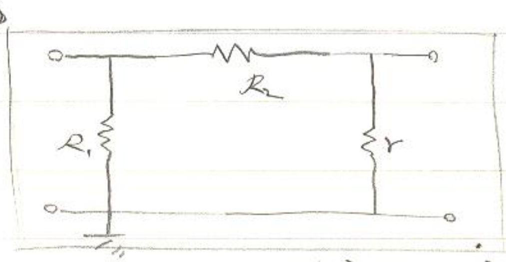


2) output current를 series로 sense해서 signal에 voltage를 series로 mix해주는 feedback 구성.

→ series - series 구성

feedback network

1)



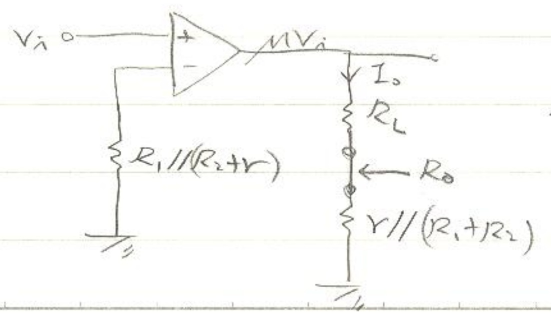
series - series 구성이므로 z - parameter 등가회로 사용

$$\begin{bmatrix} V_1 \\ V_2 \end{bmatrix} = \begin{bmatrix} z_{11} & z_{12} \\ z_{21} & z_{22} \end{bmatrix}\begin{bmatrix} I_1 \\ I_2 \end{bmatrix} \Rightarrow \begin{array}{l} V_1 = z_{11}I_1 + z_{12}I_2 \\ V_2 = z_{21}I_1 + z_{22}I_2 \end{array} \Rightarrow z_{11} = \left.\frac{V_1}{I_1}\right|_{I_2=0} \quad z_{22} = \left.\frac{V_2}{I_2}\right|_{I_1=0} \quad z_{12} = \left.\frac{V_1}{I_2}\right|_{I_1=0}.$$

$$z_{11} = R_1 /\!/ (R_2 + r), \quad z_{22} = r /\!/ (R_1 + R_2) \quad z_{12} = \frac{r}{(R_1+R_2)+r}\cdot R_1$$

A-circuit을 다시 그리면

$$A = \frac{I_o}{V_i}$$



$$\mu V_i = I_o\left(R_L + r /\!/ (R_1 + R_2)\right).$$

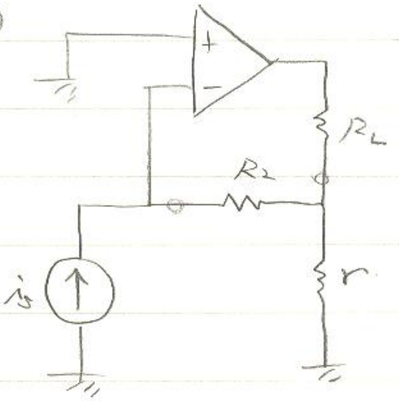
$$\Rightarrow \boxed{A} = \frac{I_o}{V_i} = \boxed{\frac{\mu}{R_L + r /\!/ (R_1 + R_2)}}$$

$\boxed{\beta} = z_{12} = \boxed{\dfrac{r}{(R_1+R_2)+r} R_1}$

$$A_f = \frac{A}{1+A\beta} = \frac{\dfrac{\mu}{R_L + r//(R_1+R_2)}}{1 + \dfrac{R_1 r}{(R_1+R_2)+r} \cdot \dfrac{\mu}{R_L + r//(R_1+R_2)}}$$

3) $\boxed{\lim_{\mu\to\infty} A_f} = \dfrac{\dfrac{1}{R_L + r//(R_1+R_2)}}{\dfrac{R_1 r}{[(R_1+R_2)+r][R_L+r//(R_1+R_2)]}} = \boxed{\dfrac{[(R_1+R_2)+r][R_L+r//(R_1+R_2)]}{R_1 r[R_L+r//(R_1+R_2)]}}$

(d)

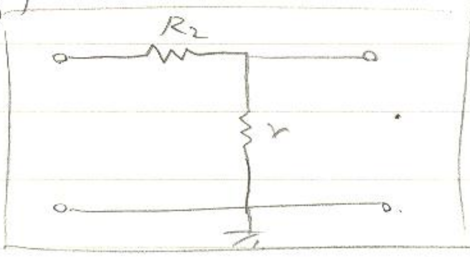


2) series로 output current를 sense하고

signal current에 shunt로 current를 mix하는 구성

→ shunt - series 구성

1) feedback network

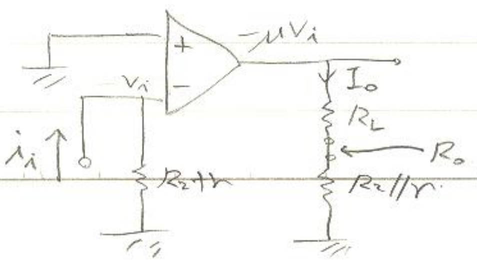


g-parameter two-port network로 이 회로를 대체하면.

