1.

11-1

11.1

$\cdot$ Power $= 2.5mW = VI = 2.5 \times I_c$

$\Rightarrow I_c = 1mA$

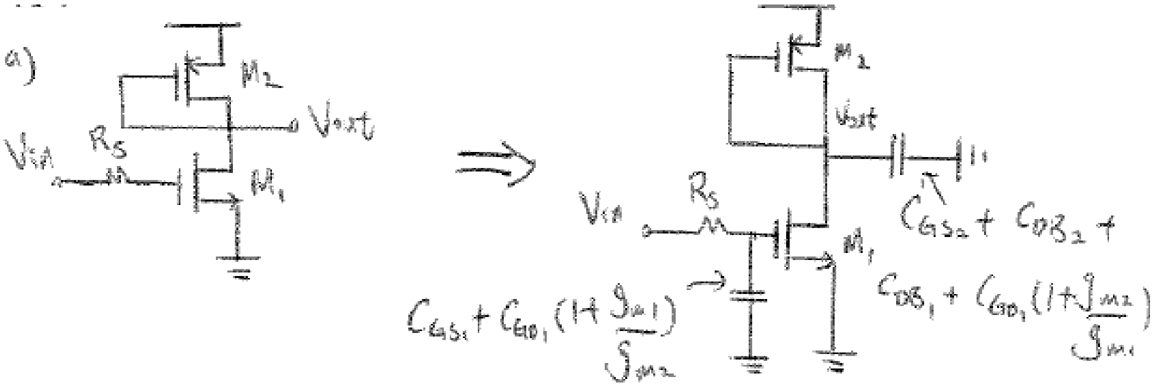
$\cdot$ max. DC gain $= 1.8 = \left| - \frac{I_c \cdot R_1}{V_T} \right| = \frac{1mA \cdot R_1}{26mV}$

$\Rightarrow R_1 = 46.8\Omega$

$\therefore \frac{1}{2\pi \times R_1 \times C_L} = 1.2GHz$

$\Rightarrow C_L \approx 2.84pF$

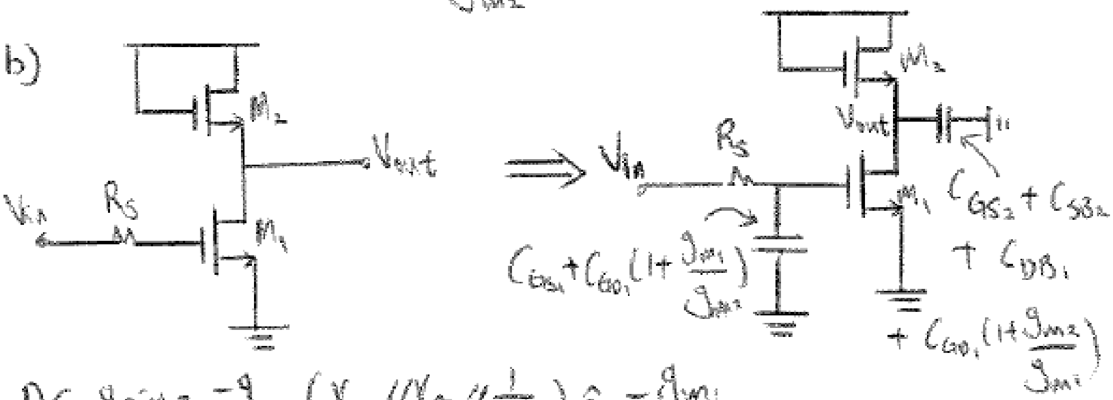
a)



$$\text{DC gain} = -g_{m1}\left(r_{o1} \,//\, r_{o2} \,//\, \frac{1}{g_{m2}}\right) \approx -\frac{g_{m1}}{g_{m2}}$$

$$\omega_{pin} = \frac{1}{R_S\left(C_{GS1} + C_{GD1}\left(1+\frac{g_{m1}}{g_{m2}}\right)\right)} \qquad \omega_{pout} = \frac{g_{m2}}{\left(C_{GS2} + C_{DB2} + C_{DB1} + C_{GD1}\left(1+\frac{g_{m2}}{g_{m1}}\right)\right)}$$

b)

