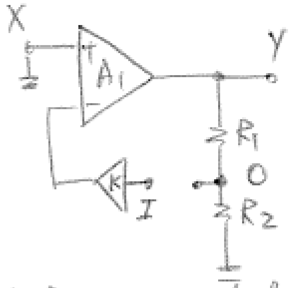
**1.** 12-3

(a)

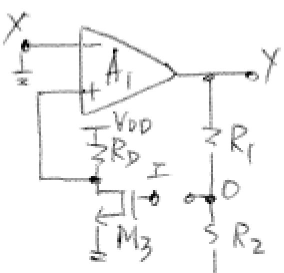



(X is grounded in loop-gain calculation)

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

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

(b)

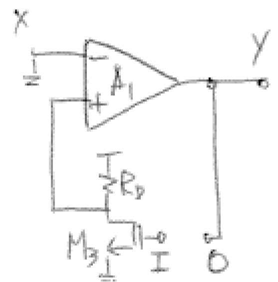



(X is grounded)

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

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

(c)

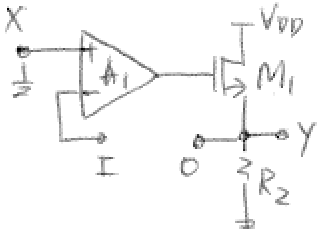



(X is grounded)

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

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

(d)




(X is grounded)

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

$$\Rightarrow -\frac{O}{I} = \text{Loop Gain} = +A_1\frac{g_{m1}R_2}{1+g_{m1}R_2}$$

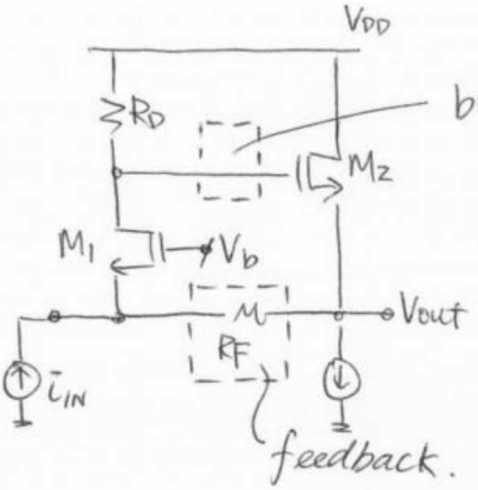
12-14

(a) Sense Mechanism: Voltage output ($M_3$)
Return Mechanism: Voltage to Gate of $M_2$.

(b) Sense Mechanism: Current from $M_3$
Return Mechanism: Voltage to Gate of $M_2$.

(c) Sense Mechanism: Voltage Divider ($\frac{R_2}{R_1+R_2}$)
Return Mechanism: Voltage to Gate of $M_2$.

12-25




(a) $i_{IN} \uparrow \Rightarrow V_{G,M_2} \uparrow$ (Common Gate ; $i_{IN}$ mostly flows to $M_1$ ∵ resistance $= \frac{1}{g_m}$)

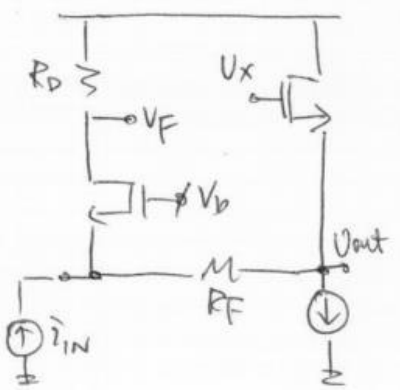
$\Rightarrow V_{out} \uparrow$ (Source Follower)

$\Rightarrow R_F$ momentarily provides more current to source of $M_1$)

$\Rightarrow V_{G,M_2} \uparrow$

$\Rightarrow$ Positive feedback.