$$\begin{bmatrix} I_1 \\ V_2 \end{bmatrix} = \begin{bmatrix} g_{11} & g_{12} \\ g_{21} & g_{22} \end{bmatrix}\begin{bmatrix} V_1 \\ I_2 \end{bmatrix} \Rightarrow \begin{array}{l} I_1 = g_{11}V_1 + g_{12}I_2 \\ V_2 = g_{21}V_1 + g_{22}I_2 \end{array} \Rightarrow g_{11} = \frac{I_1}{V_1}\bigg|_{I_2=0} \quad g_{22} = \frac{V_2}{I_2}\bigg|_{V_1=0} \quad g_{12} = \frac{I_1}{I_2}\bigg|_{V_1=0}.$$

$$g_{11} = \frac{1}{R_2+r}, \quad g_{22} = R_2//r, \quad g_{12} = -\frac{r}{R_2+r}.$$

A circuit을 다시 그려보면. $\quad A = \dfrac{I_o}{i_i}$



$V_i = i_i(R_2+r)$ ($\because$ ideal-op amp).

$-\mu V_i = I_o(R_L + R_2//r)$ ($\because$ gain을 μ라 가정)

$$\Rightarrow \boxed{A} = \frac{I_o}{i_i} = \frac{v_i}{i_i}\cdot\frac{I_o}{v_i}$$

$$= \boxed{(R_2+r)\left(\frac{-\mu}{R_L+R_2/\!/r}\right)}$$

$$\boxed{\beta} = g_{12} = \boxed{\frac{-r}{R_2+r}}$$

$$A_f = \frac{A}{1+A\beta} = \frac{-(R_2+r)\mu \,/\, (R_L+R_2/\!/r)}{1+(R_2+r)\left(\frac{-\mu}{R_L+R_2/\!/r}\right)\left(\frac{-r}{R_2+r}\right)}$$

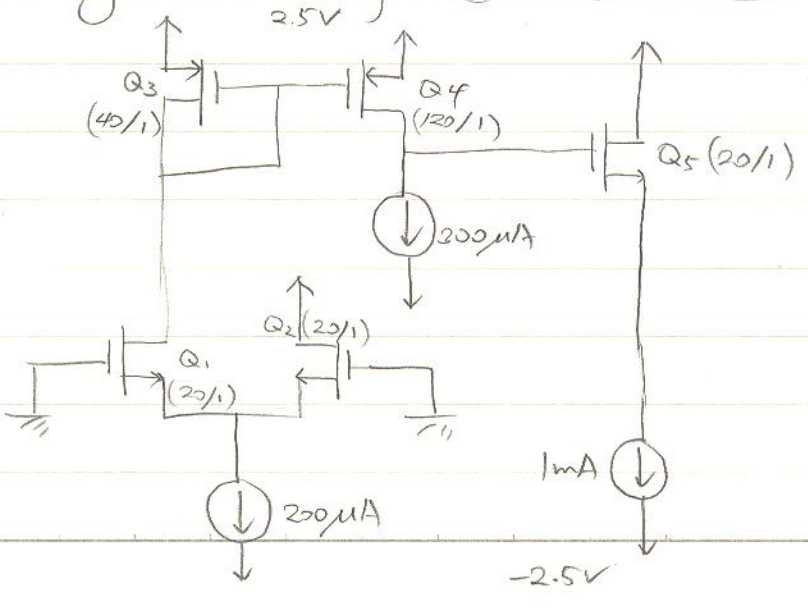
3)
$$\boxed{\lim_{\mu\to\infty} A_f} = -\frac{\dfrac{(R_2+r)}{(R_L+R_2/\!/r)}}{\dfrac{(\cancel{R_2+r})r}{(\cancel{R_2+r})(R_L+R_2/\!/r)}} = -\frac{R_2+r}{r} = \boxed{\frac{1}{\beta}}$$

$\boxed{8.33}$ 문제에 주어져 있는 회로는 series-shunt amplifier.

10. feedback factor $\beta = 1$.

$K_n' = 2k_p' = 120\,\mu A/V^2$. $|V_t| = 0.7V$. $|V_A'| = 24V/\mu m$.

(a) with the feedback loop opened and the gate terminals of Q_1 and Q_2 grounded $\Rightarrow$ find the DC current & the V_{ov} at each of Q_1 to Q_5



* I_{Q4}는 전류원에 의해 300μA가 되는 것인가?. 아님 전류미러의 출력을 전류원으로 그린 것인가?

Q_1과 Q_2의 bias current를 I_{Q_1}, I_{Q_2}라 할때

Q_1, Q_2에는 동상모드 입력이 없고, 완벽히 정합되어 있으며 (∵drain voltage의 차이로 인한 I_D의 mismatch 무시).

$\boxed{I_{Q_1}} = \boxed{I_{Q_2}} = \frac{1}{2}(200\mu A) = \boxed{100\mu A}$.

