1. M_2: $R_{out2} = \frac{1}{g_{m2}} // \frac{1}{g_{mb2}} // r_{o2}$.

$V_{in} \cdot \left(\frac{1}{r_\pi} + g_m + \frac{1}{r_o}\right) = i_{out}$

M_1: $R_{in} = r_\pi = \frac{V_A}{I_c}$ $\quad I_c = I_s\left(e^{\frac{qV_{BE}}{kT}} - 1\right)\left(1 + \frac{V_{CE}}{V_A}\right)$.

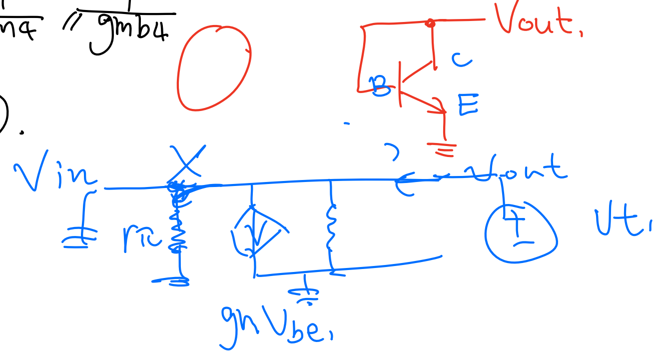
$R_{out1} = r_o // R_C = r_o // R_{out2} = r_o // \frac{1}{g_{m2}} // \frac{1}{g_{mb2}} // r_{o2}$ $\quad$ Rout.

$G_{m1} = -g_{m1}$. $\quad \therefore A_{v1} = -g_{m1}\left(r_o // \frac{1}{g_{m2}} // \frac{1}{g_{mb2}} // r_{o2}\right)$

$R_{in2} = \infty$. $\quad$ for M_3: $R_{out3} = r_{o3}$ $\quad \frac{V_{out}}{r_\pi} + g_m V_{out} = i_t$

for M_4: $R_{out4} = r_{o4} // r_{o3} // \frac{1}{g_{m4}} // \frac{1}{g_{mb4}}$

$G_{m2} = g_{m4}\left(r_{o4} // r_{o3} // \frac{1}{g_{m4}} // \frac{1}{g_{mb4}}\right)$.



2. (1) $V_{in} = 4 + 0.01\sin(\omega t)$.

$I_{D1} = I_{D2}$ $\quad V_{OUT}$.

$\frac{1}{2}\mu_p C_{ox}\left(\frac{W}{L_{eff}}\right)_1 (V_{SG} - V_{THP})^2 = \frac{1}{2}\mu_n C_{ox}\left(\frac{W}{L_{eff}}\right)_2 (V_{GS} - V_{THN})^2$.

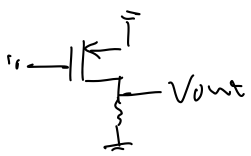
$\cancel{\frac{1}{2}} \cdot 3.835\times10^{-5} \cdot \frac{100}{2.18 - 2\cdot0.09}\left[(5-4) - 0.8\right]^2 = \cancel{\frac{1}{2}} \cdot 1.342\times10^{-4} \cdot \frac{1}{5.16 - 2\cdot0.08} \cdot (x - 0.7)^2$

$x = 2.39 = V_{OUT}$. $\quad I_D = 3.835\times10^{-5}$

Vout:

$R_{out2} = \frac{1}{g_{m2}} // r_{o2}$. $\quad g_{m2} = \frac{2I_D}{V_{GS} - V_{TH}} = \frac{2\cdot3.835}{2.39 - 0.7} = 4.538$.

$= \frac{1}{4.538} = \frac{1}{g_{m2}}$



$G_{m1} = -g_{m1}$

$R_{out1} = R_D // r_o = R_{out2} // r_{o1} = R_{out2}$.

$\therefore A_v = -g_{m1} \cdot R_{out2} = -\frac{g_{m1}}{g_{m2}}$. $\quad g_{m1} = \frac{2I_D}{V_{GS} - V_{TH}} = \frac{2\cdot3.835}{5 - 4 - 0.8} = 38.35$.

$A_v = -8.45$ $\quad \therefore V_{out} = -8.45 \cdot 0.01 \sin\omega t$.

$= -0.0845 \sin\omega t$.

(2) $I_{D1} + I_{D3} = I_{D2}$.

$2 \cdot \frac{1}{2}\mu_p C_{ox}\left(\frac{W}{L_{eff}}\right)_1 (V_{SG} - V_{THP})^2 = \frac{1}{2}\mu_n C_{ox}\left(\frac{W}{L_{eff}}\right)(V_{GS} - V_{THN})^2$.

