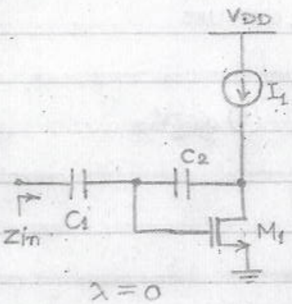
9+10+10+2+5+6+10+8+15

* Reduce ~~...~~ NO ~~...~~ marks for small mistakes like final combining.

[redacted]

(1) Problem 6.6

(a)



$\lambda = 0$

Eq. ckt $\Rightarrow$ 1
correct ans $\Rightarrow$ 2
partial $\Rightarrow$ 3
total = 3.

If $\lambda = 0$,

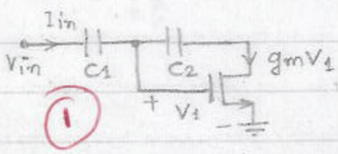
$I_D = g_m V_1$

$\therefore I_{in} = g_m V_1$

$$V_{in} - \frac{I_{in}}{sC_1} - V_1 = 0$$

$$\therefore V_{in} - \frac{I_{in}}{sC_1} - \frac{I_{in}}{g_m} = 0$$

AC equivalent circuit

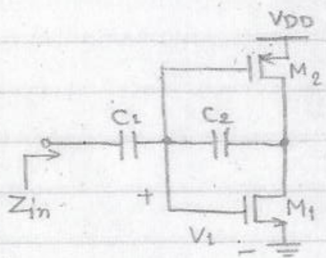


1

$$\therefore \frac{V_{in}}{I_{in}} = \frac{1}{sC_1} + \frac{1}{g_m}$$

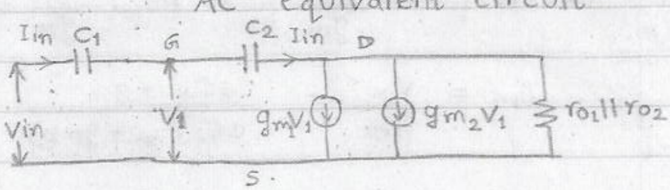
$$\therefore Z_{in} = \frac{V_{in}}{I_{in}} = \frac{g_m + sC_1}{sC_1 g_m}$$

(b)



$\lambda \neq 0$

AC equivalent circuit



Eq ckt = 1
correct ans = 2
partial 3
total $\Rightarrow$ 3.

$$V_1 = V_{in} - \frac{I_{in}}{sC_1}$$

$$I_{in} = g_{m_1} V_1 + g_{m_2} V_1 + \frac{\left(V_1 - \frac{I_{in}}{sC_2}\right)}{r_{o1} \| r_{o2}}$$

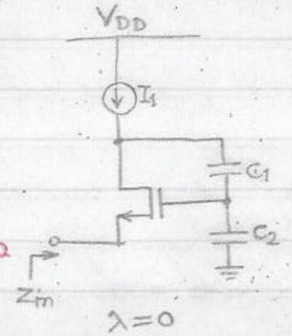
$$\therefore I_{in} = (g_{m_1} + g_{m_2})\left(V_{in} - \frac{I_{in}}{sC_1}\right) + \frac{1}{r_{o1}\|r_{o2}}\left(V_{in} - \frac{I_{in}}{sC_1} - \frac{I_{in}}{sC_2}\right)$$

$$\therefore I_{in}\left\{1 + \frac{1}{sC_1}(g_{m_1} + g_{m_2}) + \frac{1}{r_{o1}\|r_{o2}}\left(\frac{1}{sC_1} + \frac{1}{sC_2}\right)\right\}$$

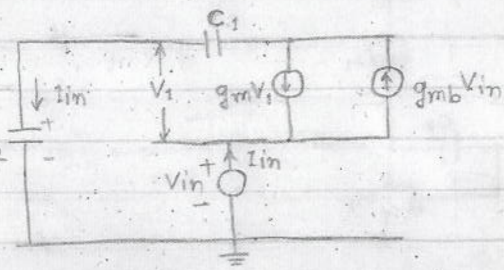
$$= \left(g_{m_1} + g_{m_2} + \frac{1}{r_{o1}\|r_{o2}}\right) V_{in}$$

$$\therefore Z_{in} = \frac{V_{in}}{I_{in}} = \frac{1 + \frac{1}{sC_1}(g_{m_1} + g_{m_2}) + \frac{1}{r_{o1}\|r_{o2}}\left(\frac{1}{sC_1} + \frac{1}{sC_2}\right)}{g_{m_1} + g_{m_2} + \frac{1}{r_{o1}\|r_{o2}}}$$

(c)



AC equivalent circuit



Eqvl ckt =) 1
Correct analysis =) 2
2 partial = 13
total = 3

$$I_{in} = -g_m V_1 + g_{mb} V_{in} \Rightarrow V_1 = \frac{-I_{in}}{g_m} + \frac{V_{in}\, g_{mb}}{g_m}$$

$$V_{C_2} = V_1 + V_{in} = \frac{I_{in}}{sC_2}$$

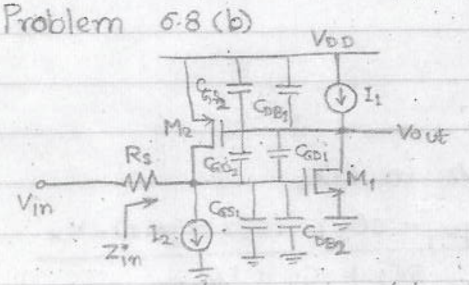
$$\therefore V_{in} + V_{in}\frac{g_{mb}}{g_m} - \frac{I_{in}}{g_m} = \frac{I_{in}}{sC_2}$$

$$\therefore V_{in}\left\{1 + \frac{g_{mb}}{g_m}\right\} = I_{in}\left\{\frac{1}{g_m} + \frac{1}{sC_2}\right\}$$

$$\therefore Z_{in} = \frac{V_{in}}{I_{in}} = \frac{sC_2 + g_m}{sC_2(g_m + g_{mb})}$$

[redacted]

Problem 6.8 (b)



