ANS1

Q1. (a), $V_{o(G_1)} = g_{m1} \cdot (\frac{1}{g_{m3}} // r_{o1}) \cdot g_{m4} \cdot (r_{o2} // r_{o4}) \cdot V_{G_1}$

$V_{o(G_2)} = g_{m2} \cdot (r_{o2} // r_{o4}) \cdot V_{G_2}$ Let $(r_{o2} // r_{o4}) = R_o$, $g_{m1} = g_{m2}$, $g_{m3} = g_{m4}$, $\frac{1}{g_{m3}} // r_{o1} \approx \frac{1}{g_{m3}}$

$V_{o(G_1)} - V_{o(G_2)} = g_{m1} \cdot (\frac{1}{g_{m3}} // r_{o1}) \cdot g_{m4} \cdot R_o V_{G_1} - g_{m1} R_o V_{G_2}$

$\approx g_{m1} R_o (V_{G_1} - V_{G_2})$

$A_v = g_m R_o$.

Q1

(b)

$V_{ICMR(max)} = V_{DD} - V_{OV5} - V_{OV1} - |V_{thp}|$

$V_{ICMR(min)} = V_{gs3} - V_{th1}$

$ICMR = V_{DD} - V_{OV5} - V_{OV1} - |V_{thp}| - V_{gs3} + V_{th1}$

ANS2

Q2. 假設每個 MOS $V_{OV} = 0.2$, $L = 1\mu$

$g_{m1} = \frac{2 \times 100\mu}{0.2} = 1m$, $g_{m3} = \frac{2 \times 100\mu}{0.2} = 1m$ $r_{o4} = \frac{1}{0.04 \cdot 100\mu} = 250k = r_{o2} = r_{o1}$

$\therefore \frac{1}{g_{m3}} // r_{o1} // r_{o3} = 1k // 100k // 250k \approx \frac{1}{g_{m3}}$

$\therefore A_v \approx g_{m1} \cdot (r_{o1} // r_{o4} // r_{o2}) = 1m \cdot 83.3k = 83.3$

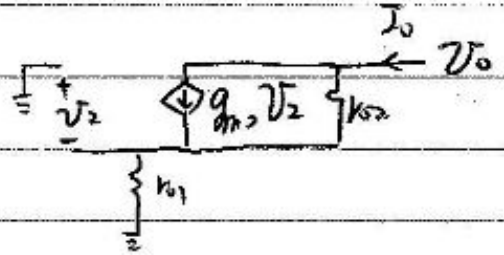
1b. $100\mu = \frac{1}{2} \cdot 50\mu \times \left(\frac{W}{L}\right)_9 \cdot 0.2^2 \Rightarrow \left(\frac{W}{L}\right)_{8,9} = \frac{100}{1}$, $\left(\frac{W}{L}\right)_{6,7} = \frac{200}{1}$

$100\mu = \frac{1}{2} \cdot 100 \cdot \left(\frac{W}{L}\right)_{10} \cdot 0.2^2 \Rightarrow \left(\frac{W}{L}\right)_{10} = \frac{50}{1}$, $\left(\frac{W}{L}\right)_5 = \frac{100}{1}$

$\left(\frac{W}{L}\right)_{1,2,3,4} = \frac{50}{1}$

ANS3

Q_3 : (a)



$$I_o = g_{m2}V_2 + \frac{V_o + V_2}{r_{o2}}$$

$$V_2 = -I_o r_{o1}$$

$$I_o = g_{m2}V_2 + \frac{V_o - I_o r_{o1}}{r_{o2}}$$

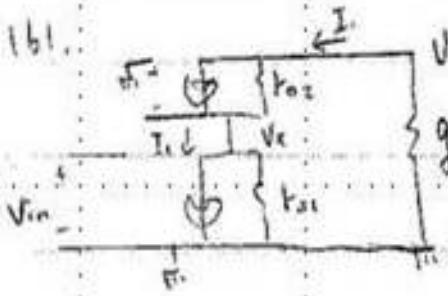
$R_{oN} = r_{o2} + r_{o1} + g_{m2} r_{o2} r_{o1}$ (不含 body effect) 含 body effect $= r_{o2} + r_{o1} + (g_{m2} + g_{mb2}) r_{o2} r_{o1}$