이 전류는 미러의 입력 트랜지스터 Q_3를 통해 공급될 것임 $\boxed{I_{Q3} = 100\mu A}$

이때 $\boxed{I_{Q4}} = \frac{(W/L)_4}{(W/L)_3} I_{Q3} = \frac{120}{40} I_{Q3} = 3I_{Q3} = \boxed{300\mu A}$

$\boxed{I_{Q5}} = \boxed{1mA}$

문제에서처럼 $Q_1 \sim Q_5$가 모두 동작한다고 가정하면

$I_{Q_1} = \frac{1}{2} k_n' \left(\frac{W}{L}\right) V_{ov_1}^2 \Rightarrow 100\mu = \frac{1}{2} \cdot 120\mu \cdot 20 V_{ov_1}^2 \Rightarrow \boxed{V_{ov_1} = 0.29V}$

마찬가지로 $100\mu = \frac{1}{2} \cdot 120\mu \cdot 20 V_{ov_2}^2 \Rightarrow \boxed{V_{ov_2} = 0.29V}$

$100\mu A = \frac{1}{2} \cdot 60\mu \cdot 40 V_{ov_3}^2 \Rightarrow \boxed{V_{ov_3} = -0.29V}$

$300\mu = \frac{1}{2} \cdot 60\mu \cdot 120 V_{ov_4}^2 \Rightarrow \boxed{V_{ov_4} = -0.29V}$

$1000\mu = \frac{1}{2} \cdot 120\mu \cdot 20 V_{ov_5}^2 \Rightarrow \boxed{V_{ov_5} = 0.91V}$

(b). for Q_1

$\boxed{g_{m1}} = \sqrt{2k_n'(W/L)I_{Q_1}} = \sqrt{2(120\mu)(20)100\mu} = 692.82\mu = \boxed{693\mu A/V}$

$\boxed{r_{o1}} = \frac{|V_A'|}{I_{Q_1}} = \frac{24V/\cancel{\mu m} \cdot 1\cancel{\mu m}}{100\mu} = \boxed{240k\Omega}$

for Q_2

$\boxed{g_{m2}} = \sqrt{2(120\mu)(20)100\mu} = g_{m1} = \boxed{693\mu A/V}$

$\boxed{r_{o2}} = \frac{|V_A|}{I_{Q_2}} = r_{o1} = \boxed{240k\Omega}$

for Q_3.

$\boxed{g_{m3}} = \sqrt{2(60\mu)(40)100\mu} = \boxed{693\mu A/V}$.

$\boxed{r_{o3}} = \boxed{240k\Omega}$

for Q4

$\boxed{g_{m4}} = \sqrt{2(60\mu)(120)300\mu} = \boxed{2078\ \mu A/V}$

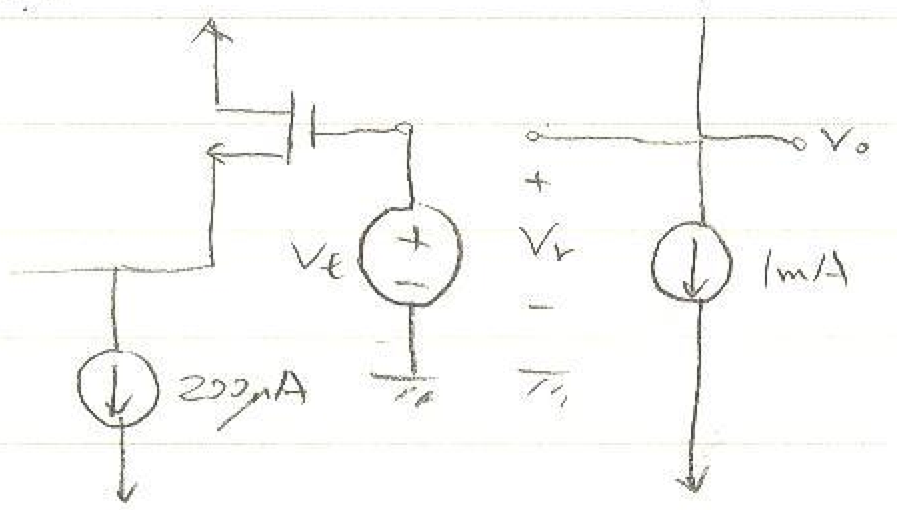
$\boxed{r_{o4}} = 24/300\mu = \boxed{80\ k\Omega}$

for Q5

$\boxed{g_{m5}} = \sqrt{2(60\mu)20(1000\mu)} = \boxed{1550\ \mu A/V}$

$\boxed{r_{o5}} = 24/1000\mu = \boxed{24\ k\Omega}$

(c).



밑의 그림처럼 바꾸어 구하면

$$-\frac{V_t}{V_r} = A\beta \approx g_{m1}(r_{o1} // r_{o3})$$

$\beta = 1 \quad \therefore \boxed{A} = g_{m1}(r_{o2} // r_{o3})$

$= \boxed{84}$

(d) $\boxed{A_f} = \dfrac{A}{1+A\beta} = \dfrac{84}{1+84} = \boxed{0.988\ V/V}$

$\boxed{R_o} = r_{o5} = \boxed{24k}$?