Let $C_1 = C_{GS_2} + C_{DB_1}$

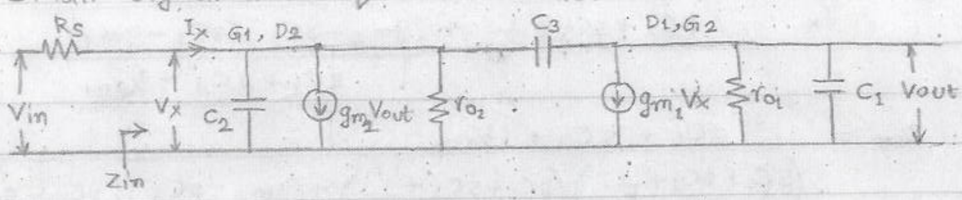
$C_2 = C_{GS_1} + C_{DB_2}$

$C_3 = C_{GD_1} + C_{GD_2}$

Small signal AC equivalent model

Eqvt ckt => 1

correct Analysis => 4



total => 5

give partial credits

$$I_x = V_x \cdot sC_2 + g_{m_2} V_{out} + \frac{V_x}{r_{o_2}} + (V_x - V_{out})\, sC_3 \quad \ldots (i)$$

$$V_x = V_{in} - I_x R_S \quad \ldots (ii)$$

2

$$V_{out} \cdot sC_1 + \frac{V_{out}}{r_{o_1}} + g_{m_1} V_x + (V_{out} - V_x)\, sC_3 = 0 \quad \ldots (iii)$$

(ii) in (i) $\Rightarrow$

$$\frac{V_{in} - V_x}{R_S} = V_x \cdot sC_2 + g_{m_2} V_{out} + \frac{V_x}{r_{o_2}} + (V_x - V_{out})\, sC_3 \quad \ldots (iv)$$

$$(iii) \Rightarrow \quad V_{out} \left\{ sC_1 + sC_3 + \frac{1}{r_{o_1}} \right\} = V_x \,(sC_3 - g_{m_1})$$

$$\therefore \quad V_x = \frac{sC_1 + sC_3 + 1/r_{o_1}}{sC_3 - g_{m_1}}\, V_{out} \quad \ldots (v)$$

1

(iv) $\Rightarrow$

$$\frac{V_{in}}{R_S} = \left\{ sC_2 + \frac{1}{R_S} + \frac{1}{r_{o_2}} + sC_3 \right\} \left\{ \frac{sC_1 + sC_3 + 1/r_{o_1}}{sC_3 - g_{m_1}} \right\} V_{out} + (g_{m_2} - sC_3)\, V_{out}$$

$$\therefore \frac{V_{out}}{V_{in}} = \frac{1}{R_S} \cdot \frac{1}{\left(sC_2 + \frac{1}{R_S} + \frac{1}{r_{o_2}} + sC_3 \right) \left(\frac{sC_1 + sC_3 + 1/r_{o_1}}{sC_3 - g_{m_1}} \right) + g_{m_2} - sC_3}$$

$$\therefore \frac{V_{out}}{V_{in}} = \frac{(sC_3 - g_{m_1})/R_S}{s^2 (C_1C_2 + C_2C_3 + C_1C_3) + s\left\{ (C_2 + C_3) \cdot \frac{1}{r_{o_1}} + \left(\frac{1}{R_S} + \frac{1}{r_{o_2}} \right)(C_1 + C_3) + (g_{m_1} + g_{m_2})\, C_3 \right\} - g_{m_1} g_{m_2} + \frac{1}{r_{o_1}} \left(\frac{1}{r_{o_2}} + R_S \right)}$$

$$Z_{in} = \frac{V_x}{I_x}$$

Substitute for V_{out} from (v) in (i),

$$I_x = V_x \cdot \left(sC_2 + sC_3 + \frac{1}{r_{o2}}\right) + \frac{(g_{m_2} - sC_3) \cdot (sC_3 - g_{m1}) \cdot V_x}{sC_1 + sC_3 + 1/r_{o1}}$$

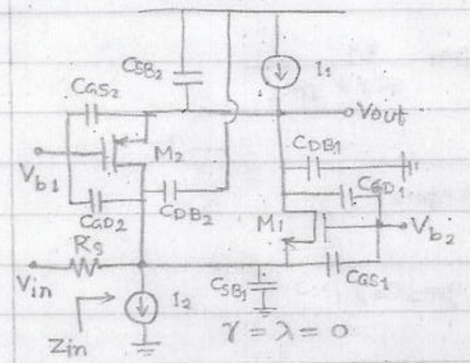
1

$$\therefore Z_{in} = \frac{V_x}{I_x} = \frac{1}{sC_2 + sC_3 + \frac{1}{r_{o2}} + \frac{(g_{m2} - sC_3)(sC_3 - g_{m1})}{sC_1 + sC_3 + 1/r_{o1}}}$$

$$\therefore Z_{in} = \frac{sC_1 + sC_3 + 1/r_{o1}}{\left(sC_2 + sC_3 + \frac{1}{r_{o2}}\right)\left(sC_1 + sC_3 + \frac{1}{r_{o1}}\right) + (g_{m2} - sC_3)(sC_3 - g_{m1})}$$

$$\therefore Z_{in} = \frac{sC_1 + sC_3 + 1/r_{o1}}{s^2(C_1C_2 + C_2C_3 + C_1C_3) + s\left\{\frac{1}{r_{o2}}(C_1 + C_3) + \frac{1}{r_{o1}}(C_2 + C_3) + (g_{m2} + g_{m1})C_3\right\} - g_{m1}g_{m2} + \frac{1}{r_{o1}r_{o2}}}$$

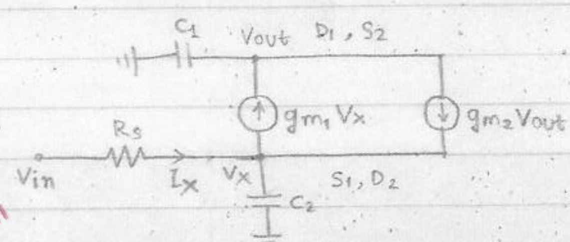
Problem 6.8 (e)



∴ Let $C_1 = C_{DB1} + C_{GD1} + C_{SB2} + C_{GS2}$

$C_2 = C_{GD2} + C_{DB2} + C_{SB1} + C_{GS1}$

Small signal AC equivalent model



Eqvt ckt = 1

Basic eqn = 2

Final $\frac{V_{out}}{V_{in}} = 1$

Final $Z_{in} = 1$

total = 5

$V_x = V_{in} - I_x R_s$ ... (i)

$I_x = V_x \cdot sC_2 + g_{m1} V_x - g_{m2} V_{out}$ ... (ii)