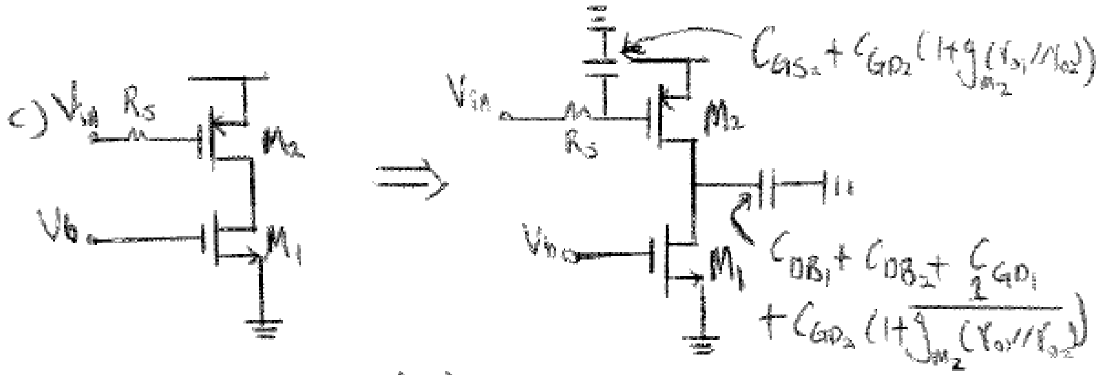


$$\text{DC gain} = -g_{m1}\left(r_{o1} \,//\, r_{o2} \,//\, \frac{1}{g_{m2}}\right) \approx -\frac{g_{m1}}{g_{m2}}$$

$$\omega_{pin} = \frac{1}{R_S\left(C_{GS1} + C_{GD1}\left(1+\frac{g_{m1}}{g_{m2}}\right)\right)}$$

$$\omega_{pout} = \frac{g_{m2}}{C_{SB2} + C_{GS2} + C_{DB1} + C_{GD1}\left(1+\frac{g_{m2}}{g_{m1}}\right)}$$

c)



DC gain: $-g_{m2}(r_{o1}//r_{o2})$

$$\omega_{pin} = \frac{1}{R_S(C_{GS_2} + C_{GD_2}(1+g_{m_2}(r_{o1}//r_{o2})))}$$

$$\omega_{pout} = \frac{1}{(r_{o1}//r_{o2})[C_{DB_1} + C_{DB_2} + C_{GD_1} + C_{GD_2}(1+\frac{1}{g_{m2}(r_{o1}//r_{o2})})]}$$

$$\omega_{pout} \approx \frac{1}{(r_{o1}//r_{o2})[C_{DB_1} + C_{DB_2} + C_{GD_1} + C_{GD_2}]}$$

since $g_{m2}(r_{o1}//r_{o2}) \gg 1$

11-33

(a) Note that the DC gain is $A_v = -\infty$ if we assume $V_A = \infty$.

$$\omega_{p,in} = \frac{1}{(R_S \parallel r_\pi)\left[C_\pi + C_\mu(1 - A_v)\right]} = \boxed{0}$$

$$\omega_{p,out} = \boxed{0}$$

(b)

$$\frac{V_{out}}{V_{Thev}}(s) = \lim_{R_L \to \infty} \frac{(C_\mu s - g_m) R_L}{as^2 + bs + 1}$$

$$a = (R_S \parallel r_\pi) R_L (C_\pi C_\mu + C_{CS} C_\mu + C_\pi C_{CS})$$

$$b = (1 + g_m R_L) C_\mu (R_S \parallel r_\pi) + (R_S \parallel r_\pi) C_\pi + R_L (C_\mu + C_{CS})$$