$\boxed{R_{of}} = \dfrac{R_o}{1+A\beta} = \dfrac{24k}{85} = \boxed{280\ \Omega}$

(e). $V_o/V_s = 5$ 를 얻기 위해 feedback connection을 voltage division $R_1/(R_1+R_2)$ 을 통해 바꾸면 $\beta' = 1/5.3$

$$\Rightarrow A_f = \frac{84}{1+84/5.3} = \frac{84}{16.8} = 5$$

이때 $1 + A\beta' = 16.8$

$\boxed{R'_{of}} = \dfrac{R_o}{1+A\beta'} = \dfrac{24}{16.8} = \boxed{1428\ \Omega}$

8-39. 이회로는 series - series feedback으로 볼수 있다

4

Q_1, Q_2, // Q_3, Q_4가 완전히 정합되었다고 가정

$I_{Q_1} = I_{Q_2} = 0.1mA = I_{Q_3} = I_{Q_4}$

$I_{Q_5} = 0.8mA$

구한 I 값들로 gm과 ro들의 값들을 모두 구할수 있다

→ $g_{m1} = \sqrt{2(20\mu)\frac{36}{10}(0.1m)} = 120\mu A/V$

$g_{m2} = g_{m1} = 120\mu A/V = g_{m3} = g_{m4}$

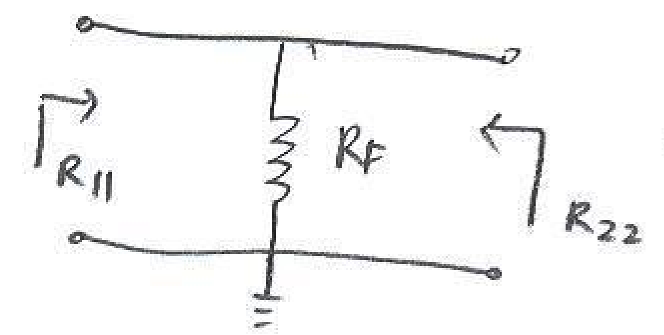
$g_{m5} = \sqrt{2(20\mu)(200)(800\mu)} = 800\mu A/V$

$r_{o1} = \frac{|V_A|}{I_{Q_1}} = 1M\Omega$

$r_{o2} = r_{o1} = 1M\Omega = r_{o3} = r_{o4}$

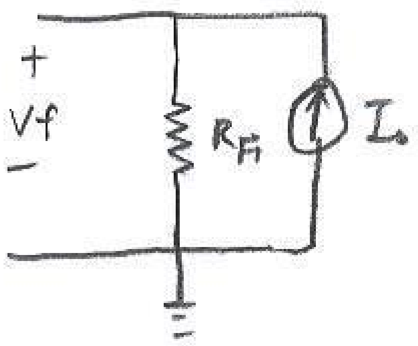
$r_{o5} = \frac{|V_A|}{I_{Q_5}} = \frac{100V}{800\mu} = 125k\Omega$

이제 β회로 분석



→ $R_{11} = R_F = 10k\Omega$

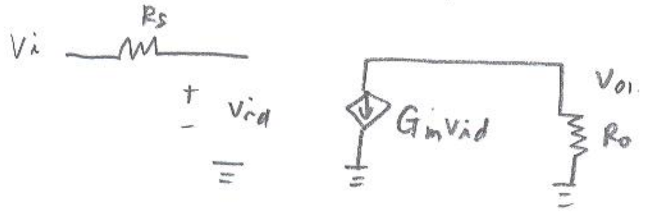
$R_{22} = R_F = 10k\Omega$



→ $\beta = \frac{V_f}{I_o} = R_F = 10k\Omega$

예제 A circuit을 첫째단과 둘째단으로 나누어 생각

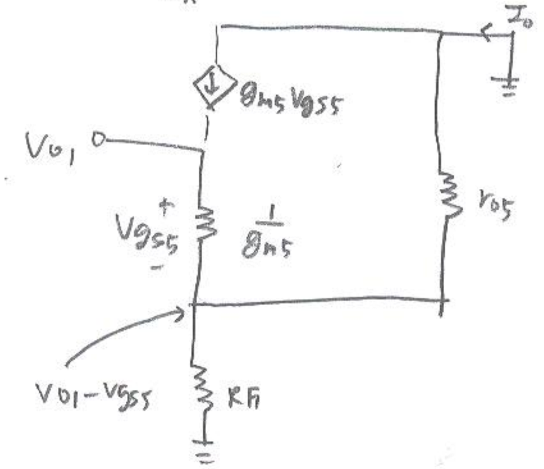
첫째단



$$R_o = r_{o2} \parallel r_{o4}$$

$$G_{m1} = g_{m2}$$

$$\rightarrow \frac{V_o}{V_i} = -G_{m1} R_o = -g_{m2}(r_{o2} \parallel r_{o4}) \quad \text{— ①}$$