$V_{out} \cdot sC_1 = g_{m1} V_x - g_{m2} V_{out}$

$\therefore V_{out} \cdot (sC_1 + g_{m2}) = g_{m1} V_x$ ... (iii)

(ii) in (i) ⇒

$V_x = V_{in} - (V_x \cdot sC_2 + g_{m1} V_x - g_{m2} V_{out}) R_s$

(iii) ⇒

$$\frac{V_{out}}{g_{m1}} (sC_1 + g_{m2}) = V_{in} - (sC_2 + g_{m1}) R_s \cdot \frac{V_{out}}{g_{m1}} (sC_1 + g_{m2}) + g_{m2} R_s V_{out}$$

$$\therefore V_{out} \left\{ \frac{sC_1 + g_{m2}}{g_{m1}} + \frac{(sC_2 + g_{m1})(sC_1 + g_{m2}) R_s}{g_{m1}} - g_{m2} R_s \right\} = V_{in}$$

$$\therefore \frac{V_{out}}{V_{in}} = \frac{g_{m1}}{s^2 C_1 C_2 R_s + s\{C_1 + (g_{m2} C_2 + g_{m1} C_1) R_s\} + g_{m2}}$$

$$Z_{in} = \frac{V_x}{I_x}$$

Substitute Vout from (iii) in (ii),

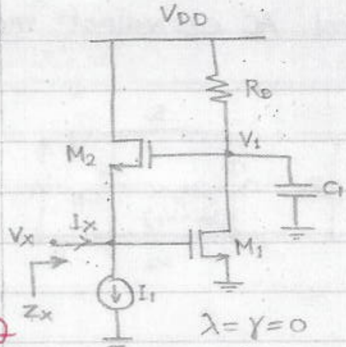
$$I_x = V_x \cdot sC_2 + g_{m1} V_x - g_{m2} \cdot g_{m1} \frac{V_x}{sC_1 + g_{m2}}$$

$$\therefore \frac{V_x}{I_x} = \frac{sC_1 + g_{m2}}{(sC_2 + g_{m1})(sC_1 + g_{m2}) - g_{m1} g_{m2}}$$

$$\therefore Z_{in} = \frac{V_x}{I_x} = \frac{sC_1 + g_{m2}}{s^2 C_1 C_2 + s(g_{m1} C_1 + g_{m2} C_2)}$$

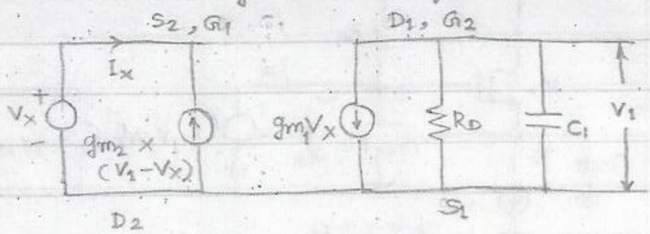
Problem 6.12

(a)



$\lambda = \gamma = 0$

Small signal AC equivalent circuit



Eqvt ckt = 1
Basic equations = 2
Zx = 1
Plot = 1
total => 5

$I_x = -g_{m2}(V_1 - V_x) \quad \ldots (i)$

$g_{m1}V_x + \dfrac{V_1}{R_D} + V_1 \cdot s \cdot C_1 = 0$

$V_1 = \dfrac{-g_{m1} V_x}{\frac{1}{R_D} + sC_1} \quad \ldots (ii)$

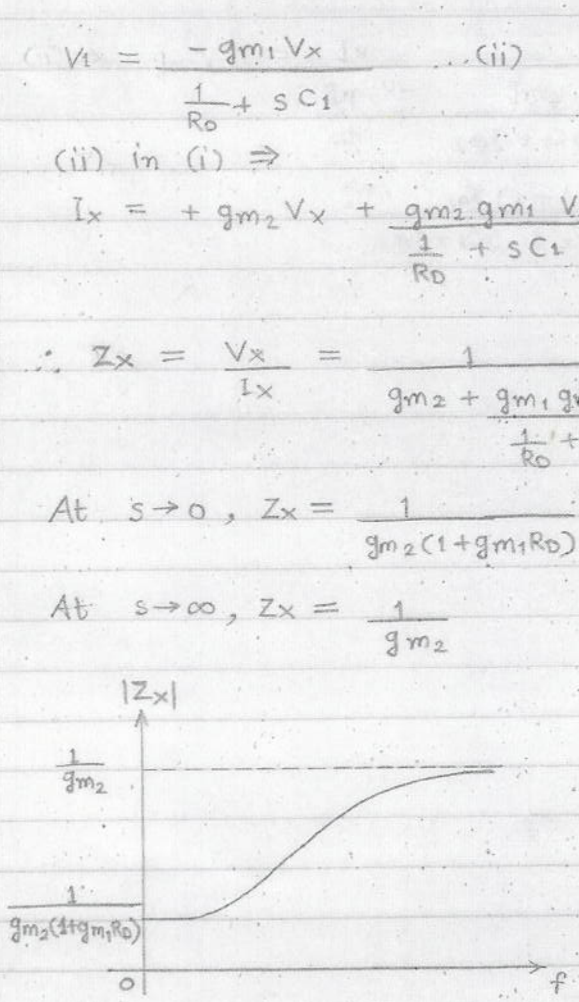
(ii) in (i) $\Rightarrow$

$I_x = +g_{m2} V_x + \dfrac{g_{m2} \cdot g_{m1} V_x}{\frac{1}{R_D} + sC_1}$

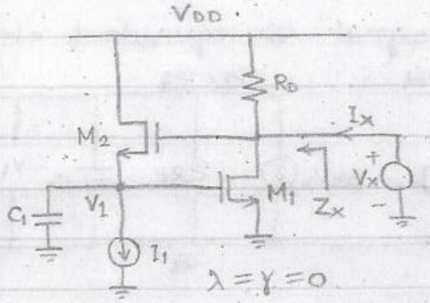
$\therefore Z_x = \dfrac{V_x}{I_x} = \dfrac{1}{g_{m2} + \dfrac{g_{m1} g_{m2}}{\frac{1}{R_D} + sC_1}} = \dfrac{1 + sR_D C_1}{g_{m2}(g_{m1}R_D + sR_D C_1 + 1)}$

