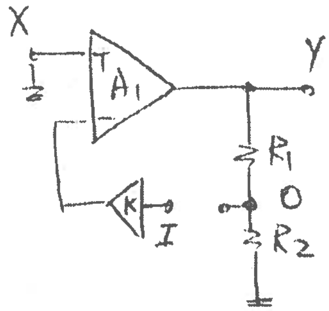
4.

(a)

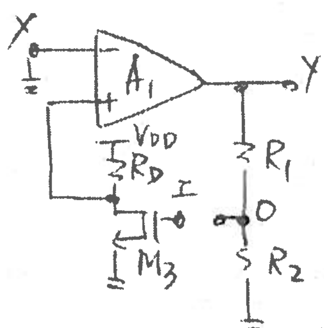


$$O = Y \frac{R_2}{R_1+R_2} = (-IK)A_1\left(\frac{R_2}{R_1+R_2}\right)$$

$$\Rightarrow -\frac{O}{I} = \text{Loop Gain} = +KA_1\left(\frac{R_2}{R_1+R_2}\right)$$

(X is grounded in loop-gain calculation)

(b)

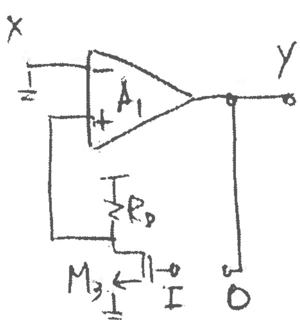


(X is grounded)

$$O = Y\left(\frac{R_2}{R_1+R_2}\right) = -Ig_{m3}R_D A_1\left(\frac{R_2}{R_1+R_2}\right)$$

$$\Rightarrow -\frac{O}{I} = \text{Loop Gain} = +g_{m3}R_D A_1\left(\frac{R_2}{R_1+R_2}\right)$$

(c)

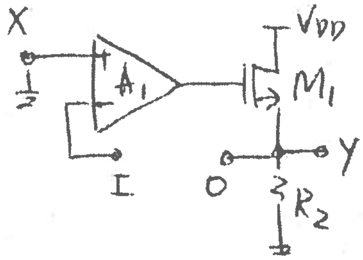


(X is grounded)

$$O = Y = -Ig_{m3}R_D A_1$$

$$\Rightarrow -\frac{O}{I} = \text{Loop Gain} = +g_{m3}R_D A_1$$

(d)



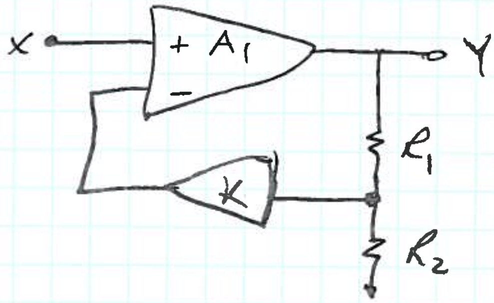
(X is grounded)

$$O = Y = -I \times \frac{g_{m1} R_2}{1 + g_{m1} R_2} \times A_1$$

$$\Rightarrow -\frac{O}{I} = \text{Loop Gain}$$

$$= + A_1 \frac{g_{m1} R_2}{1 + g_{m1} R_2}$$

5. a.

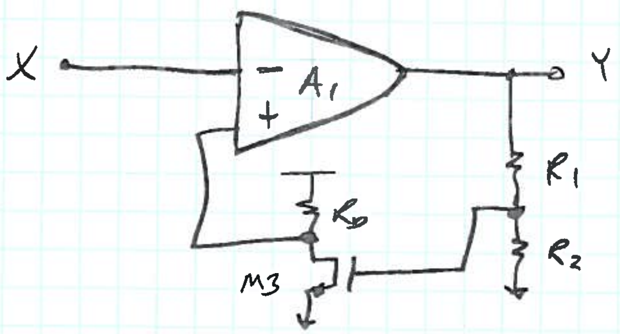


$A_{OL} = A_1$

$\text{FB factor} = \left(\frac{R_2}{R_1+R_2}\right) K$

$$\boxed{\frac{Y}{X} = \frac{A_1}{1 + \left(\frac{R_2}{R_1+R_2}\right) K A_1}}$$

b.