PMOS 的 $R_{op} = r_{o3} + r_{o4} + g_{m3} r_{o3} r_{o4}$ → 含 body effect $= r_{o3} + r_{o4} + (g_{m3} + g_{mb3}) r_{o3} r_{o4}$

$R_o = R_{oN} // R_{op}$

ANS3

(b)



$V_{gs_2} = -V_x$, $V_{gs_1} = V_{in}$

$$\begin{cases} (I_1 - g_{m_1} V_{in}) \cdot r_{o_1} = V_x \\ (V_o - V_x) = [I_1 - g_{m_2}(-V_x)]\, r_{o_2} \\ I_1 = \dfrac{-V_o}{R_p} \end{cases}$$

$V_o - V_x = \left(I_1 + g_{m_2}(I_1 - g_{m_1} V_{in})\, r_{o_1}\right) r_{o_2}$

$V_o = I_1 r_{o_2} + g_{m_2} r_{o_1} r_{o_2} I_1 - g_{m_1} g_{m_2} V_{in} r_{o_1} r_{o_2} + I_1 r_{o_1} - g_{m_1} V_{in} r_{o_1}$

$V_o = I_1 (r_{o_2} + g_{m_2} r_{o_1} r_{o_2} + r_{o_1}) - V_{in} (g_{m_1} g_{m_2} r_{o_1} r_{o_2} + g_{m_1} r_{o_1})$ Let $g_{m_2} r_{o_2} r_{o_1} = R_N$

$V_o = -\dfrac{R_N}{R_p} V_o - V_{in} g_{m_1} R_N$

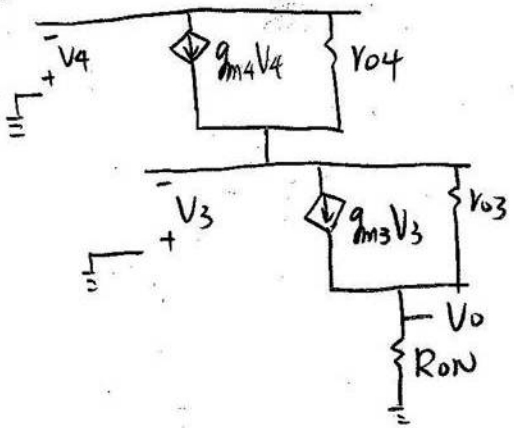
$V_o \left(\dfrac{R_p + R_N}{R_p}\right) = -V_{in} g_{m_1} R_N$

$A_V = -g_{m_1} \dfrac{R_p R_N}{R_p + R_N} = -g_{m_1} R_{out} = -g_{m_1} \left(g_{m_3} r_{o_3} r_{o_4} \,/\!/\, g_{m_2} r_{o_2} r_{o_1}\right)$

ANS3

Q3

(c)



$R_{ON} = g_{m2} r_{o2} r_{o1}$

$\frac{V_o}{R_{ON}} = -g_{m3} V_3 + \frac{-V_3 - V_o}{r_{o3}}$

$V_o r_{o3} = -g_{m3} R_{ON} r_{o3} V_3 - V_3 R_{ON} - V_o R_{ON}$

$V_3 = \frac{-V_o (r_{o3} + R_{ON})}{g_{m3} R_{ON} r_{o3} + R_{ON}} = -V_o A \qquad A = \frac{r_{o3} + R_{ON}}{g_{m3} R_{ON} r_{o3} + R_{ON}}$