At $s \to 0$, $Z_x = \dfrac{1}{g_{m2}(1 + g_{m1}R_D)}$

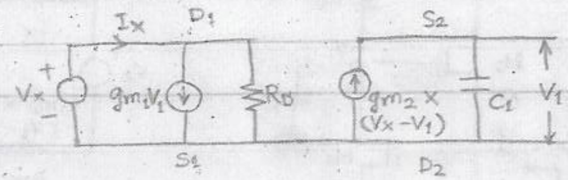
At $s \to \infty$, $Z_x = \dfrac{1}{g_{m2}}$



(b)



Small signal AC equivalent model



Equi ckt => 1

Basic eqn => 2

Z_x => 1

plot => 1

total = 5

$$V_1 = \frac{g_{m2}(V_x - V_1)}{sC_1}$$

$$\therefore (sC_1 + g_{m2})V_1 = g_{m2}V_x \quad \ldots (i)$$

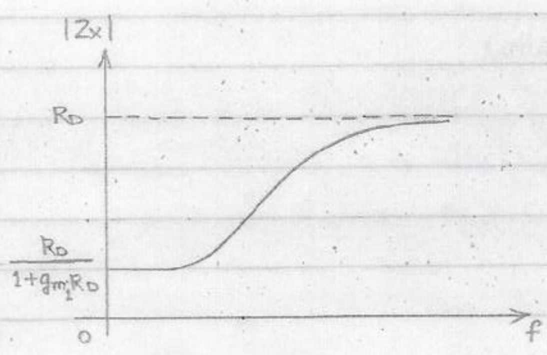
$$I_x = g_{m1}V_1 + \frac{V_x}{R_D}$$

$$(i) \Rightarrow I_x = g_{m1}\, g_{m2} \frac{V_x}{sC_1 + g_{m2}} + \frac{V_x}{R_D}$$

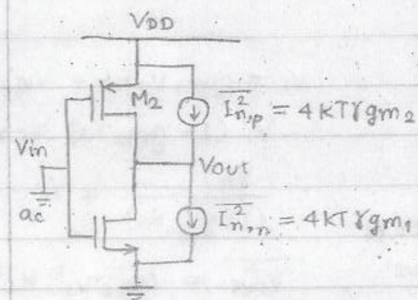
$$\therefore Z_x = \frac{V_x}{I_x} = \frac{(sC_1 + g_{m2})R_D}{R_D g_{m1} g_{m2} + sC_1 + g_{m2}}$$

At $s \to 0$, $Z_x = \dfrac{R_D}{1 + g_{m1}R_D}$

At $s \to \infty$, $Z_x = R_D$



(2) Problem 7.5



$$\overline{V^2_{n,out}} = \left(\overline{I^2_{n,p}} + \overline{I^2_{n,n}}\right)(r_{o1} \| r_{o2})^2$$
$$= 4kT \cdot \frac{2}{3}\,(g_{m1} + g_{m2})\,(r_{o1} \| r_{o2})^2$$

$$|A_v| = (g_{m1} + g_{m2})(r_{o1} \| r_{o2})$$

total => 2

Input referred noise:

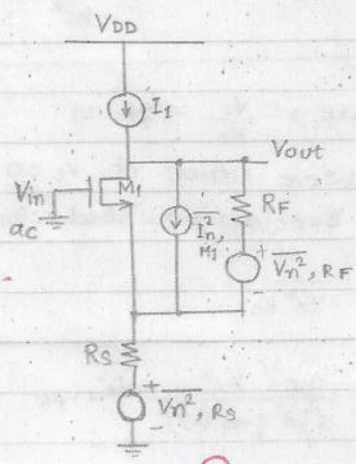
$$\overline{V^2_{n,in}} = \frac{\overline{V^2_{n,out}}}{|A_v|^2} = 4kT\left(\frac{2}{3}\right)\frac{1}{g_{m1}+g_{m2}} \quad (1)$$

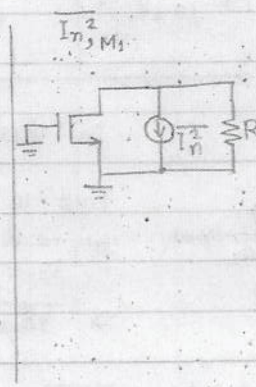
$\overline{V^2_{n,in}}$ decreases with increase in g_{m2}

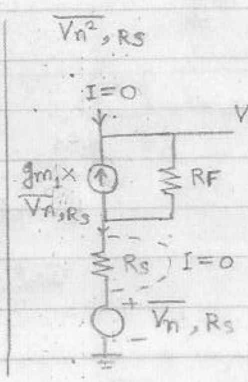
whereas in equation (7.59) $\overline{V^2_{n,in}} = 4kT\cdot\left(\frac{2}{3}\right)\left\{\frac{1}{g_{m1}} + \frac{g_{m2}}{g_{m1}^2}\right\}$

i.e. $\overline{V^2_{n,in}}$ increases with increase in g_{m2}. (1)

Problem 7.6(c)







$$V_{out} = \overline{V_{n,Rs}} + g_{m1} R_F \overline{V_{n,Rs}} = (1 + g_{m1} R_F) \times \overline{V_{n,Rs}}$$

one for each noise comp.
1 for your final answer
& 1 for total => 5.

$$|A_v| = g_{m1} R_F \quad (1)$$

(1) (1) (1)

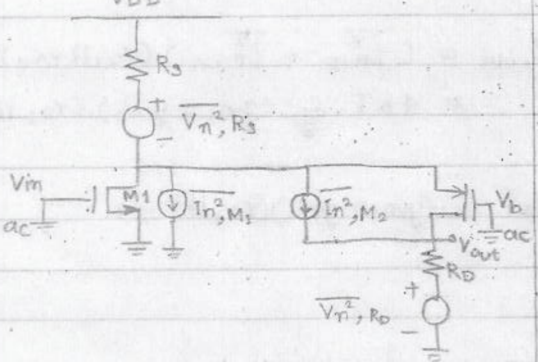
$$\overline{V^2_{n,out}} = \overline{V^2_{n,RF}} + (1 + g_{m1}R_F)^2\,\overline{V^2_{n,Rs}} + \overline{I^2_{n,M1}} \cdot R_F^2$$
$$= 4kTR_F + 4kTR_S(1 + g_{m1}R_F)^2 + 4kT\left(\frac{2}{3}\right) \cdot g_{m1} R_F^2$$

Input referred noise:

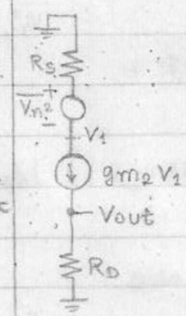
$$\overline{V^2_{n,in}} = \frac{\overline{V^2_{n,out}}}{|A_v|^2} = \frac{4kT}{g_{m1}^2 R_F} + \frac{4kTR_S(1+g_{m1}R_F)^2}{g_{m1}^2 R_F^2} + \frac{4kT}{g_{m1}}\left(\frac{2}{3}\right)$$

(1)

Problem 7-6 (f)



$\overline{V_n^2}, R_S$



$$V_1 = -(g_{m2} V_1 R_S + V_n)$$

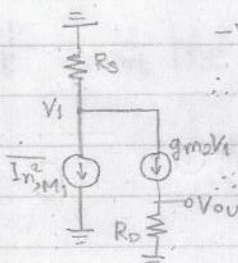
$$\therefore V_1 (1 + g_{m2} R_S) = -V_n$$

$$\therefore \frac{-V_n}{(1+g_{m2}R_S)} = V_1$$

$$\overline{V_{out}^2} = g_{m2}^2 V_1^2 R_D^2$$

$$= \frac{g_{m2}^2 R_D^2 \overline{V_{n2}^2}, R_S}{(1+g_{m2}R_S)^2}$$ 1

$\overline{I_n^2}, M_1$



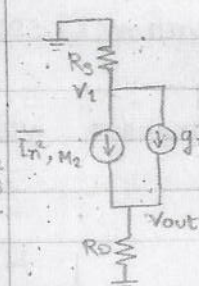
$$-V_1 = (I_n + g_{m2} V_1) R_S$$

$$\therefore V_1(1+g_{m2}R_S) = -I_n R_S$$

$$\overline{V_{out}^2} = g_{m2}^2 V_1^2 R_D^2$$

$$\therefore \overline{V_{out}^2} = \frac{g_{m2}^2 R_D^2 \overline{I_n^2}, M_1 R_S^2}{(1+g_{m2}R_S)^2}$$ 1

$\overline{I_n^2}, M_2$



$$-V_1 = (g_{m2} V_1 + I_n) R_S$$

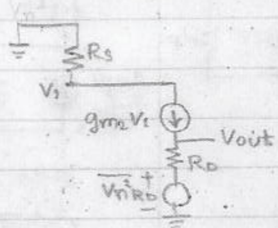
$$\therefore V_1(1+g_{m2}R_S) = -I_n R_S$$

$$\overline{V_{out}^2} = (g_{m2} V_1 + I_n)^2 R_D^2$$

$$= \frac{V_1^2 R_D^2}{R_S^2}$$

1 $$= \frac{R_D}{\cancel{R_S^2}} \frac{\overline{I_{n,M_2}^2} \cancel{R_S^2}}{(1+g_{m2}R_S)^2}$$

$\overline{V_n^2}, R_D$



In this case, $\frac{V_1}{R_S} = g_{m2} V_1$

This is possible either if $V_1 = 0$ or $g_{m2} = R_S^{-1}$. Considering that $g_{m2} \neq \frac{1}{R_S}$,

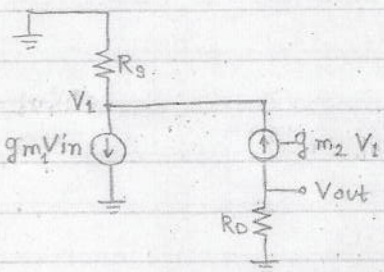
$V_1 = 0$

$\Rightarrow \overline{V_{out}^2} = \overline{V_n^2} R_D$ 1

$$\overline{V_{n,out}^2} = \overline{V_n^2}_{,R_D} + \frac{g_{m2}^2 R_D^2}{(1+g_{m2}R_S)^2} \overline{I_n^2}, M_1 R_S^2 + \frac{g_{m2}^2 R_D^2}{(1+g_{m2}R_S)^2} \overline{V_{n2}^2}, R_S + \frac{R_D}{(1+g_{m2}R_S)^2} \overline{I_n^2}, M_2$$

$$\therefore \overline{V_{n,out}^2} = 4kTR_D + 4kT\left(\frac{2}{3}\right) g_{m1} \frac{g_{m2}^2 R_S^2 R_D^2}{(1+g_{m2}R_S)^2} + 4kTR_S \frac{g_{m2}^2}{(1+g_{m2}R_S)^2} R_D^2 + 4kT\left(\frac{2}{3}\right) \frac{g_{m2} R_D^2}{(1+g_{m2}R_S)^2}$$

To calculate gain:



$$\frac{V_1}{R_S} + g_{m_1}V_{in} = -g_{m_2}V_1$$

$$\therefore V_1\left(\frac{1}{R_S} + g_{m_2}\right) = -g_{m_1}V_{in}$$

$$V_{out} = -g_{m_2}V_1 R_D$$

$$\therefore V_{out} = \frac{g_{m_2}g_{m_1}}{\left(\frac{1}{R_S} + g_{m_2}\right)} R_D \cdot V_{in}$$

$$\therefore A_V = \frac{V_{out}}{V_{in}} = \frac{g_{m1}g_{m2}R_S R_D}{(1 + g_{m2}R_S)}$$ (1)

Input referred noise:

$$\overline{V^2_{n,in}} = \frac{\overline{V^2_{n,out}}}{|A_V|^2}$$

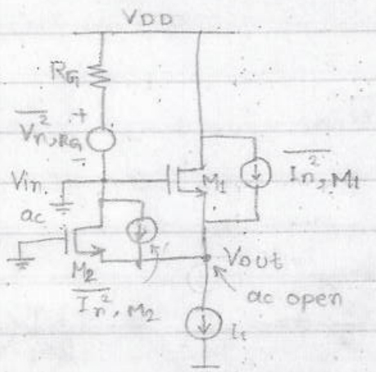
$$\therefore \overline{V^2_{n,in}} = \frac{4kT(1+g_{m_2}R_S)^2}{g_{m_1}^2 g_{m_2}^2 R_D} + \frac{4kT}{g_{m_1}}\left(\frac{2}{3}\right) + \frac{4kT}{g_{m_1}^2 R_S} + \frac{4kT}{g_{m_1}^2 g_{m_2} R_S^2}\left(\frac{2}{3}\right)$$

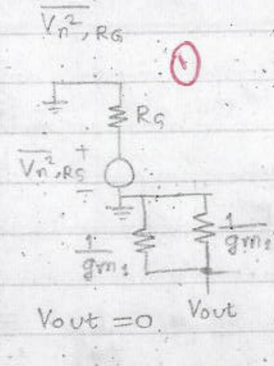
(1)

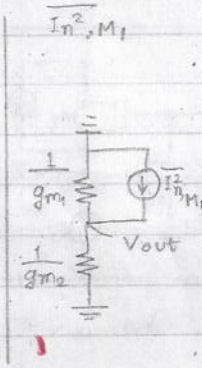
total ⇒ 6

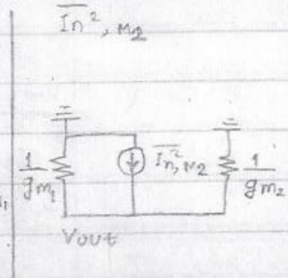
Problem 7.9(e)

For input referred noise voltage : $V_{in} = 0$.