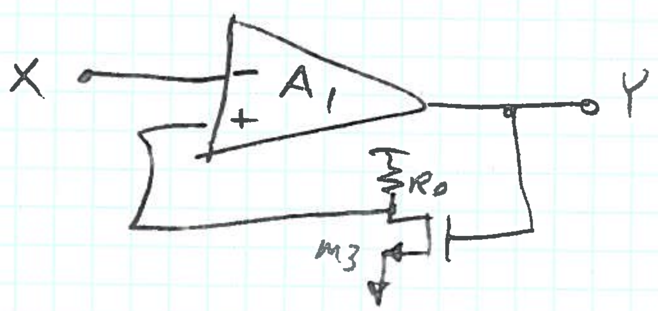


$A_{OL} = -A_1$

$\text{FB Factor} = \left(\frac{R_2}{R_1+R_2}\right)\left(-g_{m3} R_D\right.$

$$\boxed{\frac{Y}{X} = \frac{-A_1}{1 + \left(\frac{R_2}{R_1+R_2}\right)(g_{m3} R_D)(A_1)}}$$

c.

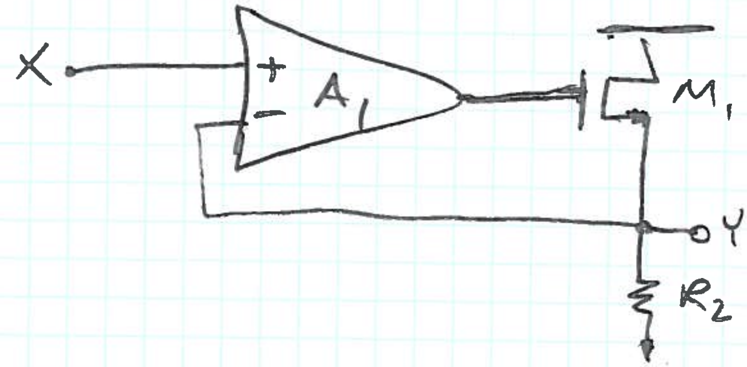


$A_{OL} = -A_1$

$\text{FB Factor} = -g_{m3} R_D$

$$\boxed{\frac{Y}{X} = \frac{-A_1}{1 + g_{m3} R_D A_1}}$$

d.

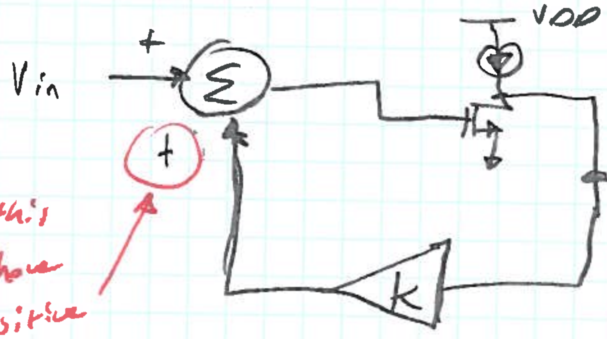


$$A_{OL} = \frac{A_1 R_2}{1/g_{m1} + R_2} = \frac{A_1 g_{m1} R_2}{1 + g_{m1} R_2}$$

FB factor = 1

$$\boxed{\frac{Y}{X} = \frac{\dfrac{A_1 g_{m1} R_2}{1 + g_{m1} R_2}}{1 + \dfrac{A_1 g_{m1} R_2}{1 + g_{m1} R_2}}}$$

9.



Note, this should have been positive

$\mu_n C_{ox}$ varies $\pm 10\%$

λ varies $\pm 20\%$

$$A_{OL} = -g_{m1} r_{o1} \qquad \text{FB Factor} = K$$

$$\frac{V_{out}}{V_{IN}} = \frac{A_{OL}}{1+KA_{OL}} = \frac{-g_{m1} r_{o1}}{1+Kg_{m1}r_{o1}} = \frac{-\left(\sqrt{\mu_n C_{ox}\frac{W}{L}2I_D}\right)\left(\frac{1}{\lambda I_D}\right)}{1+K\left(\sqrt{\mu_n C_{ox}\frac{W}{L}2I_D}\right)\left(\frac{1}{\lambda I_D}\right)}$$