$$\frac{I_o}{V_{o1}} = \frac{I_o}{V_{gs5}} \cdot \frac{V_{gs5}}{V_{o1}} = g_{m3} \frac{\frac{1}{g_{m5}}}{\frac{1}{g_{m5}} + R_{F1} \parallel r_{o5}} \quad \text{— ②}$$

$$= \frac{1}{\frac{1}{g_{m5}} + R_{F1} / r_{o5}}$$

①, ②에서

$$A = \frac{V_{o1}}{V_i} \cdot \frac{I_o}{V_{o1}} = -g_{m2}(r_{o2} \parallel r_{o4}) \frac{1}{\frac{1}{g_{m5}} + R_{F1} / r_{o5}}$$

$$= -20\mu\,(1M \parallel 1M) \left(\frac{-5.85\ mA/V}{1.25k + 9.25k} \right)$$

$$= 5.85\ mA/V$$

$$A_f = \frac{A}{1 + A\beta} = \frac{-5.85\ mA/V}{1 + (-5.85\ mA/V)(10k\Omega)}$$

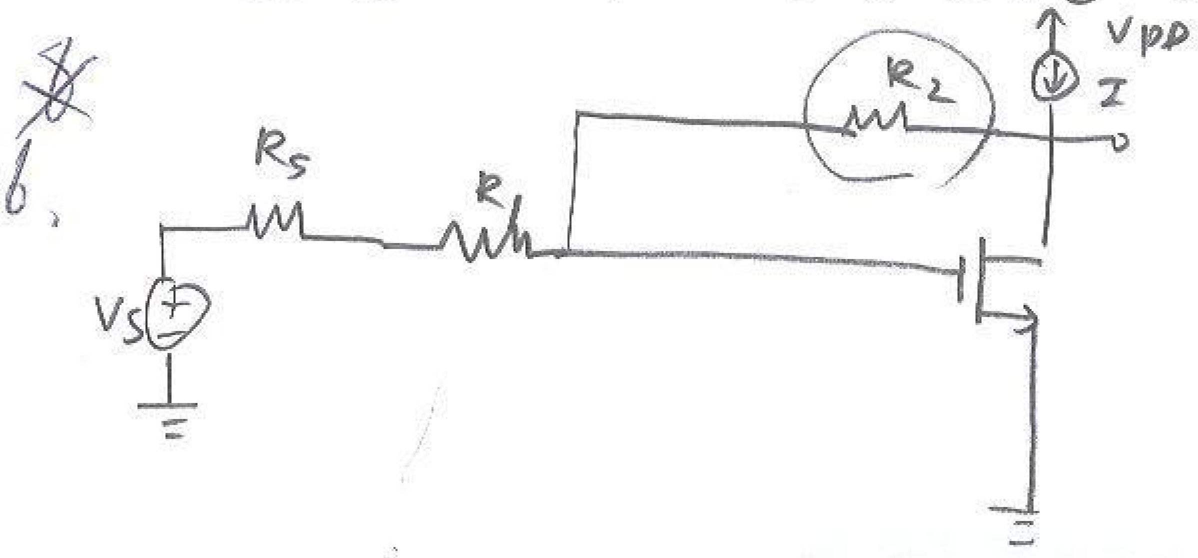
$$= -98.3\ mA/V$$

$$\frac{V_o}{V_S} = \frac{I_o}{V_s}(R_{F1} \parallel r_o)$$

$$= (-98.3\ m)(10k \parallel 125k) = -0.909\ V/V$$

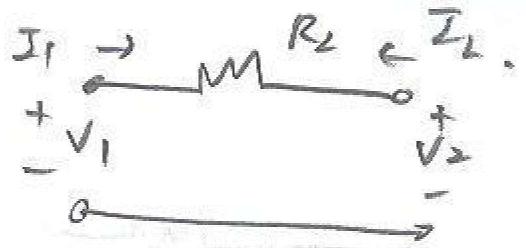
8-42 shunt-shunt 로 이루어진 간단한 증폭회로

~~6~~ 6.