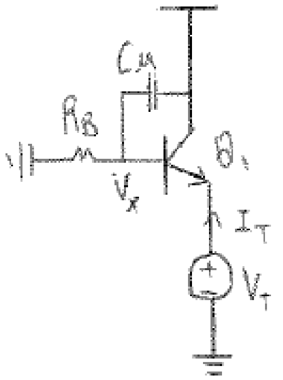
$$\lim_{R_L \to \infty} \frac{(C_\mu s - g_m) R_L}{as^2 + bs + 1} = \frac{C_\mu s - g_m}{\left[(R_S \parallel r_\pi)(C_\pi C_\mu + C_{CS} C_\mu + C_\pi C_{CS})\right] s^2 + \left[g_m C_\mu (R_S \parallel r_\pi) + C_\mu + C_{CS}\right] s}$$

$$= \frac{C_\mu s - g_m}{s\left\{(R_S \parallel r_\pi)(C_\pi C_\mu + C_{CS} C_\mu + C_\pi C_{CS}) s + \left[g_m C_\mu (R_S \parallel r_\pi) + C_\mu + C_{CS}\right]\right\}}$$

$$|\omega_{p1}| = \boxed{0}$$

$$|\omega_{p2}| = \boxed{\frac{g_m C_\mu (R_S \parallel r_\pi) + C_\mu + C_{CS}}{(R_S \parallel r_\pi)(C_\pi C_\mu + C_{CS} C_\mu + C_\pi C_{CS})}}$$

We can see that the Miller approximation correctly predicts the input pole to be at DC. However, it incorrectly estimates the output pole to be at DC as well, when in fact it is not, as we can see from the direct analysis.



$V_A = \infty$,

$\frac{\beta}{\beta+1} \approx 1$, if $\beta \gg 1$

$$I_T = -(V_x - V_T)\, g_m \alpha \approx -(V_x - V_T)\, g_m$$

$$V_x = \frac{I_T}{\beta}\left(R_B // \frac{1}{C_\mu s}\right)$$

$$I_T = \left(V_T - \frac{I_T}{\beta}\left(R_B // \frac{1}{C_\mu s}\right)\right) g_m$$

$$I_T = g_m V_T - \frac{g_m}{\beta}\left(R_B // \frac{1}{C_\mu s}\right) I_T$$

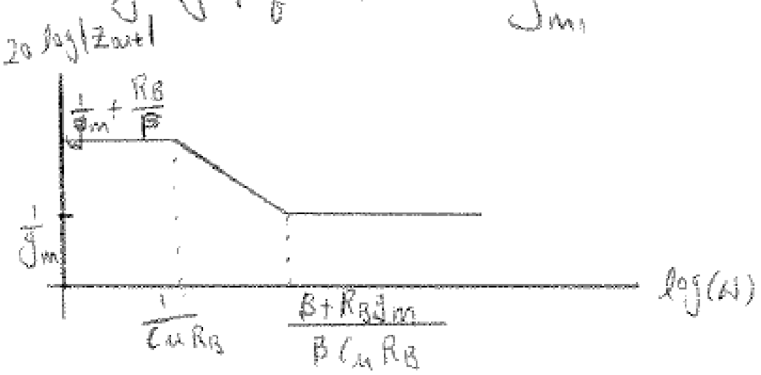
$$I_T\left(1 + \frac{g_m}{\beta}\left(R_B // \frac{1}{C_\mu s}\right)\right) = g_m V_T$$

$$\frac{V_T}{I_T} = \frac{1}{g_m} + \frac{R_B // \frac{1}{C_\mu s}}{\beta} = \frac{\beta C_\mu R_B \left(s + \frac{\beta + R_B g_m}{\beta C_\mu R_B}\right)}{g_m \beta (1 + C_\mu R_B s)}$$