$V_{OUT} = \boxed{3.09}$ $\quad I_{D1} = I_{D3} = 3.835\times10^{-5}$, $\quad I_{D2} = 7.67\times10^{-5}$

for M_3: $R_{out} = r_{o3}$. X.

Then for M_1: $G_{m1} = -g_{m1}$.

$R_{out1} = R_D // r_o \Rightarrow$

same as (1). $V_{out} = -8.45 \cdots$

3. (A) for M_5: $R_{out} = \frac{1}{g_{m5}} // \frac{1}{g_{mb5}} // r_{o5} = \frac{1}{g_{m5}} = R_D$.

for upper part: M_3: $R_{out3} = r_{o3}$. X.

M_2: $R_{out} = r_{o2}$ X.

$$G_m = -g_{m1} \frac{r_{o1}}{r_{o1} + r_{o2} // (\frac{1}{g_{m2}+g_{mb2}})} = \frac{r_{o1}}{r_{o1} + \frac{1}{g_{m2}}} = -g_{m1}.$$

$R_{out} = (r_{o1} // r_{o3}) \cdots // R_D = R_D = \frac{1}{g_{m5}}$.

$\therefore A_V = -g_{m1} \cdot \frac{1}{g_{m5}}$ ✓

(B). $A_{v1} = -g_m \cdot (R_D // r_o) = -g_{m1}(R_D // r_{o1})$ ✗

$A_{v2} = g_{m1} \cdot (r_{o1} // \frac{1}{g_{m1}} // R_D)$ ✗

(C). for M_2: $r_{o2} = R_{out} = \infty$.

part A: $G_{m1} = g_{m1}$. $R_{out1} = \cancel{r_{o1}} // \cancel{R_S} // \frac{1}{g_{m1}} // \cancel{\frac{1}{g_{mb1}}}$

$= \frac{1}{g_{m1}}$.

$A_{v1} = 1$.

second part: the same as (P1)

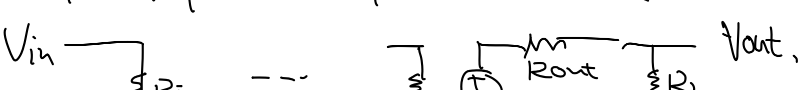
third part: $G_m = -g_{m5}$.

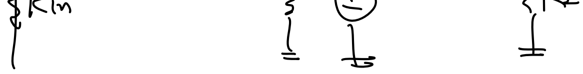
$R_{out} = R_D // r_{o5} = R_D$.

$\therefore A_{v3} = -g_{m5} \cdot R_D$.

forth part: $A_v = 1$. $R_{out} = \frac{1}{g_{m6}}$ $G_m = g_{m6}$.

$R_{out} = \cancel{r_{o6}} // R_S // \frac{1}{g_{m6}} // \cancel{\frac{1}{g_{mb6}}}$





$= R_L // \frac{1}{g_{m6}}$

$$\therefore A_V = \frac{1 \cdot 1 \cdot -g_{m5} \cdot R_D \cdot 1 \cdot \dfrac{\frac{1}{g_{m6}}}{\frac{1}{g_{m6}} + R_L} V_{in}}{V_{in}}$$

$$= -g_{m5} \cdot R_D \cdot \frac{1}{1 + R_L \cdot g_{m6}}$$

4. A: NMOS

$V_{GS} > V_{TH}$. $V_x > 0.7$.

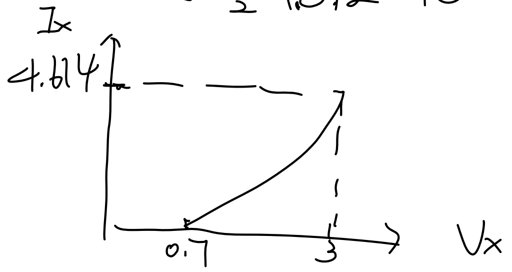
$\therefore V_x \in (0, 0.7)$ $I_x = 0$.

$V_{DS} < V_{GS} - V_{TH}$.

$x < x - 0.7$ ×. alway sat:

$$\therefore I_D = \frac{1}{2} \mu_n C_{ox} \left(\frac{W}{L_{eff}}\right) (V_{GS} - V_{TH})^2 (1 + \lambda V_{DS}).$$

$$= \frac{1}{2} \cdot 1.342 \times 10^{-4} \cdot \frac{20}{2} \cdot (x - 0.7)^2 (1 + 0.1 x).$$



B: NMOS.

$V_{GS} > V_{TH}$. alway √

$V_{DS} < V_{GS} - V_{TH}$.