First consider "High" Variation

$$\frac{|A_{OL}|}{1-KA_{OL}} = \frac{|A_{OL}|}{1+LG} = \frac{\frac{\sqrt{1.1}}{0.8}|A_{OL}|}{1+\frac{\sqrt{1.1}}{0.8}LG} \leq \frac{1.05|A_{OL}|}{1+LG}$$

$$\frac{\sqrt{1.1}}{0.8}(1+LG) \leq 1.05 + \frac{1.05\sqrt{1.1}}{0.8}LG$$

$$\frac{0.05\sqrt{1.1}}{0.8}LG \geq \frac{\sqrt{1.1}}{0.8} - 1.05$$

$$LG \geq 3.98$$

Next consider "Low" Variation

$$\frac{|A_{OL}|}{1+LG} = \frac{\frac{\sqrt{0.9}}{1.2}|A_{OL}|}{1+\frac{\sqrt{0.9}}{1.2}LG} \geq \frac{0.95|A_{OL}|}{1+LG}$$

$$\frac{\sqrt{0.9}}{1.2}(1+LG) \geq 0.95 + \frac{0.95\sqrt{0.9}}{1.2}LG$$

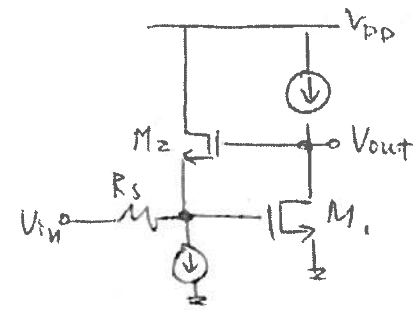
$$\frac{0.05\sqrt{0.9}}{1.2}LG \geq 0.95 - \frac{\sqrt{0.9}}{1.2}$$

$$\boxed{LG \geq 4.03}$$ (larger than above)

22.

~~23.~~ First, recognize that

(a) both input & output are voltages.



* V_{in} primarily drives the Gate of M_1.

Sequence : Suppose V_{in} increases by ΔV_{in}

$\Rightarrow$ V_{out} drops by $+g_{m_1}\Delta V_{in} \times r_{o_1}$ (Common-Source)

$\Rightarrow$ Source of M_2 decreases by same amount (Source follower)

$\therefore$ $V_{in} \uparrow \Rightarrow V_{M_1,D} \downarrow \Rightarrow V_{M_1,G} \downarrow$

$\Rightarrow$ effective V_{in} driving $M_{1,G} \downarrow$

$\Rightarrow$ negative feedback

(b) $V_{in} \uparrow \Rightarrow V_{out} \downarrow \Rightarrow V_{M_2,G} \uparrow$

$\Rightarrow$ effective V_{in} driving $M_{1,G} \uparrow$

$\Rightarrow$ positive feedback.

(c) $v_{in} \uparrow \Rightarrow v_{out} \downarrow \Rightarrow v_{M1,G} \downarrow$

$\Rightarrow$ effective v_{in} driving $M_{1,G} \downarrow$

$\Rightarrow$ negative feedback.

(d) $v_{in} \uparrow \Rightarrow v_{out} \uparrow$ (common-base, M_1)

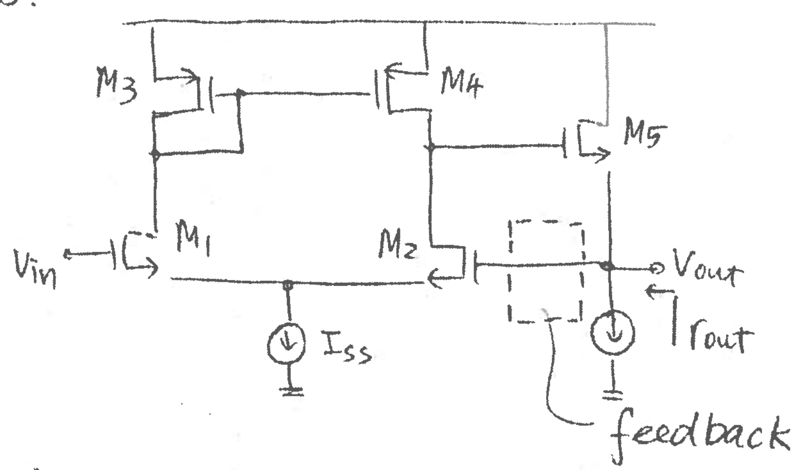
$\Rightarrow v_{M1,S} \downarrow$

$\Rightarrow$ effective v_{in} driving $M_{1,S} \downarrow$

$\Rightarrow$ negative feedback

27.