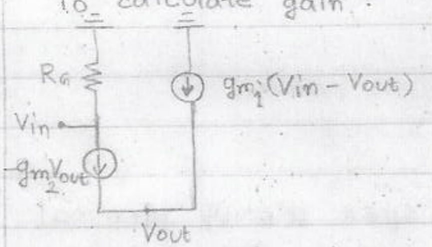


$$\overline{V_{n,out}^2} = \overline{I_{n,M_1}^2}\left(\frac{1}{g_{m1}} \parallel \frac{1}{g_{m2}}\right)^2 + \overline{I_{n,M_2}^2}\left(\frac{1}{g_{m1}} \parallel \frac{1}{g_{m2}}\right)^2$$

$$= 4kT \cdot \frac{2}{3} g_{m1} \cdot \frac{1}{(g_{m1}+g_{m2})^2} + 4kT \cdot \frac{2}{3} g_{m2} \frac{1}{(g_{m1}+g_{m2})^2}$$

$$= 4kT \cdot \frac{2}{3} \cdot \frac{1}{g_{m1}+g_{m2}}$$

To calculate gain :



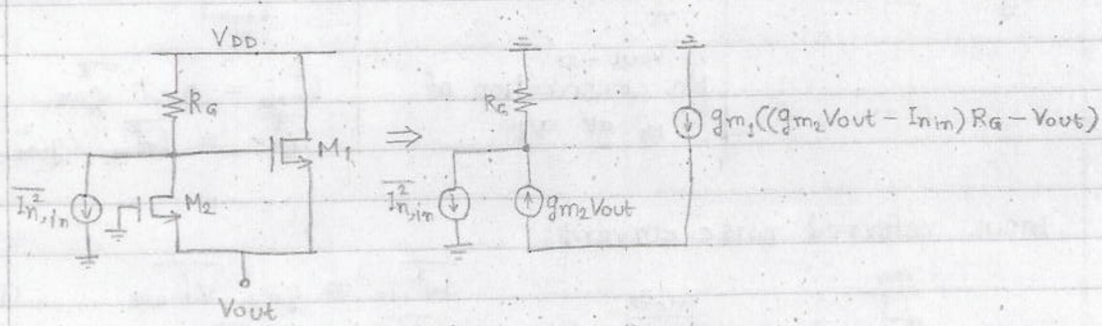
$$-g_{m2}V_{out} = -g_{m1}(V_{in} - V_{out})$$

$$\therefore \quad g_{m2}V_{out} = g_{m1}V_{in} - g_{m1}V_{out}$$

$$\therefore \quad A_V = \frac{V_{out}}{V_{in}} = \frac{g_{m1}}{g_{m1}+g_{m2}}$$

Input referred noise voltage : $\overline{V_{n,in}^2} = \dfrac{\overline{V_{n,out}^2}}{|A_V|^2} = 4kT \cdot \dfrac{2}{3} \dfrac{g_{m1}+g_{m2}}{g_{m1}^2}$

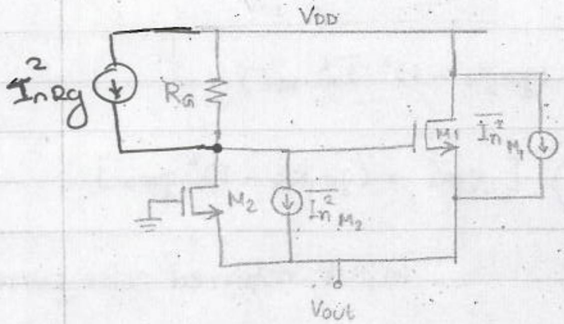
For input referred noise current : We open input terminal



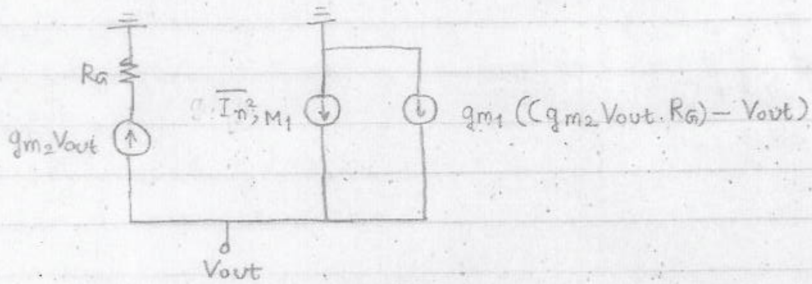
$$\therefore \quad g_{m1}((g_{m2}V_{out} - I_{n,in})R_G - V_{out}) = g_{m2}V_{out}$$

$$\therefore \quad (g_{m1}g_{m2}R_G - g_{m1} - g_{m2})V_{out} = g_{m1}R_G I_{n,in}$$

$$\therefore \quad \overline{I_{n,in}^2} = \frac{\overline{V_{n,out}^2}\,(g_{m1}g_{m2}R_G - g_{m1} - g_{m2})^2}{g_{m1}^2 R_G^2} \quad \ldots (i)$$