$x < 1 - 0.7$.

$x \in (0, 0.3)$.

$$I_D = \mu_n C_{ox} \frac{W}{L_{eff}} \left[(V_{GS} - V_{TH}) V_{DS} - \frac{1}{2} V_{DS}^2 \right]$$

$$= 1.342 \times 10^{-4} \cdot \frac{20}{2} \left[(1 - 0.7) x - \frac{1}{2} x^2 \right]$$

$$= 6.039 \times 10^{-5}$$

$x \in [0.3, 3]$

$V_{DS} > \cdots$

$$I_D = \frac{1}{2} \mu_n C_{ox} \frac{W}{L_{eff}} (V_{GS} - V_{TH})^2 (1 + \lambda V_{DS})$$

$$= \frac{1}{2} \cdot 1.342 \times 10^{-4} \cdot \frac{20}{2} \cdot (1 - 0.7)^2 (1 + \lambda x).$$

$$= 6.22 \times 10^{-5} \sim 7.85 \times 10^{-5}$$

Upper = r_{o1}.

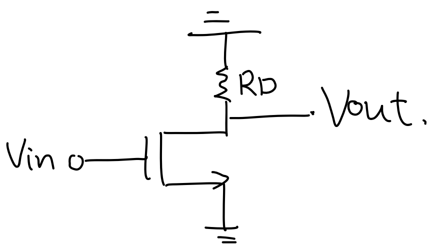
$R_D = R + r_{o1}$.

$A_{DM} = \dfrac{V_{out1} - V_{out2}}{V_d}$, $= V_{in1} - V_{in2}$.

$V_{out1} = -g_{m3}\left(r_{o3} \parallel (R + r_{o1})\right) \dfrac{V_d}{2}$.

$\therefore A_{DM} = -g_{m3}\left(r_{o3} \parallel (R + r_{o1})\right)$

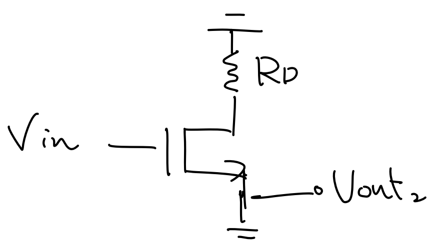
3(b) $A_V = \dfrac{V_{out1}}{V_{in}}$

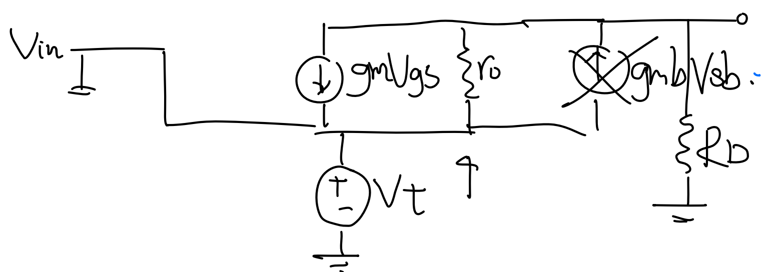


$G_m = -g_{m1}$

$R_{out} = R_D \parallel r_{o1}$.

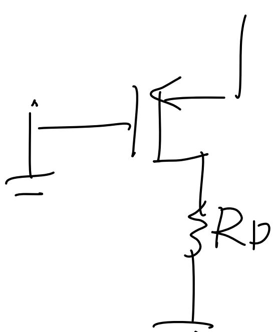
$\therefore A_v = -g_{m1}(R_D \parallel r_{o1})$.