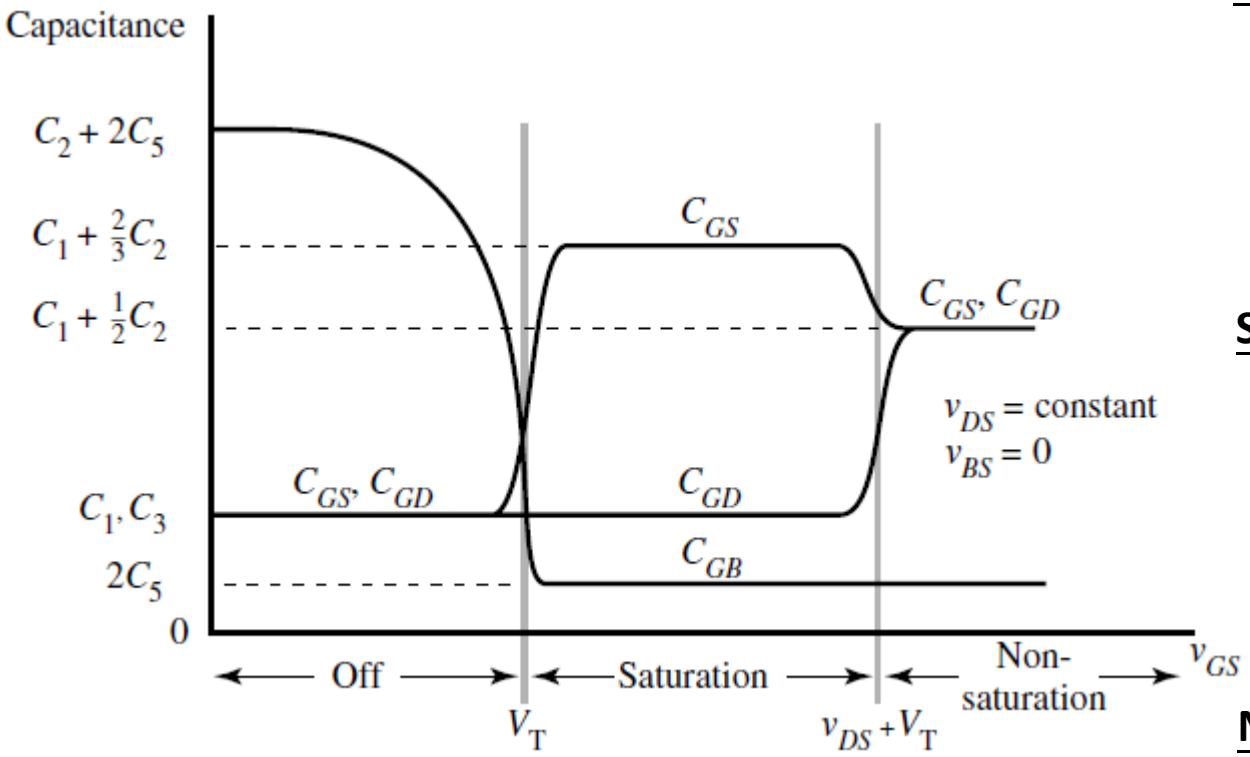
$\frac{V_o}{R_{ON}} = -g_{m4} V_{DD} + \frac{V_{DD} + V_3}{r_{o4}}$

$V_o r_{o4} = -g_{m4} R_{ON} r_{o4} V_{DD} + V_{DD} R_{ON} - A R_{ON} V_o$

$A_{vdd} = \frac{V_o}{V_{DD}} = \frac{1 - g_{m4} R_{ON} r_{o4} + R_{ON}}{r_{o4} + A R_{ON}} \approx -g_{m4} (g_{m2} r_{o2} r_{o1} \,//\, g_{m3} r_{o3} r_{o4})$

$PSRR = \frac{A_v}{A_{vdd}} = \frac{-g_{m1} (g_{m2} r_{o2} r_{o1} \,//\, g_{m3} r_{o3} r_{o4})}{-g_{m4} (g_{m2} r_{o2} r_{o1} \,//\, g_{m3} r_{o3} r_{o4})} = \frac{g_{m1}}{g_{m4}}$