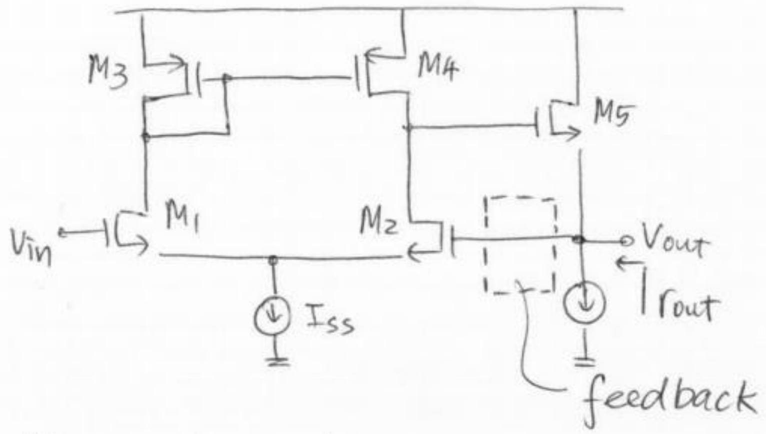
(b)




$$v_F = v_X \frac{g_{m1}R_D}{1+g_{m2}(R_F+\frac{1}{g_{m1}})}$$

$$\Rightarrow -\frac{v_F}{v_X} = \text{Loop Gain} = -\frac{g_{m1}R_D}{1+g_{m2}(R_F+\frac{1}{g_{m1}})}$$

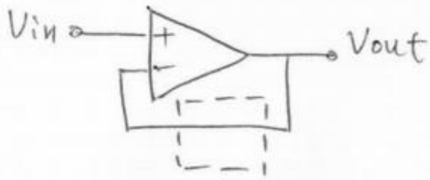
∴ feedback is positive.




$\lambda > 0$

$r_{out}$ low.

Note that $V_{out}$ is directly fed back to input :




∴ gain ≈ 1 (a buffer)

⇒ $k = 1$.

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

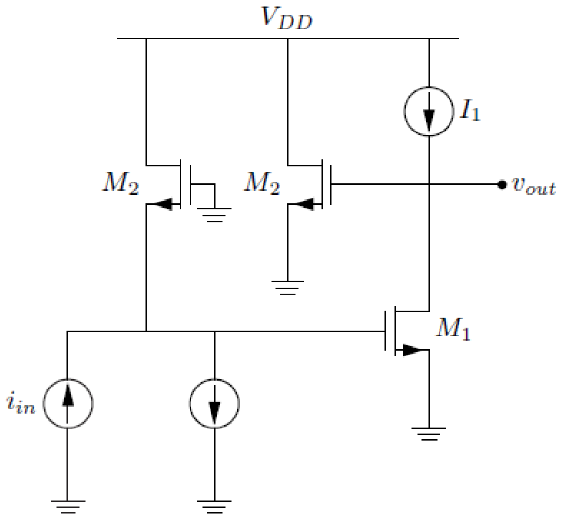
$$= g_{m1}(r_{o2} \| r_{o4}) \times \frac{g_{m5} r_{o5}}{g_{m5} r_{o5} + 1} \quad \left(\approx g_{m1}(r_{o2} \| r_{o4})\right)$$

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

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

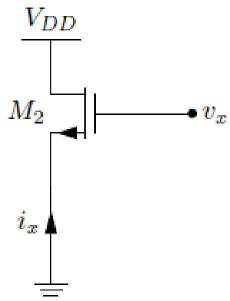
12-49

(a) We can break the feedback network as shown here:




$$A_{OL} = -g_{m1} r_{o1} \left( \frac{1}{g_{m2}} \parallel r_{o2} \right)$$

To find the feedback factor $K$, we can use the following diagram:




$$K = \frac{v_x}{i_x} = -g_{m2}$$

$$\frac{v_{out}}{i_{in}} = \boxed{-\frac{g_{m1} r_{o1} \left( \frac{1}{g_{m2}} \parallel r_{o2} \right)}{1 + g_{m1} g_{m2} r_{o1} \left( \frac{1}{g_{m2}} \parallel r_{o2} \right)}}$$