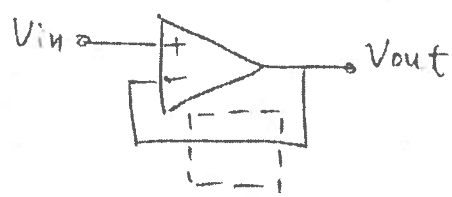
~~28.~~



$\lambda > 0$

r_{out} low.

Note that Vout is directly fed back to input:



$\therefore$ gain ≈ 1 (a buffer)

$\Rightarrow k = 1$.

$A_{O.L.}$ (i.e. without feedback)

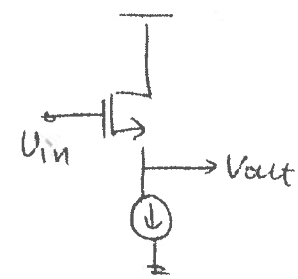
$$= g_{m1}(r_{o2} \parallel r_{o4}) \times \frac{g_{m5} r_{o5}}{g_{m5} r_{o5} + 1} \quad \left(\approx g_{m1}(r_{o2} \parallel r_{o4})\right)$$

$$\Rightarrow A_{C.L.} = \frac{A_{OL}}{1 + A_{OL} k} = \frac{g_{m1}(r_{o2} \parallel r_{o4})\left(\frac{g_{m5} r_{o5}}{g_{m5} r_{o5}+1}\right)}{1 + g_{m1}(r_{o2} \parallel r_{o4})\left(\frac{g_{m5} r_{o5}}{g_{m5} r_{o5}+1}\right)}$$

$$r_{out} = \frac{r_{out}\,(\text{no feedback})}{1 + A_{O.L.} \times k} = \frac{\left(\frac{1}{g_{m5}} \parallel r_{o5}\right)}{1 + g_{m1}(r_{o2} \parallel r_{o4})\left(\frac{g_{m5} r_{o5}}{g_{m5} r_{o5}+1}\right)}$$

$$\text{Gain} = A = \frac{g_m r_o}{g_m r_o + 1}$$

$$r_{out} = \frac{1}{g_m} \parallel r_o$$



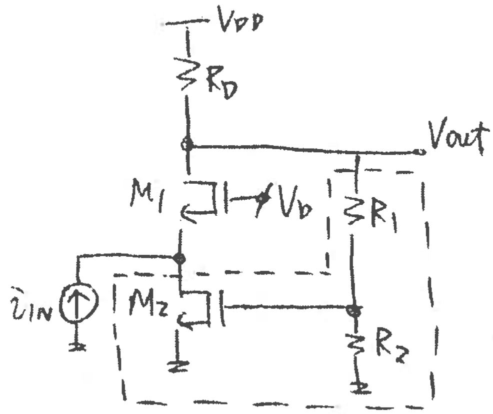
$\lambda > 0$

In comparison, the amplifier's gain is reduced by $\dfrac{g_{m1}(r_{o2} \parallel r_{o4})}{1 + g_{m1}(r_{o2} \parallel r_{o4})\left(\dfrac{g_{m5} r_{o5}}{g_{m5} r_{o5} + 1}\right)}$ times. $\left(= \dfrac{A_{C.L.}}{A}\right)$. Output resistance of the amplifier is reduced by $\left[1 + g_{m1}(r_{o2} \parallel r_{o4})\left(\dfrac{g_{m5} r_{o5}}{g_{m5} r_{o5} + 1}\right)\right]$ times.

33.
~~24.~~

$R_{O.L.} = \dfrac{V_{out}}{i_{IN}}$ (no feedback)

$= R_D$



$\lambda = 0$

$R_1 + R_2 \gg 1$.