ANS4



Off

$$C_{GB} = C_2 + 2C_5 = C_{ox}(W_{eff})(L_{eff}) + \text{CGBO}(L_{eff})$$

$$C_{GS} = C_1 \cong C_{ox}(\text{LD})(W_{eff}) = \text{CGSO}(W_{eff})$$

$$C_{GD} = C_3 \cong C_{ox}(\text{LD})(W_{eff}) = \text{CGDO}(W_{eff})$$

Saturation

$$C_{GB} = 2C_5 = \text{CGBO}\,(L_{eff})$$

$$C_{GS} = C_1 + \tfrac{2}{3}C_2 = C_{ox}(\text{LD} + 0.67L_{eff})(W_{eff})$$

$$= \text{CGSO}(W_{eff}) + 0.67C_{ox}(W_{eff})(L_{eff})$$

$$C_{GD} = C_3 \cong C_{ox}(\text{LD})(W_{eff}) = \text{CGDO}(W_{eff})$$

Nonsaturated

$$C_{GB} = 2C_5 = \text{CGBO}\,(L_{eff})$$

$$C_{GS} = C_1 + 0.5C_2 = C_{ox}(\text{LD} + 0.5L_{eff})(W_{eff})$$

$$= (\text{CGSO} + 0.5C_{ox}L_{eff})W_{eff}$$

$$C_{GD} = C_3 + 0.5C_2 = C_{ox}(\text{LD} + 0.5L_{eff})(W_{eff})$$

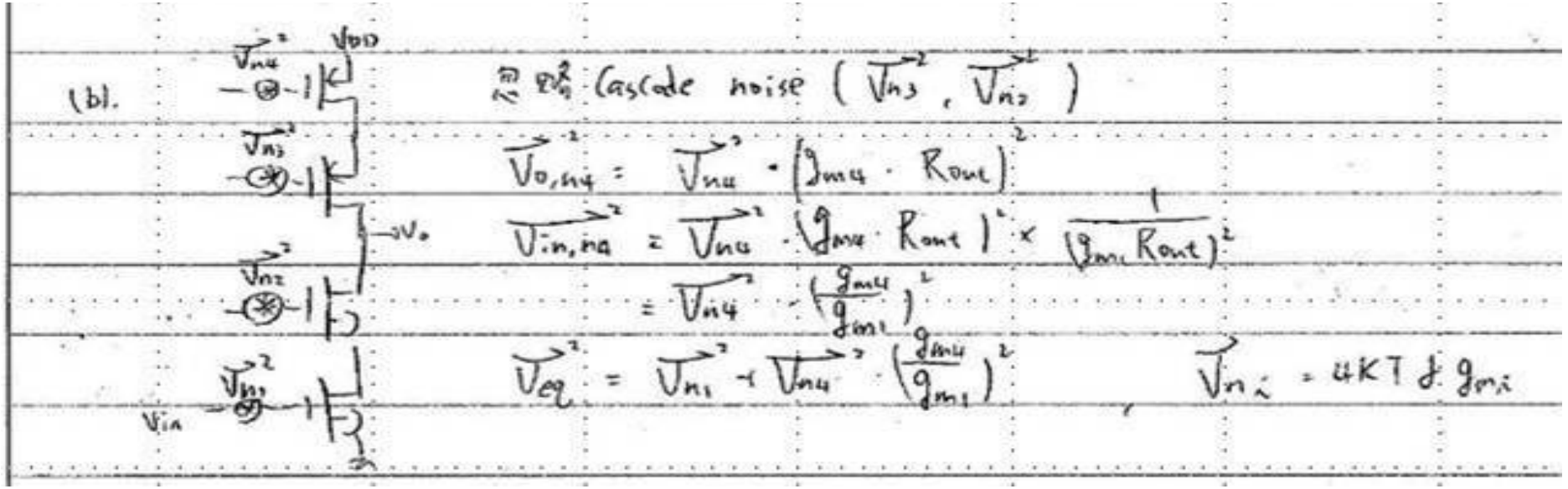
$$= (\text{CGDO} + 0.5C_{ox}L_{eff})W_{eff}$$

ANS5

(a)

$$4kT\gamma\frac{1}{g_{m1}}=\frac{K_f}{C_{ox}(WL)_1}\frac{1}{f_c}\Rightarrow f_c=\frac{K_f}{C_{ox}(WL)_1}\frac{g_{m1}}{4kT\gamma}$$

(b).



ANS6 (option 1)

C_L = 10 pF, I > 100 μA to meet SR > 10 V/μs
I < 330 μA to meet P_{diss} < 1 mW => **I = 200 μA**

$$\left(\frac{W}{L}\right)_3 = \frac{2I_{D3}}{K_p'\left(V_{DD} - Vout,max\right)^2} = 32$$