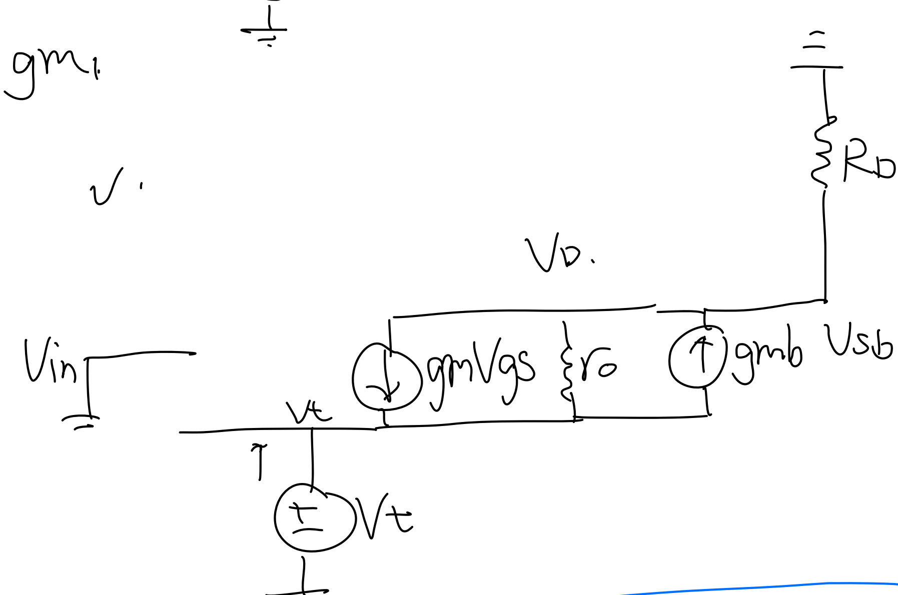




$G_{m,} = \dfrac{i_{out}}{V_{in}} = -g_{m1}$

$R_{out} = \dfrac{V_t}{i_t} =$ V.





$\frac{V_t}{i_t}$

$$\begin{cases} i_t = g_m(-V_t) + \frac{V_D - V_t}{r_o} + (g_{mb}V_t). \\ \cancel{g_m(-V_t) + \frac{V_D - V_t}{r_o} + \frac{V_D}{R_D} = g_{mb}V_t.} \end{cases}$$

$$\frac{V_D}{r_o} + \frac{V_D}{R_D} = g_m V_t + g_{mb}V_t + \frac{V_t}{r_o}.$$

$$V_D = i_t \cdot R_D.$$

$$i_t = g_m(-V_t) + \frac{i_t \cdot R_D - V_t}{r_o} + (-g_{mb}V_t)$$

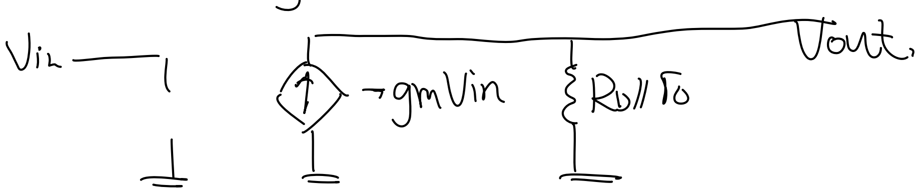
$$g_m V_t + \frac{V_t}{r_o} + g_{mb} \cdot V_t = i_t\left(\frac{R_D}{r_o} - 1\right)$$

$$R_{out.} = \frac{V_t}{i_t} = \frac{\frac{R_D}{r_o} - 1}{g_m + \frac{1}{r_o} + g_{mb}.}$$

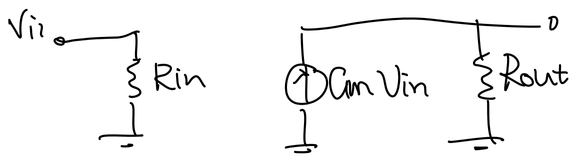
$$= \frac{R_D - r_o}{g_m r_o + 1 + g_{mb} r_o,}$$

$R_{out} = R_D // r_o.$

1) $G_m = -g_m$

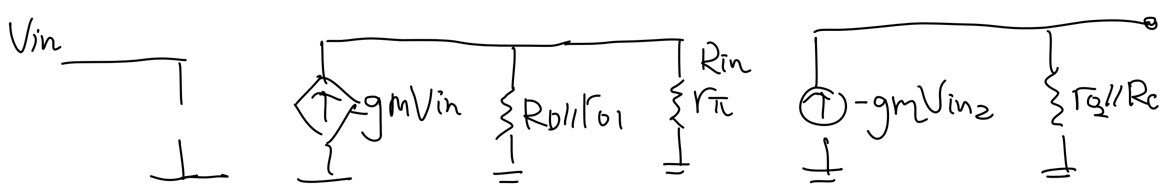


2)



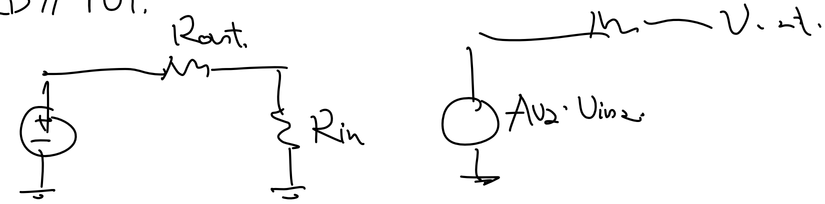
$R_{in} = r_\pi$ $\quad G_m = -g_m$ $\quad R_{out} = r_o // R_C.$

3)



$A_{v1} = -g_{m1} \cdot (R_D // r_{o1})$

$R_{out1} = R_D // r_{o1}.$



$$A_{v1}\cdot V_{in}\cdot \frac{R_{in}}{R_{out}+R_{in}}\cdot A_{v2} = V_{out}.$$

$$\frac{R_{out1}\,R_{in2}}{R_{out1}+R_{in2}}\cdot R_{out2}.$$

S3/2.