K (feedback factor)

$= g_{m2} \times \dfrac{R_2}{R_1 + R_2}$

$\Rightarrow R_{C.L.} = \dfrac{V_{out}}{i_{IN}} = \dfrac{R_D}{1 + R_D \times g_{m2} \dfrac{R_2}{R_1+R_2}}$

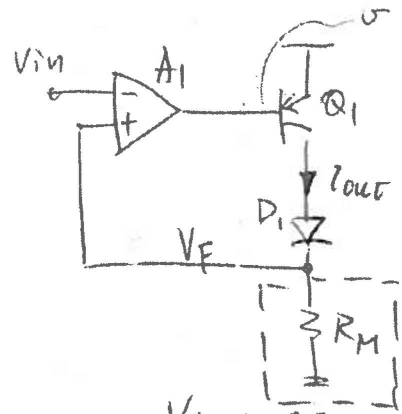
$r_{in}|_{C.L.} = \dfrac{1/g_{m1}}{1 + R_D \times g_{m2} \dfrac{R_2}{R_1+R_2}}$

$r_{out}|_{C.L.} = \dfrac{R_D}{1 + R_D \times g_{m2} \dfrac{R_2}{R_1+R_2}}$

35.
~~36.~~

(a) $G_{O.L.} = \dfrac{i_{out}}{v_{in}} = g_{m1} A_1$

(common emitter)



$V_A \to \infty$

R_M small.

(b) K (feedback factor)

$\Rightarrow V_F = i_{out} \times R_M$

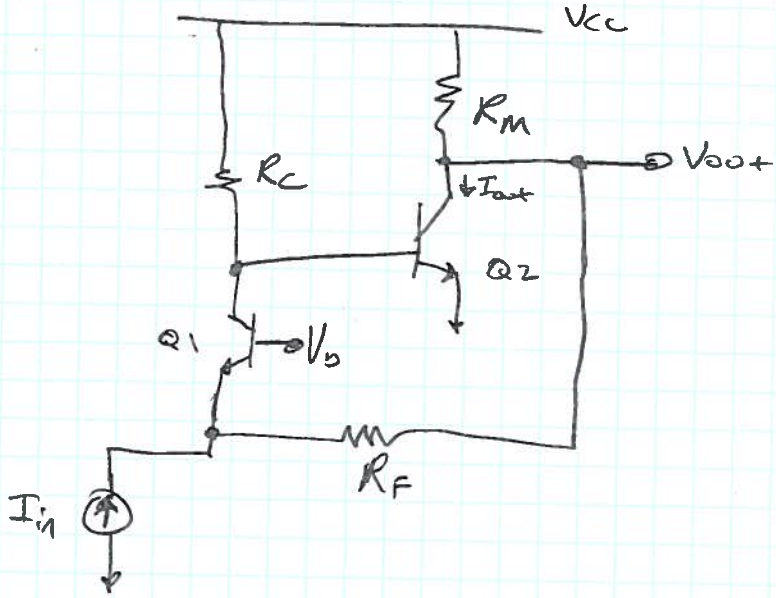
$\Rightarrow K = \dfrac{V_F}{i_{out}} = R_M$

$\therefore$ Loop Gain $= G_{OL} K = g_{m1} A_1 R_M$

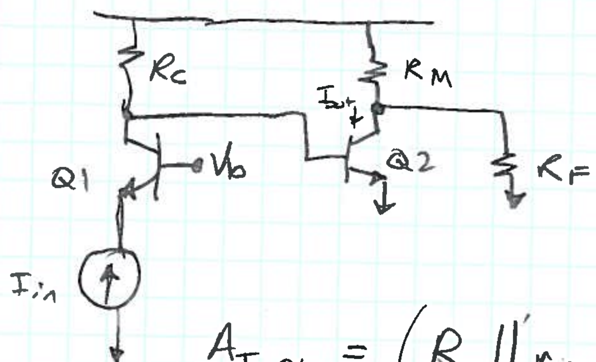
$$G_{CL} = \frac{G_{OL}}{1 + G_{OL} K} = \frac{g_{m1} A_1}{1 + g_{m1} A_1 R_M}$$

40.