Zero: $\frac{\beta + R_B g_m}{\beta C_\mu R_B}$, Pole: $\frac{1}{C_\mu R_B}$

At DC, $|Z_{out}| = \frac{1}{g_{m1}} + \frac{R_B}{\beta}$

At very high freq : $|Z_{out}| = \frac{1}{g_{m1}}$



11-48

$$
\begin{aligned}
I_D &= \frac{1}{2}\left(\frac{W}{L}\right)_1 \mu_n C_{ox} V_{ov}^2 = 0.5 \text{ mA} \\
(W/L)_1 &= (W/L)_2 = \boxed{250} \\
W_1 &= W_2 = 45 \ \mu\text{m} \\
g_{m1} &= g_{m2} = \frac{W}{L}\mu_n C_{ox} V_{ov} = 5 \text{ mS} \\
C_{GD1} &= C_{GD2} = C_0 W = 9 \text{ fF} \\
C_{GS1} &= C_{GS2} = \frac{2}{3} W L C_{ox} = 64.8 \text{ fF} \\
\omega_{p,in} &= \frac{1}{R_G\left\{C_{GS1} + C_{GD1}\left(1 + \frac{g_{m1}}{g_{m2}}\right)\right\}} = 2\pi \times 5 \text{ GHz} \\
R_G &= \boxed{384\ \Omega} \\
\omega_{p,out} &= \frac{1}{R_D C_{GD2}} = 2\pi \times 10 \text{ GHz} \\
R_D &= \boxed{1.768\ \text{k}\Omega} \\
A_v &= -g_{m1} R_D = \boxed{-8.84}
\end{aligned}
$$

2.1

. $A_v = -g_m \cdot R_L = \frac{1}{150} \times 2k\Omega \approx 13.3V/V$

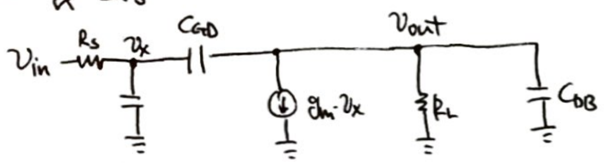
① input에서의 pole

$$|\omega_1| = \frac{1}{R_S \times (C_{GS} + (1+g_m R_L) \cdot C_{GD})} \approx 3.59\,Grad/s \qquad \therefore f_{p1} = 571.4\,MHz$$

② output 에서의 pole

$$|\omega_2| = \frac{1}{R_L \times (C_{DB} + (1+\frac{1}{g_m R_L}) C_{GD})} \approx 2.69\,Grad/s \qquad \therefore f_{p2} = 427.8\,MHz$$

2.2 & 2.3



① v_x에서

$$\frac{v_{in} - v_x}{R_S} = sC_{GS} \cdot v_x + sC_{GD} \cdot (v_x - v_{out})$$

② v_{out} 에서

$$g_m \cdot v_x + \frac{v_{out}}{R_L} + sC_{DB} \cdot v_{out} = sC_{GD}(v_x - v_{out})$$

→ 정리하면

$$\frac{v_{out}}{v_{in}} = \frac{(s \cdot C_{GD} - g_m) R_L}{as^2 + bs + 1}$$

where, $a = R_S \cdot R_L \cdot (C_{GS} \cdot C_{GD} + C_{DB} \cdot C_{GD} + C_{GS} \cdot C_{DB})$

$b = (1 + g_m R_L) C_{GD} \cdot R_S + R_S \cdot C_{GS} + R_L (C_{GD} + C_{DB})$

⇒ "exact solution"

. if $\omega_{p2} \gg \omega_{p1}$,

$$|\omega_{p1}| = \frac{1}{b}, \quad |\omega_{p2}| = \frac{b}{a}, \quad |\omega_z| = \frac{g_m}{C_{GD}}$$

⇒ "dominant-pole approximation"

. 값을 대입하여 계산하면

2.2 dominant-pole approximation

$|\omega_{p1}| \approx 1.564\,Grad/s$, $\therefore f_{p1} = 249\,MHz$.

$|\omega_{p2}| \approx 30.157\,Grad/s$. $\therefore f_{p2} = 4.80\,GHz$.