$I_O = I = 1mA$로 설정

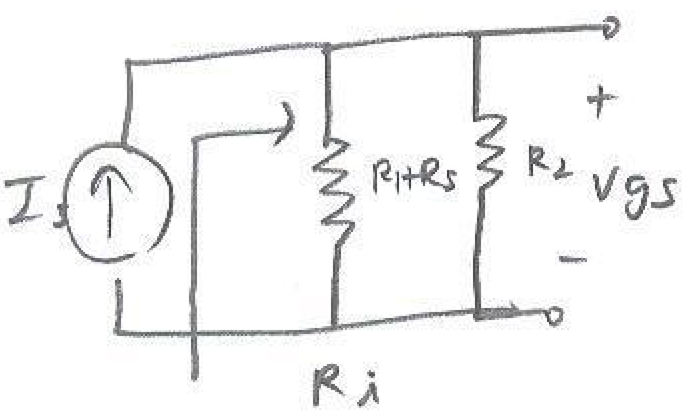
β 회로를 떼어 y parameter로 분석

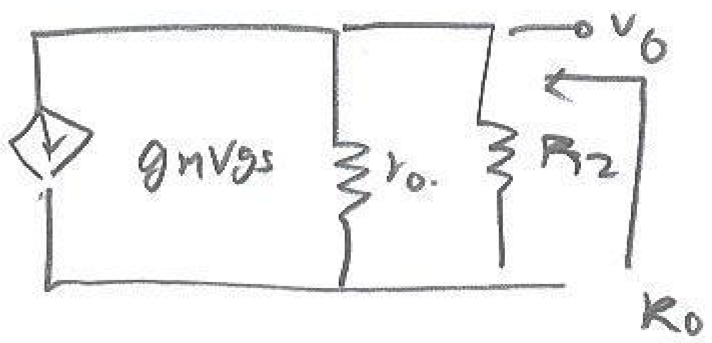


$y_{11} = \frac{1}{R_2}$ → 임피던스 $R_{11} = R_2 = R_{22}$. (∵ shunt sunt)

$y_{12} = \beta = \frac{I_1}{V_2}\Big|_{V_1=0} = -\frac{1}{R_2}$

A circuit을 Norton 법칙에 따라 등가회로로 바꾸면 (∵ shunt-shunt 이므로 전류 → 전압형태)





$$A = \frac{V_o}{i_s}$$

$$\frac{V_o}{V_{gs}} = -g_m (r_o /\!/ R_2) \quad -①$$

$$\frac{V_{gs}}{i_s} = (R_1 + R_s) /\!/ R_2 \quad -②$$

$$\therefore ①\times② = A = -(10m)(30k /\!/ 4.7M)[(1M + 10k\Omega) /\!/ 4.7M]$$

$$= (-10m)(29.9k)(831k)$$

$$= -248.469\ MV/A$$

$$// \quad \beta = y_{12} = -\frac{1}{R_2} = -\frac{1}{4.7}\,M$$

$$A_f = \frac{A}{1+A\beta} = \frac{-248469\,k}{1+(248469\,k)\left(\frac{M}{4.7}\right)}$$

$$= -4.6127\times10^{6}\ V/A$$

$$\Rightarrow \frac{V_o}{V_s} = \frac{V_o}{I_s}\cdot\frac{1}{R_2+R_1} = A_f\,\frac{1}{1.01M}$$

$$= -4.6127M\cdot\frac{1}{1.01M}$$

$$= -4.567\ V/V$$

$$R_i = (R_1+R_S)\ //R_2$$

$$= (1.01\,M)\ //\ (4.7\,M) = 831\,k\Omega$$

$$R_{if} = \frac{R_i}{1+A\beta}\quad (\because \text{shunt})$$

$$= \frac{831k\Omega}{53.866} = 15.429k\Omega$$

$$R_{in} = R_{if} - R_S = 15.427k\Omega - 10\,k\Omega$$

$$= 5.427\,k\Omega$$

$$R_o = r_o // R_2 = 30k // 4.7M = 29.9\,k\Omega$$

$$R_{of} = \frac{R_o}{1+A\beta} = \frac{29.9k}{53.866} = 0.555k\Omega$$

($\because$ shunt)

There's no R_L $\therefore$ $R_{of} = R_{out}$

$= 0.555k\Omega$

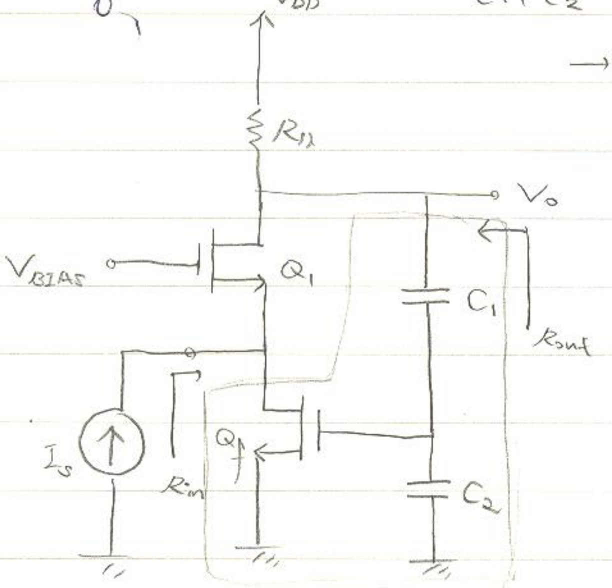
8.52

b)

$g_{m1} = 5mA/V$. $R_D = 10k\Omega$. $C_1 = 0.9pF$. $C_2 = 0.1pF$. $g_{mf} = 1mA/V$

C_1, C_2 are sufficiently small

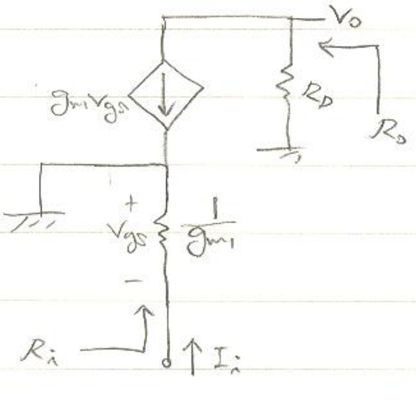
→ loading effect can be neglected.



shunt-shunt feedback network

feedback network

수정된 A circuit (loading effect가 없으므로 feedback network는 무시된다.) 의 소신호 분석.