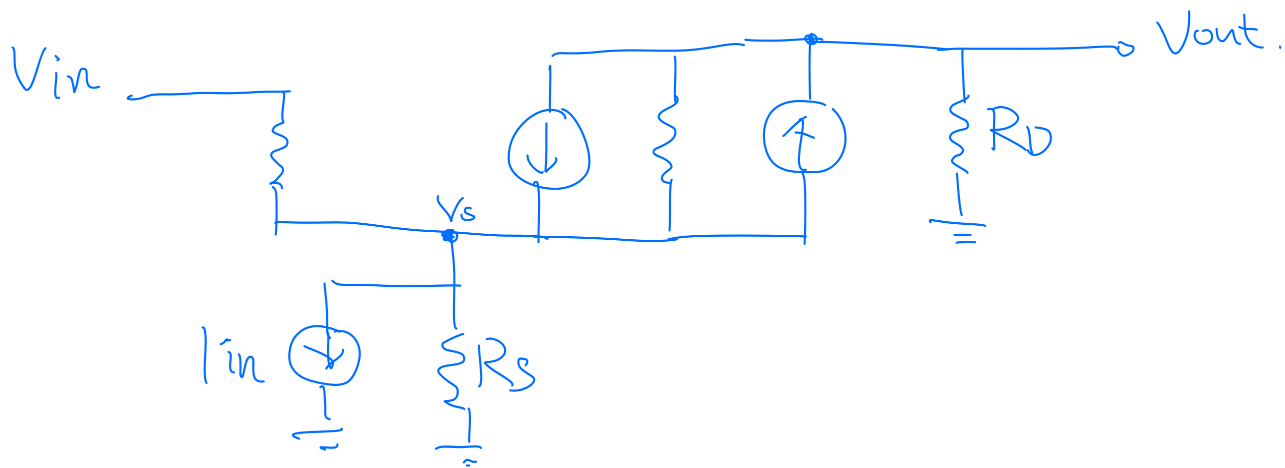
Rout.

R_o 右下 $= r_{o3}.$

$R_{out} = (g_{m2}+g_{mb2})\, r_{o2}\, r_{o3} + r_{o2} + r_{o3}.$

R 左上 $= r_{o1}.$

$$[(r_{o1} // R_2) + R_1] // [(g_{m2}+g_{mb2})\, r_{o2} r_{o3} + r_{o2} + r_{o3}] // R_D$$



$$\begin{cases} \dfrac{V_{out}}{R_D} - \cancel{g_{mb}(V_s - V_{out})} + \dfrac{V_{out}-V_s}{r_o} + g_m(\cancel{V_{out}} - V_s) = 0. \\ \cancel{g_{mb}(V_s - V_{out})} - g_m(\cancel{V_{out}} - V_s) + \dfrac{V_s - V_{out}}{r_o} + I_{in} + \dfrac{V_s}{R_s} = 0. \end{cases}$$

$$I: \quad \frac{V_{DD}-V_{OUT}}{R_D.} = \frac{1}{2}\mu_n C_{ox}\frac{W}{L_{eff}}(V_{GS}-V_{THN})^2(1+\lambda V_{DS}).$$

$$= \frac{V_S}{R_S} + I_{in}$$

$$\sqrt{\frac{\mu_n \frac{x}{2-2\cdot 0.08}}{\mu_p \frac{5}{2-2\cdot 0.09}}} = -6.$$

$$x = 51.99.$$

$P: V_{SD} > V_{SG} - |V_{THP}|$

$N: V_{DS} > V_{GS} - V_{TH}$

$5 - V_{OUT} > V_{DD} - V_{ov} - \ldots \; v.$

$V_{OUT} > V_{in} - V_{TH}$

$I_D = I_D$

$$\cancel{\tfrac{1}{2}} \mu_n \cancel{C_{ox}} \frac{W}{L_{eff}} \cdot (V_{GS} - V_{TH})^2 = \cancel{\tfrac{1}{2}} \mu_p \cancel{C_{ox}} \frac{W}{L_{eff}} (V_{SG} - V_{TH})^2$$

$$350 \cdot (V_{in} - 0.7)^2 \cdot \frac{52}{2-2\cdot 0.08} = 100 \cdot \frac{5}{2-2\cdot 0.09} \cdot (5 - V_{OUT} - 0.8)^2$$