$$\left(\frac{W}{L}\right)_4 = \frac{1}{8}\left(\frac{W}{L}\right)_3 = 4$$

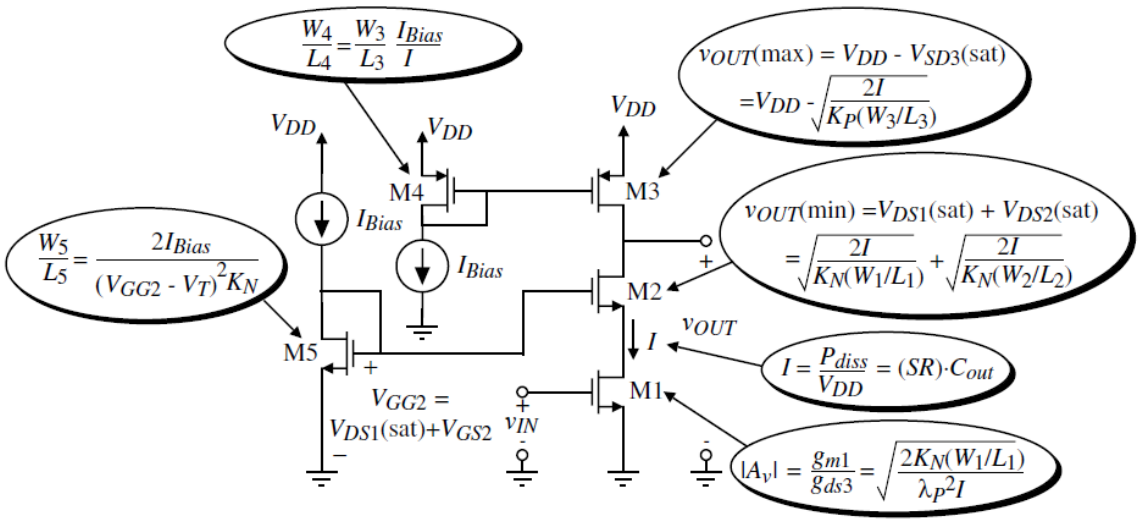
$$\left(\frac{W}{L}\right)_1 = \frac{2I_{D1}}{K_n' V_{ov1}^{\ 2}} = 16 \Rightarrow V_{ov1} = 0.5V$$

Using V_{ov2}=0.5V, V_{ov1}=0.5V

$$\left(\frac{W}{L}\right)_2 = \frac{2I_{D2}}{K_n' V_{ov2}^{\ 2}} = 16$$

$$V_{ov5} = V_{ov1} + V_{ov2} = 1V,\ I_{D5} = I_{D1}/4$$

$$\left(\frac{W}{L}\right)_5 = \frac{2I_{D5}}{K_n' V_{ov5}^{\ 2}} = 1$$



$$|A_v| = g_m r_o = \frac{2I}{V_{ov}}\frac{1}{\lambda I}$$

$$V_{ov} = \frac{2}{\lambda |A_v|}$$

ANS6 (option 2)

Q. $I = \frac{10}{1m} \cdot 10P = 0.1m$, $I_{tot} = \frac{1m}{3.3} = 0.3m$

$V_{OV3} = 0.5$, $0.1m = \frac{1}{2} \cdot 50u \left(\frac{W}{L}\right)_3 \cdot 0.5^2 \Rightarrow \left(\frac{W}{L}\right)_3 = \frac{16}{1}$, $r_{o3} = \frac{1}{0.04 \cdot 100n} = 250k$

$A_v = 100 = g_{m1} \cdot 250k$, $g_{m1} = 0.4m = \frac{2 \cdot 100n}{V_{OV1}}$, $V_{OV1} = 0.5$, $V_{OV2} = 1 - 0.5 = 0.5$.

$0.1m = \frac{1}{2} \cdot 100u \cdot \left(\frac{W}{L}\right)_{1,2} \cdot 0.5^2 \Rightarrow \left(\frac{W}{L}\right)_{1,2} = \frac{8}{1}$

$M_4 = M_3$ $(1=1)$.

$V_{gs5} = V_{OV1} + V_{gs2} = 2V_{OV1,2} + V_{th} \Rightarrow V_{OV5} = 2V_{OV1,2} \Rightarrow \left(\frac{W}{L}\right)_5 = \frac{1}{4}\left(\frac{W}{L}\right)_{1,2}$.

$\left(\frac{W}{L}\right)_{1,2} = \frac{8}{1}$, $\left(\frac{W}{L}\right)_{3,4} = \frac{16}{1}$, $\left(\frac{W}{L}\right)_5 = \frac{2}{1}$

$I_{total} = 0.1m \cdot 3$ (符合 P_{diss}).