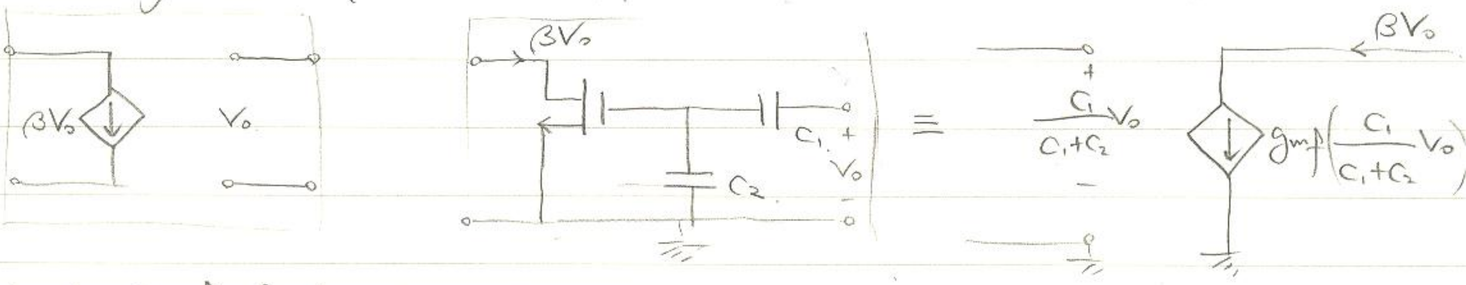


$$A = \frac{V_o}{I_i} = \frac{v_{gs}}{I_i} \cdot \frac{V_o}{v_{gs}}$$

$$= \left(-\frac{1}{g_{m1}}\right)\left(-g_{m1}R_D\right) = R_D$$

$R_i = 1/g_{m1}$, $R_o = R_D$

feedback parameter β를 구하기 위해서 (r_o 무시)



shunt-shunt feedback network의 ideal 형태

$\therefore \beta = \dfrac{C_1}{C_1+C_2} g_{mf}$

$\Rightarrow \boxed{A_f} = \dfrac{A}{1+A\beta} = \dfrac{R_D}{1+R_D\left(\dfrac{C_1}{C_1+C_2}\right)g_{mf}} = \dfrac{10k}{1+10k(0.1)(1m)} = \boxed{5k\Omega}$

$R_{if} = \dfrac{R_i}{1+A\beta} = \dfrac{1}{g_{m1}}\left(\dfrac{1}{1+1}\right) = \dfrac{1}{2g_{m1}} = \dfrac{1}{10m} = 0.1k\Omega$

$\boxed{R_{in} = R_{if} = 0.1k\Omega}$ ($\because$ Q_f쪽으로 보는 저항은 없다고 생각)

$R_{of} = \dfrac{R_o}{1+A\beta} = R_D\left(\dfrac{1}{2}\right) = \boxed{5k\Omega = R_{out}}$

$\boxed{8.75}$ For the amplifier described by Fig 8.37
4. with f. independent feedback,
Determine the minimum closed-loop voltage gain
for phase margin of 90° and 45°.

① phase margin : 90°

$\Rightarrow \phi = -90° = -\left[\tan^{-1}\left(\dfrac{f}{10^5}\right) + \tan^{-1}\left(\dfrac{f}{10^6}\right) + \tan^{-1}\left(\dfrac{f}{10^7}\right)\right]$

$\Rightarrow \tan^{-1}\left(\dfrac{f}{10^5}\right) + \tan^{-1}\left(\dfrac{f}{10^6}\right) + \tan^{-1}\left(\dfrac{f}{10^7}\right) = 90°$

$\Rightarrow$ 그림으로부터 대충 $f = 3\times10^5 Hz$로 놓고 계산을 해보면

$\left.\tan^{-1}\left(\dfrac{f}{10^5}\right) + \tan^{-1}\left(\dfrac{f}{10^6}\right) + \tan^{-1}\left(\dfrac{f}{10^7}\right)\right|_{f=3\times10^5 Hz} = 89.9°$

$\therefore$ 90°의 phase margin을 갖는 frequency를 $3\times10^5 Hz$로 결정.

한편 phase margin을 결정하는 frequency는 $20\log|A(j\omega)|$와 $20\log\dfrac{1}{\beta}$이 교차하는 frequency로 이때, $20\log|A\beta| = 0$ $\therefore |A\beta| = 1$.

이때 $|A(f_1)| = \left| \dfrac{10^5}{(1+jf/10^5)(1+jf/10^6)(1+jf/10^7)} \right|_{f=f_1}$ from (8.79)

$$= \frac{10^5}{\sqrt{1+3^2}\sqrt{1+0.3^2}\sqrt{1+0.03^2}} = 30.28\times10^3$$

from $|A\beta|=1 \Rightarrow \beta = 33.0\times10^{-6}$.

