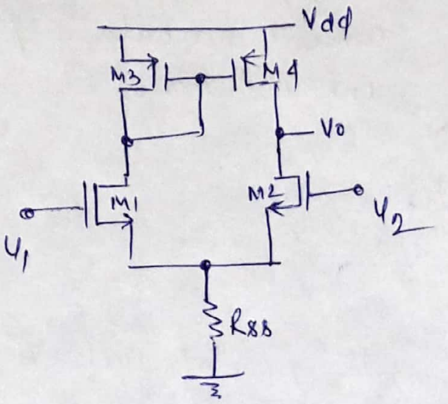
Quiz-1 - EE-204

Ques.



M1 & M2 are matched

so: $g_{m1} = g_{m2} = g_m$

$r_{o1} = r_{o2} = r_o$

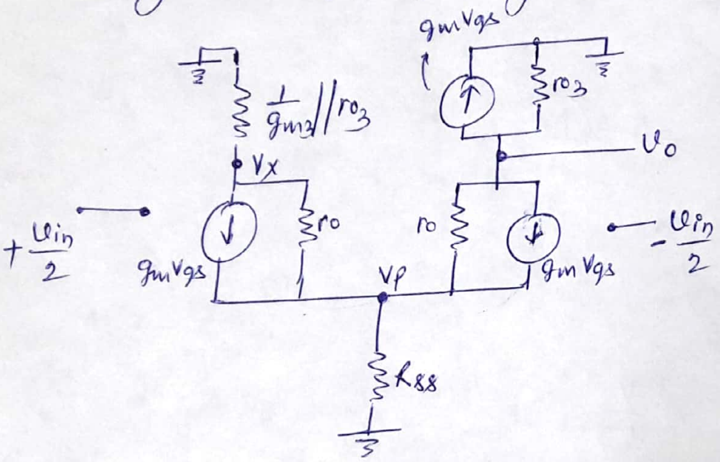
Similary M3 & M4 are matched

$g_{m3} = g_{m4} = g_{m3}$

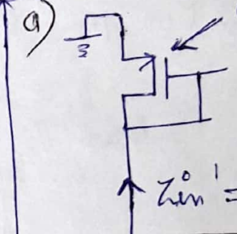
$r_{o3} = r_{o4} = r_{o3}$.

Part (a) Calculating $A_{DM} = \dfrac{V_o}{v_1 - v_2} = \dfrac{v_o}{v_{in}}$.

Since $\lambda \neq 0$, so we need to write KCL ~~and KVL~~ at every node for finding A_{DM}.



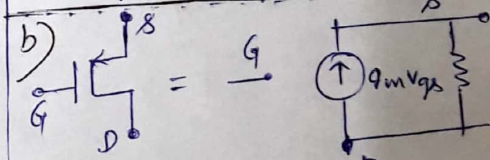
a)



diode connected load

$Z_{in}' = \frac{1}{g_{m3}} || r_{o3}$

b)



small signal equv. ckt for PMOS.

Writing KCL @ node V_P.

$$\Rightarrow \frac{V_P - V_x}{r_o} + \frac{V_P - V_o}{r_o} + \frac{V_P}{R_{ss}} = g_m\left(\frac{v_{in}}{2} - V_P\right) + g_m\left(-\frac{v_{in}}{2} - V_P\right)$$

$$V_P\left[\frac{2}{r_o} + \frac{1}{R_{ss}} + 2g_m\right] = \frac{V_x + V_o}{r_o}$$

$$\frac{V_P}{R_{ss}} = \frac{(V_x + V_o)}{[2R_{ss} + r_o + 2r_o R_{ss} g_m]}$$

$\Rightarrow$ this expression will give the amount of current flowing into Rss. i.e. $\left(\frac{V_P}{R_{ss}}\right)$

$$\frac{\underbrace{(V_x + V_o)}_{\text{Very small quantity (in few tens of millivolts)} \; \simeq 0}}{\underbrace{2R_{ss} + r_o + 2r_o R_{ss} g_m}_{\text{very large quantity (in orders of Mega)}}}$$

Hence, there is no current flowing into Rss. ~~Here~~ So, we can consider node $V_P \simeq 0$.

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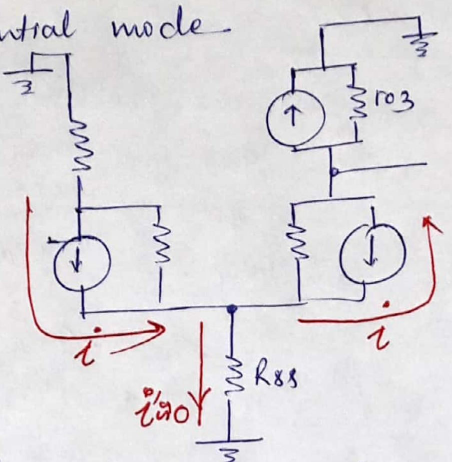
in differential mode



This fig. is to show how current avoids to flow into Rss branch.