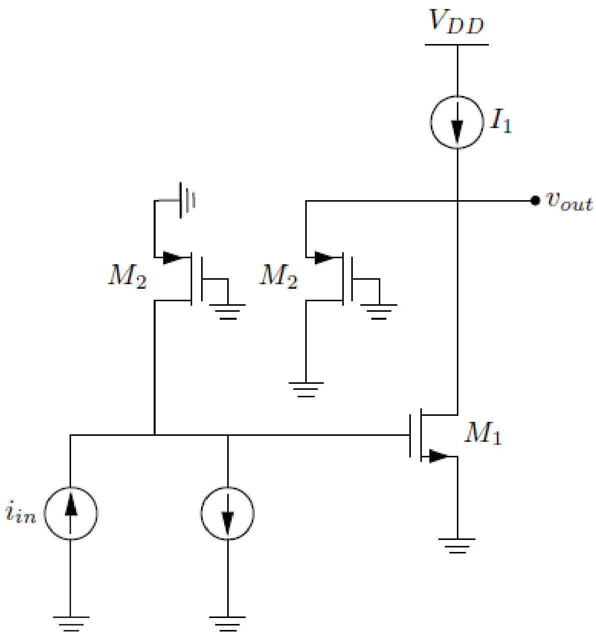
$$R_{in,open} = \frac{1}{g_{m2}} \parallel r_{o2}$$

$$R_{in,closed} = \boxed{\frac{\frac{1}{g_{m2}} \parallel r_{o2}}{1 + g_{m1} g_{m2} r_{o1} \left( \frac{1}{g_{m2}} \parallel r_{o2} \right)}}$$

$$R_{out,open} = r_{o1}$$

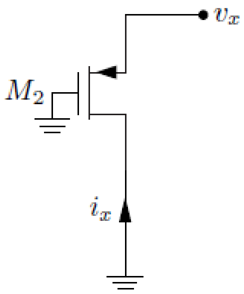
$$R_{out,closed} = \boxed{\frac{r_{o1}}{1 + g_{m1} g_{m2} r_{o1} \left( \frac{1}{g_{m2}} \parallel r_{o2} \right)}}$$

(b) We can break the feedback network as shown here:




$$A_{OL} = -g_{m1} r_{o2} \left( r_{o1} \parallel \frac{1}{g_{m2}} \parallel r_{o2} \right)$$

To find the feedback factor $K$, we can use the following diagram:




$$K = \frac{v_x}{i_x} = -g_{m2}$$

$$\frac{v_{out}}{i_{in}} = \boxed{-\frac{g_{m1} r_{o2} \left( r_{o1} \parallel \frac{1}{g_{m2}} \parallel r_{o2} \right)}{1 + g_{m1} g_{m2} r_{o2} \left( r_{o1} \parallel \frac{1}{g_{m2}} \parallel r_{o2} \right)}}$$

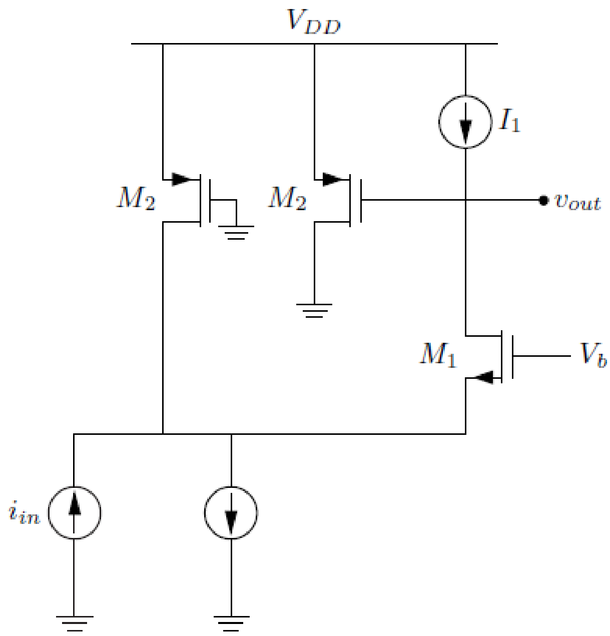
$$R_{in,open} = r_{o2}$$

$$R_{in,closed} = \boxed{\frac{r_{o2}}{1 + g_{m1} g_{m2} r_{o2} \left( r_{o1} \parallel \frac{1}{g_{m2}} \parallel r_{o2} \right)}}$$