$\therefore$ minimum closed-loop voltage gain

$$= \boxed{A_f(j0)} = \frac{A_{mid}}{1+A_{mid}\beta}$$

$$= \frac{10^5}{1+10^5(33.0\times10^{-6})} = \boxed{2.32\times10^4}$$

② phase margin : 45°

$$45^\circ = \tan^{-1}\left(\frac{f}{10^5}\right) + \tan^{-1}\left(\frac{f}{10^6}\right) + \tan^{-1}\left(\frac{f}{10^7}\right)$$

그림으로부터 $f = 10^6$ Hz.를 결정.

역시 이 frequency에서 $20\log|A(j\omega)|$ 와 $20\log\frac{1}{\beta}$ 이 교차해야 phase margin이 45°가 보장되므로,

$|A\beta|\Big|_{f=10^6} = 1$ 이때 $|A(f)| = \dfrac{10^5}{\sqrt{1+10^2}\sqrt{1+1^2}\sqrt{1+0.1^2}} = 7\times10^3$

$\Rightarrow \beta = 1.43\times10^{-4}$

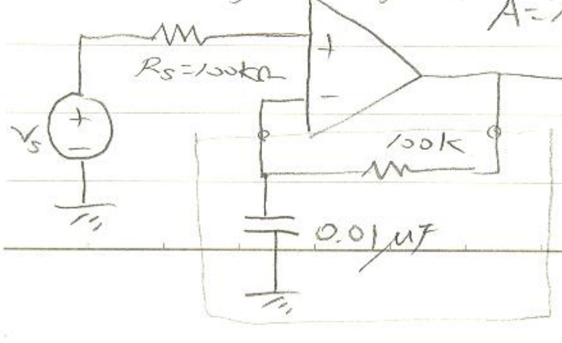
$\therefore$ minimum closed-loop voltage gain

$$A_f(j0) = \frac{10^5}{1+10^5(1.43\times10^{-4})} = \boxed{6.54\times10^3}$$

8.81 (b)

open-loop gain 10^5, single-pole rolloff $\omega_{3dB} = 10$ rad/s

$A = 10^5$

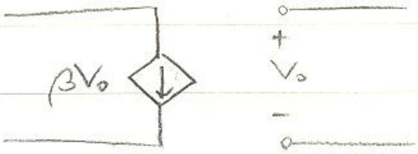


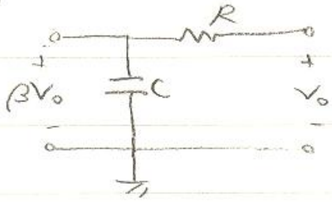
feedback network

(a) Sketch a Bode plot for the loop gain

*check

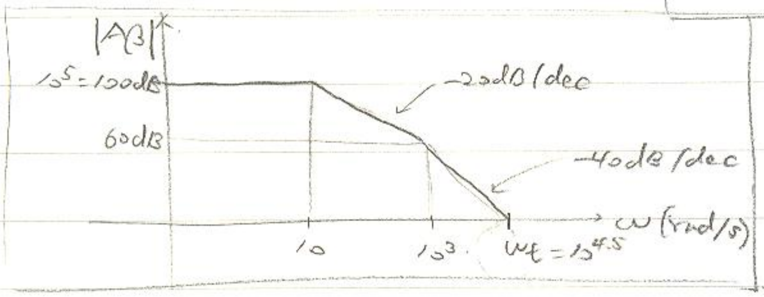
- feedback network의 loading effect를 고려하지 않으면 이를 ideal series-shunt feedback network 로 볼 수 있는데 이때





$$\Rightarrow \beta(s) = \frac{1/sC}{1/sC + R} = \frac{1}{1+sCR} = \frac{1}{1+10^{-3}s}$$

$$\therefore \boxed{A\beta(s)} = A(s)\,\beta(s) = \boxed{\frac{10^5}{1+s/10} \cdot \frac{1}{1+s/10^3}}$$



(b) the frequency at which $|A\beta| = 1$

$$|A\beta| = 1 \Rightarrow 20\log|A\beta| = 0\,dB$$

$$\boxed{\omega_t} = 10^{4.5}\ (rad/s) = \boxed{31.6 \times 10^3\ rad/s}$$

(c) $$\boxed{A_f(s)} = \frac{\dfrac{10^5}{1+s/10}}{1 + \dfrac{10^5}{1+s/10} \cdot \dfrac{1}{1+s/10^3}} = \frac{10^5(1+s/10^3)}{(1+s/10)(1+s/10^3) + 10^5}$$

$$= \boxed{\frac{10^6 s + 10^9}{s^2 + 10^3 s + 10^9}}$$

Zero at $\omega = -10^3$ rad/s

poles at $$\omega = \frac{-10^3 \pm \sqrt{10^6 - 4\times 10^9}}{2} = -500 \pm j\,31.6 \times 10^3\ rad/s$$

$\omega_0 = 31.6$ Krad/s

$Q = 31.6$

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