Considering effect of $\overline{In^2_{,M_1}}$ on $\overline{V^2_{n\,out}}$

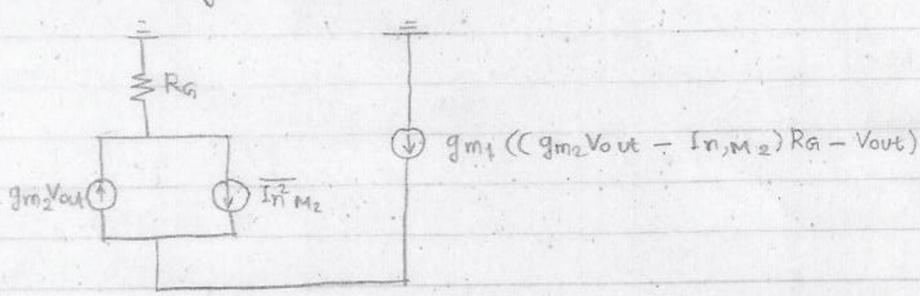


$$\therefore\ g_{m_2} V_{out} = I_{n,M_1} + g_{m_1}(g_{m_2}R_G - 1)\ V_{out}$$

$$\therefore\ I_{n,M_1} = (g_{m_1} + g_{m_2} - g_{m_1}g_{m_2}R_G)\ V_{n\,out}$$

$$\therefore\ \overline{V^2_{n\,out}}' = \frac{\overline{I^2_{n,M_1}}}{(g_{m_1} + g_{m_2} - g_{m_1}g_{m_2}R_G)^2} \quad (1)$$

Considering effect of $\overline{In^2_{,M_2}}$ on $\overline{V^2_{n,out}}$



$$\therefore\ R_G g_{m_1} g_{m_2} V_{out} - g_{m_1} I_{n\,M_2} R_G - g_{m_1} V_{out} = g_{m_2} V_{out} - I_{n\,M_2}$$

$$\therefore\ V_{out}\ (g_{m_1}g_{m_2}R_G - g_{m_1} - g_{m_2}) = I_{n\,M_2}\ (g_{m_1}R_G - 1)$$

$$\therefore\ \overline{V^2_{n\,out}}'' = \frac{\overline{I^2_{n,M_2}}\ (g_{m_1}R_G - 1)^2}{(g_{m_1}g_{m_2}R_G - g_{m_1} - g_{m_2})^2}$$

Considering the effects of both noise sources together

$$\overline{V^2_{n\,out}} = \frac{1}{(g_{m_1}g_{m_2}R_G - g_{m_1} - g_{m_2})^2}\left[\overline{I^2_{n,M_1}} + \overline{I^2_{n,M_2}}\,(g_{m_1}R_G - 1)^2\right] \quad \ldots (ii)$$

Put (ii) in (i),

$$\therefore \overline{I_n^2}_{,in} = \frac{1}{g_{m_1}^2 R_G^2} \left(\overline{I_n^2}_{,M_1} + (g_{m_1}R_G - 1)^2 \, \overline{I_n^2}_{,M_2} \right)$$

$$\therefore I_n^2{}_{,in} = \frac{1}{g_{m_1}^2 R_G^2} \, 4kT \left(\frac{2}{3}\right) \left[g_{m_1} + (g_{m_1}R_G - 1)^2 g_{m_2} \right]$$

∴ input referred noise current

Input Refferred contribution due to $I_n^2 R_g = I_n^2 R_g$. 1

total = 10

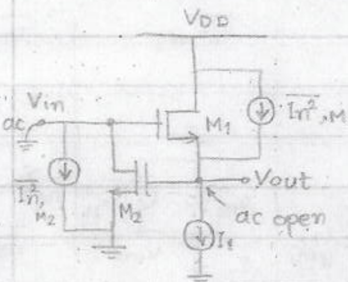
So total input referred Noise current

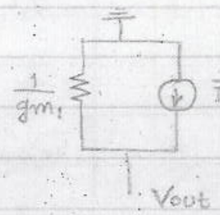
$$\Rightarrow \frac{4KT}{R_g} + \frac{1}{g_{m1}^2 R_g^2} \, 4KT \cdot \frac{2}{3} \left(g_{m1} + (g_{m1}R_g - 1)^2 g_{m2} \right).$$

1

(3) Problem 7.9(f)

For input referred noise voltage: $V_{in} = 0$.

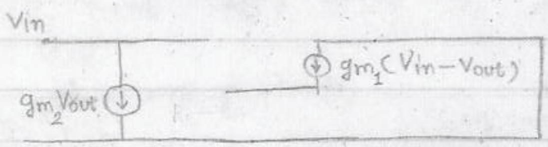




Noise due to $M_2 = 0$ 1

$$\overline{V^2_{n,out}} = \overline{In^2,_{M_1}} \cdot \frac{1}{gm_1^2} = 4kT\,\frac{2}{3}\,gm_1 \cdot \frac{1}{gm_1^2} = \frac{4kT}{gm_1}\left(\frac{2}{3}\right)$$ 1

To calculate gain:



$gm_1(V_{in} - V_{out}) = 0$

$\therefore\ V_{in} = V_{out}$

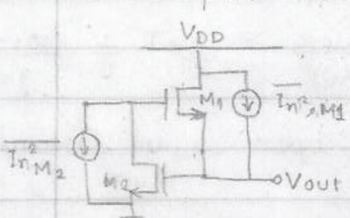
$\therefore\ A_V = 1$ 1

Input referred noise voltage:

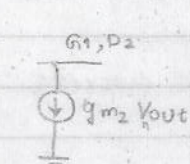
$$\overline{V^2_{n,in}} = \overline{V^2_{n,out}} = \frac{4kT}{gm_1}\left(\frac{2}{3}\right)$$ 1

(4)

For input referred current: We open the i/p terminal



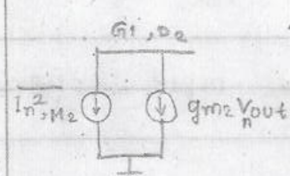
$In^2_{M_1}$



1

$\therefore\ V_{out} = 0$
No contribution of $In^2_{M_1}$ at o/p

$In^2_{M_2}$

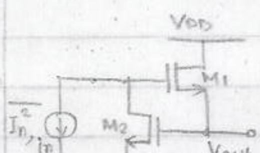


1

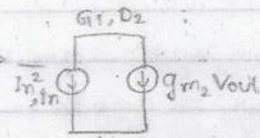
$\overline{I^2_{nM_2}} = gm_2^2\ \overline{V^2_{n,out}}$

$\therefore\ \overline{V^2_{n,out}} = \overline{In^2_{M_2}} / gm_2^2$ ...(i)

Input referred noise current:



$\Rightarrow$



1

$\overline{In^2,_{in}} = gm_2^2\ \overline{V^2_{n\,out}}$ ...(ii)

$\therefore\ \overline{In^2,_{in}} = \overline{In^2_{,M_2}} = 4kT\,\frac{2}{3}\,gm_2$ 1

④ NMOS params

$V_{th} = 0.476 \quad \mu_n C_{ox} = 248\ \mu A/V^2$

PMOS params

$V_{th} = 0.488 \quad \mu_n C_{ox} = 102\ \mu A/V^2.$

ⓐ $I_1 = I_2 = I_3 = 150\mu.$

$\frac{1}{2} \cdot \mu_n C_{ox} \frac{W}{L} \cdot (0.15)^2 = 150\mu.$

① $W_{1,2,3} = 9.67\mu m$

ⓑ $\underline{\underline{V_{b1}}}$

For M_2 to be in saturation its drain voltage has to be greater than $0.8 - V_{th}$.