$|\omega_z| \approx 83.333\,Grad/s$. $\therefore f_z = 13.263\,GHz$

2.3 exact location

$|\omega_{p1}| \approx 1.654\,Grad/s$ $\quad \therefore f_{p1} = 263\,MHz$

$|\omega_{p2}| \approx 28.502\,Grad/s$ $\quad \therefore f_{p2} = 4.536\,GHz$

$|\omega_z| \approx 83.333\,Grad/s$ $\quad \therefore f_z = 13.263\,GHz$

2.4

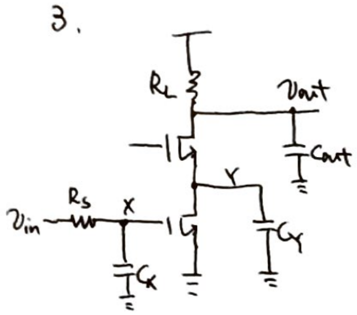
· miller effect가 부정확한 이유

① 낮은 주파수의 gain (DC gain)으로 근사한 것이라 주파수가 높아질수록 부정확.

② zero가 반영안됨

- dominant-pole approximation의 경우 $f_{p2} > 10 \cdot f_{p1}$으로, 근사값과 exact solution이 거의 유사하다.

3.



· $\frac{v_Y}{v_X} = -\frac{g_{m1}}{g_{m2}}$

· $C_X = C_{GS1} + C_{GD1}\left(1 + \frac{g_{m1}}{g_{m2}}\right)$

· $C_Y = C_{GS2} + C_{GD1}\left(1 + \frac{g_{m2}}{g_{m1}}\right) + C_{DB1} + C_{SB2}$

· $C_{out} = C_{DB2} + C_{GD2}$

따라서 pole은

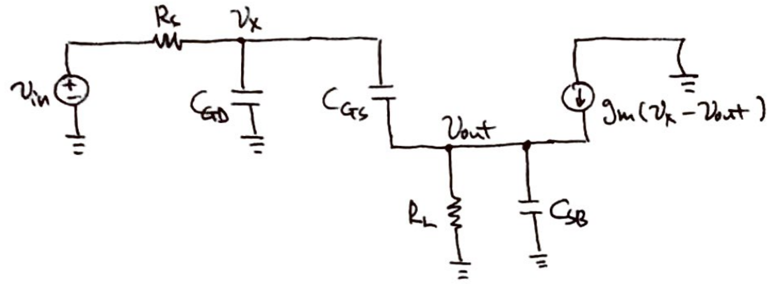
① $|\omega_{p.X}| = \frac{1}{C_X \cdot R_S} \approx 12.195$ Grad/s , $f_{pX} = 1.94$ GHz

② $|\omega_{p.Y}| = \frac{1}{C_Y \cdot \frac{1}{g_{m2}}} \approx 10.929$ Grad/s . $f_{p.Y} = 1.74$ GHz

③ $|\omega_{p.out}| = \frac{1}{C_{out} \cdot R_L} \approx 2.778$ Grad/s . $f_{p.out} = 442$ MHz

· 과제의 exact location의 1st pole 263MHz 대비 약 2배정도 1st pole frequency가 증가한다. 즉 bandwidth 증가

4.



① v_x 에서

$$\frac{v_{in} - v_x}{R_s} = s \cdot C_{GD} \cdot v_x + s \cdot C_{GS} \cdot (v_x - v_{out})$$

② v_{out} 에서

$$s \cdot C_{GS}(v_x - v_{out}) = \frac{1}{R_L} v_{out} + s C_{SB} \cdot v_{out} - g_m(v_x - v_{out})$$

→ 두 식을 정리하면

$$\frac{v_{out}}{v_{in}} = \frac{1 + s\frac{C_{GS}}{g_m}}{as^2 + bs + c},$$

where

$$a = \frac{R_s}{g_m}(C_{GD} \cdot C_{GS} + C_{GD} \cdot C_{SB} + C_{GS} \cdot C_{SB})$$

$$b = \frac{R_s}{g_m}(C_{GD} + C_{GS})(g_m + \frac{1}{R_L}) + \frac{C_{GS} + C_{SB}}{g_m} - C_{GS} \cdot R_s$$

$$c = 1 + \frac{1}{g_m R_L}$$

$$\therefore \omega_{p1} = 2\pi\left[-3.606\,\mathrm{GHz} + j(1.901\,\mathrm{GHz})\right]$$

$$\omega_{p2} = 2\pi\left[-3.606\,\mathrm{GHz} - j(1.901\,\mathrm{GHz})\right]$$