$$R_{out,open} = r_{o1} \parallel \frac{1}{g_{m2}} \parallel r_{o2}$$

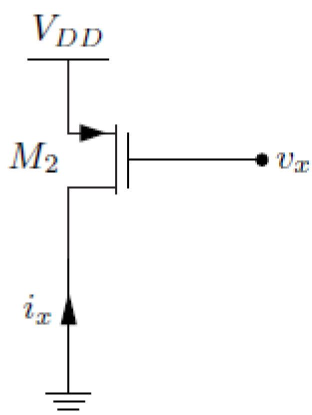
$$R_{out,closed} = \boxed{\frac{r_{o1} \parallel \frac{1}{g_{m2}} \parallel r_{o2}}{1 + g_{m1} g_{m2} r_{o2} \left( r_{o1} \parallel \frac{1}{g_{m2}} \parallel r_{o2} \right)}}$$

(c) We can break the feedback network as shown here:




$$A_{OL} = g_{m1} r_{o1} \left( \frac{1}{g_{m1}} \parallel r_{o2} \right)$$

To find the feedback factor $K$, we can use the following diagram:




$$K = \frac{i_x}{v_x} = g_{m2}$$

$$\frac{v_{out}}{i_{in}} = \boxed{\frac{g_{m1} r_{o1} \left( \frac{1}{g_{m1}} \parallel r_{o2} \right)}{1 + g_{m1} g_{m2} r_{o1} \left( \frac{1}{g_{m1}} \parallel r_{o2} \right)}}$$

$$R_{in,open} = \frac{1}{g_{m1}} \parallel r_{o2}$$

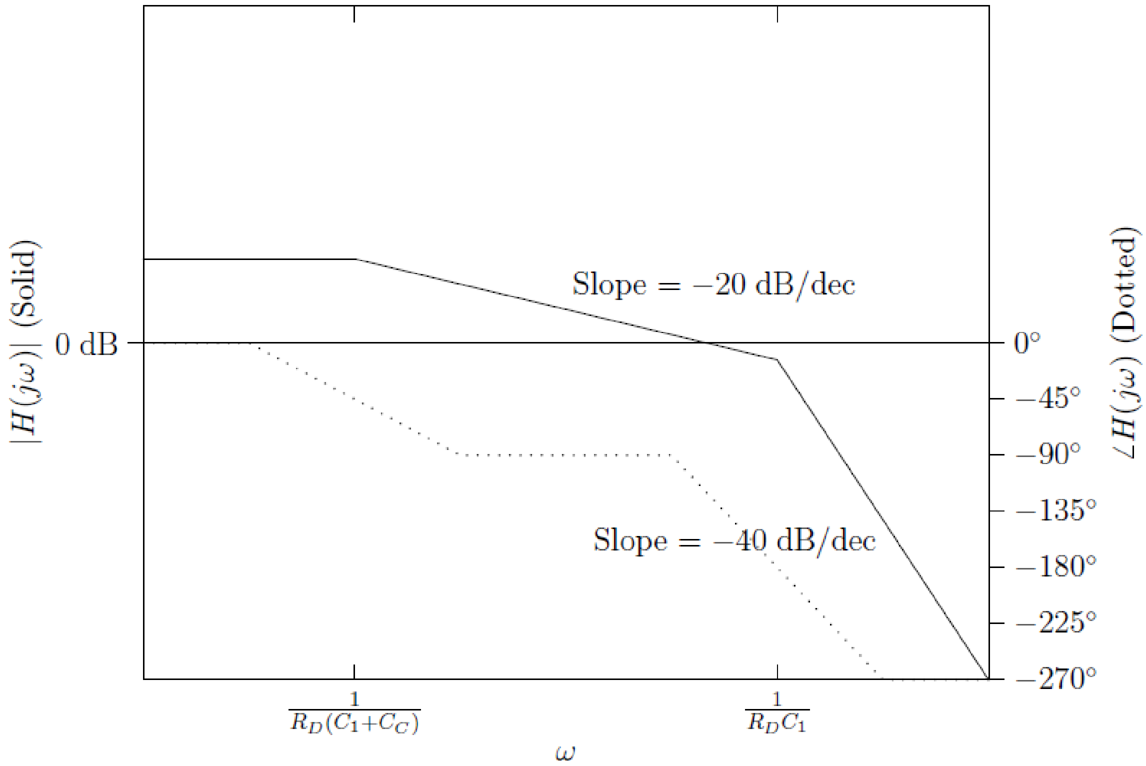
$$R_{in,closed} = \boxed{\frac{\frac{1}{g_{m1}} \parallel r_{o2}}{1 + g_{m1} g_{m2} r_{o1} \left( \frac{1}{g_{m1}} \parallel r_{o2} \right)}}$$