$\Rightarrow V_{b1} = V_{th} + V_{OD_{M3}} + 0.8 - V_{th}$

① $= 0.95V.$

$\underline{\underline{V_{b2}}}$

$$V_{OD_{M4,5,6}} = \sqrt{\frac{2\times 150}{102\times \frac{30}{0.18}}} = \sqrt{\frac{2I}{\mu_n C_{ox} W/L}}$$

$= 0.133V$

For M_5 to be in saturation

$V_{b2\,max} = V_{DD} - \{V_{OD_{M5}} + V_{OD_{M4}} + |V_{thp}|\}$

① $= 1.046V.$

Simulation ⇓

Total ⇒ 7 + ⑧ = 15

$\underline{\underline{\text{Simulation}}}$

ⓐ Netlist ⇒ 1

ⓑ proper setup for gun & V_{b1}, V_{b2} ⇒ 3

ⓒ Results ⇒ 4.

Swing

$V_{out,min} = (0.8 - V_{th}) + 0.15 = 0.474$

$V_{out,max} = V_{DD} - 2\times 0.133 = 1.534$.

maximum swing = 1.06V

(1)

(c) Mirror pole is at

$$= \frac{g_{m6}}{C_{gs5} + C_{gs6} + C_{db6} + C_{db1}} \approx \frac{g_{m6}}{2C_{gs5}}$$

(1)

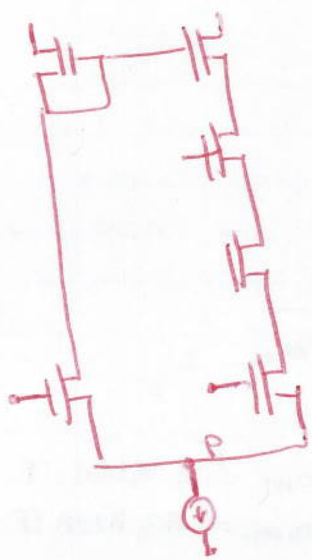
$$C_{ox} = \frac{\epsilon_{ox}}{t_{ox}} = 8.6\ fF/\mu m^2$$

$$C_{gs} \approx \frac{2}{3} C_{ox} WL = 31fF.$$

$$g_{m6} = \sqrt{2\times \mu_n C_{ox} \frac{W}{L} I} = 2.25mS.$$

mirror pole = 3.52×10^{10} rad/s.

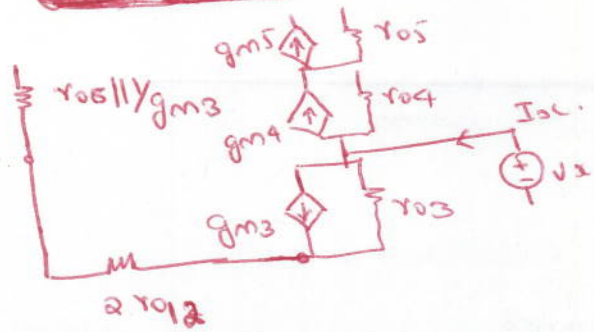
(d) Gain = Gm Rout



Assuming virtual ground at P

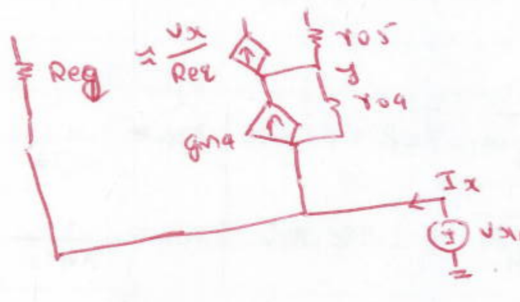
$$G_m = g_{m1,2} = \sqrt{2\times \mu_n C_{ox} \frac{W}{L} I_d}$$

$$\approx 2mS$$



$$\text{Req} \approx \left[2r_{o12} + r_{o6} \,\|\, 1/g_{m6}\right] g_{m3} r_{o3}$$
$$\approx 2r_{o12}\, g_{m3} r_{o3}.$$

=



At y.

$$\frac{V_x}{R_{eq}} + \frac{V_y}{r_{o5}} = g_{m4}(0 - V_y) + \frac{(V_x - V_y)}{r_{o4}}.$$

$$V_y\left(\frac{1}{r_{o5}} + \frac{1}{r_{o4}} + g_{m4}\right) = \frac{V_x}{r_{o4}} - \frac{V_x}{R_{eq}}$$

$$V_y g_{m4} \approx \frac{V_x}{r_{o4}}.$$

$$V_y = \frac{V_x}{g_{m4} r_{o4}}$$

$$I_x = \frac{2V_x}{R_{eq}} + \frac{V_y}{r_{o5}}$$

$$= \frac{V_x}{g_{m3} r_{o3} r_{o12}} + \frac{V_x}{g_{m4} r_{o4} r_{o5}}$$

$$R_{out} = g_{m3} r_{o3} r_{o12} \,\|\, g_{m4} r_{o4} r_{o5}$$

$$= 2m \cdot \left(\frac{1}{63\mu}\right)^2 \,\|\, 2.25m * \frac{1}{(58\mu)^2}$$

$$= 503k \,\|\, 668k \approx 287k \Rightarrow \text{Gain} \approx 560.$$

(1)

Ugb

Circuit has one dominat pole at o/p given by $\frac{1}{R_{out} C_L}$ rad/s. Assuming single pole roll off with this dominant pole.

$$UGB = g_m R_{out} \cdot \frac{1}{R_{out} C_L}$$

$$= \frac{g_m}{C_L} \approx \frac{2m}{1p}$$

(1)

$\approx$ 2G rad/s.