Now, since $V_P \approx 0$, we can write KCL at node V_x & V_o.

$$\frac{V_x}{r_o} + g_m \frac{v_{in}}{2} + \frac{V_x}{\frac{1}{g_{m3}} || r_{o3}} = 0$$

★ $\frac{1}{g_{m3}} || r_{o3} \approx \frac{1}{g_{m3}}$

★ generally, $\frac{1}{g_{m3}}$ is much lower than r_{o3}

$$\frac{V_x}{r_o} + g_m \frac{v_{in}}{2} + V_x g_{m3} = 0$$

$$V_x = \frac{-g_m v_{in}/2}{\left[\frac{1}{r_o} + g_{m3}\right]} \quad \text{—— (1)}$$

KCL @ node V_o

$$\frac{V_o}{r_o} + g_m\left(-\frac{V_{in}}{2}\right) + g_m V_x + \frac{V_o}{r_{o3}} = 0$$

$$V_o\left[\frac{1}{r_o} + \frac{1}{r_{o3}}\right] = \frac{g_m v_{in}}{2} - g_{m3} V_x \quad \text{—— (2)}$$

putting value of eqn (1) into (2) and simplyification.

$$\boxed{\frac{v_o}{v_{in}} = \frac{g_m}{2} \frac{\left[1 + 2 r_o g_{m3}\right]}{\left[1 + r_o g_{m3}\right]} (r_o || r_{o3})}$$

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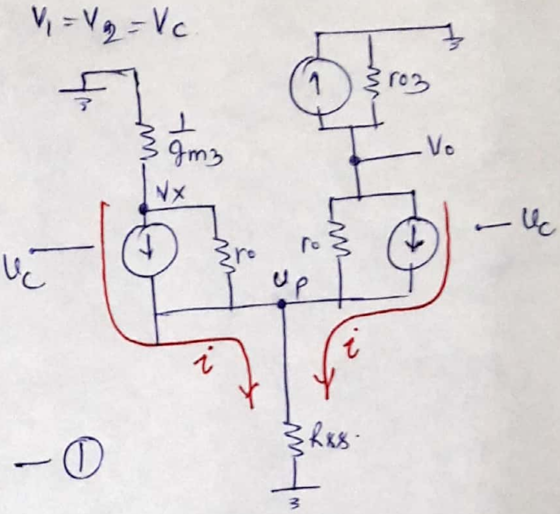
Part (b) Calculate $A_{CM} = \frac{v_o}{v_c}$

$V_1 = V_2 = V_c$



In this case, since common i/p v_c is applied, so the current would definately go into R_{ss}. Hence, v_p cannot be considered zero.

applying KCL @ node V_x.

$$\Rightarrow V_x g_{m3} + \frac{V_x - V_p}{r_o} + g_m(v_c - V_p) = 0 \quad -(1)$$

applying KCL @ node V_p.

$$\Rightarrow \frac{V_p}{R_{ss}} + \frac{V_p - V_x}{r_o} + \frac{V_p - V_o}{r_o} = 2g_m(V_c - V_p) \quad -(2)$$

applying KCL @ node V_o

$$\Rightarrow \frac{V_o - V_p}{r_o} + g_m(V_c - V_p) + \frac{V_o}{r_{o3}} + g_{m3}V_x = 0 \quad -(3)$$

putting $\frac{V_x - V_p}{r_o}$ from (1) and $\frac{V_o - V_p}{r_o}$ from (3) into eqn (2), we get, after simplification

$$\Rightarrow V_p = -2V_x g_{m3} R_{ss} - \frac{V_o R_{ss}}{r_{o3}} \quad -(4)$$

subtracting eqn (3) from eqn (1), we get

$$V_x = \frac{V_o r_o}{r_o || r_{o3}} \quad -(5)$$

simplifying eqn (1),

$$V_x\left(g_{m3} + \frac{1}{r_o}\right) + V_p\left(-g_m - \frac{1}{r_o}\right) = -g_m v_c$$

$$g_m V_c = V_p\left(\frac{1}{r_o} + g_m\right) - V_x\left(g_{m3} + \frac{1}{r_o}\right)$$

$$g_m V_c = V_p g_m - V_x\left(g_{m3} + \frac{1}{r_o}\right) \quad -(6) \quad \left[\frac{1}{r_o} + g_m \approx g_m\right]$$

putting the values of V_x & V_p from eqn (5) & (4) into eq (6). we get

$$\boxed{\frac{V_o}{V_c} = \frac{-g_m(r_o||r_{o3})}{(g_{m3}r_o + 1) + \frac{R_{ss}g_m(r_o||r_{o3})}{r_{o3}} + 2g_m g_{m3} R_{ss} r_o}}$$

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