$$R_{out,open} = r_{o1} + (1 + g_{m1} r_{o1}) r_{o2}$$

$$R_{out,closed} = \boxed{\frac{r_{o1} + (1 + g_{m1} r_{o1}) r_{o2}}{1 + g_{m1} g_{m2} r_{o1} \left( \frac{1}{g_{m1}} \parallel r_{o2} \right)}}$$

12-55

The compensation capacitor allowsus to push the pole associated with that node to a lower frequency (while the other poles do not change). This will cause the gain to start dropping sooner, so that $\omega_{GX}$ decreases. By adjusting $C_C$ properly, we can reduce $\omega_{GX}$ enough so that the phase is at $-135°$ at $\omega_{GX}$. This results in the following Bode plots:

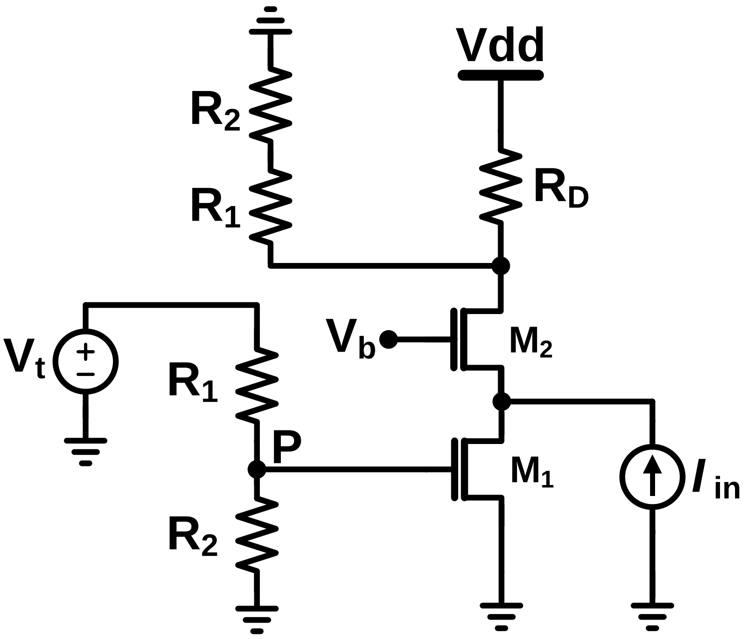


## 2.

(a) negative feedback.

(b) Voltage – Current feedback

(c)




(d) $\mathbf{R_0 = R_D || (R_1 + R_2)}$

$V_P = V_t \frac{R_2}{R_1+R_2}$

$V_F = KR_0V_t = -V_t \frac{R_2}{R_1+R_2} g_{m1} R_D || (R_1+R_2)$

$\mathbf{K = \frac{R_2}{R_1+R_2} g_{m1}}$

(e) $R_{tot} = \frac{R_D || (R_1+R_2)}{1+\frac{R_2}{R_1+R_2} g_{m1} R_D || (R_1+R_2)}$