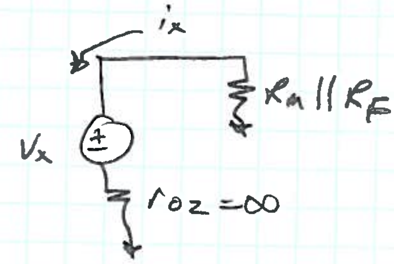
R_M is small



a. Breaking the loop (Current - Current FB)



$\Longrightarrow$ For R_{out}

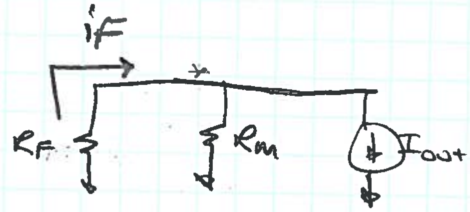


$$A_{I,OL} = \left(R_C \| r_{\pi 2}\right) g_{m2}$$

$$R_{in,OL} = r_{e1} \simeq \frac{1}{g_{m1}}$$

$$R_{out,OL} = \infty$$

For K :



$$K = \frac{R_M}{R_F + R_M} \simeq \frac{R_M}{R_F}$$

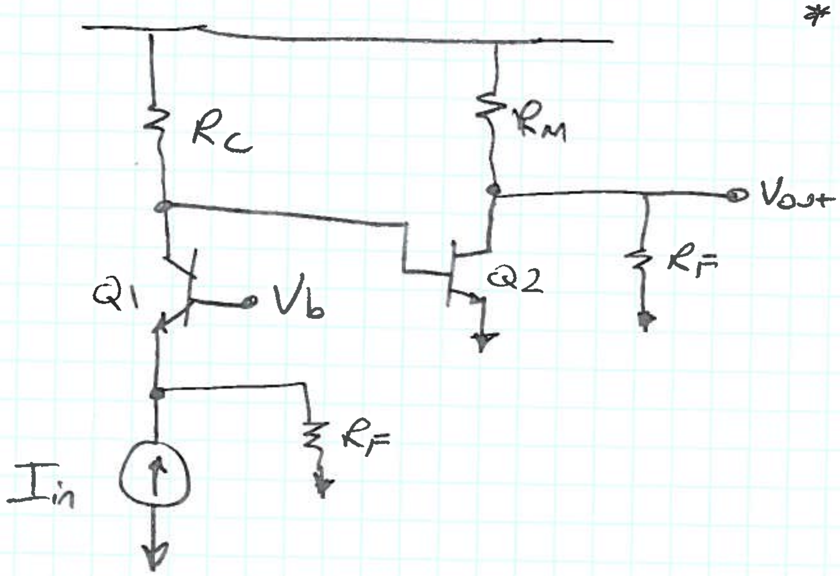
$$\boxed{A_{I,CL} = \frac{g_{m2}\left(R_C \| r_{\pi 2}\right)}{1 + \left(\frac{R_M}{R_F + R_M}\right) g_{m2}\left(R_C \| r_{\pi 2}\right)} \sim \frac{g_{m2} R_C}{1 + \frac{g_{m2} R_C R_M}{R_F}}}$$

$$\boxed{R_{in,CL} = \frac{1/g_{m1}}{1 + \left(\frac{R_M}{R_F + R_M}\right) g_{m2}\left(R_C \| r_{\pi 2}\right)} \sim \frac{1/g_{m1}}{1 + \frac{g_{m2} R_C R_M}{R_F}}}$$

$$\boxed{R_{out,CL} = \infty}$$

b. Breaking the loop (Voltage - Current)

* R_F is very large



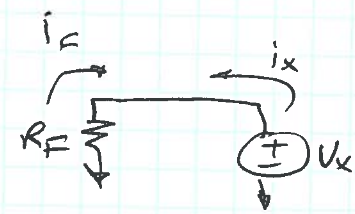
$$R_{OL} = \left(\frac{R_F}{R_F + r_{e1}}\right)(R_C \| r_{\pi 2})(-g_{m2})(R_M \| R_F)$$

$$\simeq -g_{m2} R_M R_C$$

$$R_{in,OL} = R_F \| r_{e1} \simeq \frac{1}{g_{m1}}$$

$$R_{out,OL} = R_M \| R_F \sim R_M$$

For K:



$$K = -\frac{1}{R_F}$$

$$R_{CL} \simeq \frac{-g_{m2} R_M R_C}{1 + \frac{g_{m2} R_M R_C}{R_F}}$$

$$R_{in,CL} \simeq \frac{\frac{1}{g_{m1}}}{1 + \frac{g_{m2} R_M R_C}{R_F}} \qquad R_{out,CL} \simeq \frac{R_M}{1 + \frac{g_{m2} R_M R_C}{R_F}}$$