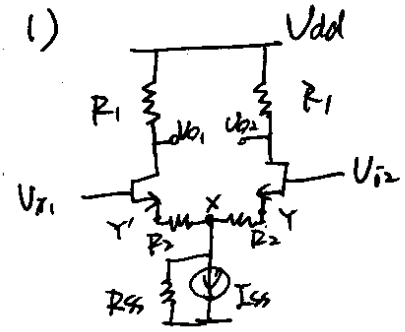
HW3 ee140 solutions Mike Chen

1)



$$V_{i1} = V_{ic} + \frac{V_{id}}{2}$$

$$V_{i2} = V_{ic} - \frac{V_{id}}{2}$$

$$V_{o1} = V_{oc} + \frac{V_{od}}{2}$$

$$V_{o2} = V_{oc} - \frac{V_{od}}{2}$$

a).

∵ $R_{ss} \gg R_2$, $\frac{1}{g_m}$ of M_1, M_2. ∴ all I_{ss} flows into diff. pair.

$$V_{Y'} = V_Y = V_{ic} - V_{to} - V_{dsat} = V_{ic} - V_{to} - \sqrt{\frac{I_{ss}/2}{\frac{1}{2}K'\cdot\frac{W}{L}}}$$

$$= V_{ic} - V_{to} - \sqrt{\frac{I_{ss}}{K'(\frac{W}{L})}} \cdot \ast$$

$$V_x = V_Y - \frac{I_{ss}}{2}R_2 = V_{ic} - V_{to} - \sqrt{\frac{I_{ss}}{K'(\frac{W}{L})}} - \frac{I_{ss}}{2}R_2 . \ast$$

$$V_{o1} = V_{o2} = V_{dd} - \frac{I_{ss}}{2}R_1 \quad \ast .$$

b). $V_{ds1,2} \geq V_{dsat}$.

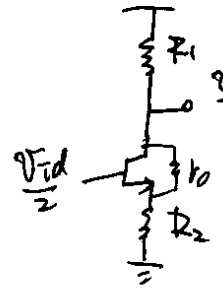
$$\therefore V_{dd} - \frac{I_{ss}}{2}R_1 - (V_{ic} - V_{dsat}) \geq V_{dsat}.$$

$$-V_{to}$$

$$\Rightarrow \quad V_{ic} \leq V_{dd} - \frac{I_{ss}}{2}R_1 + V_{to} \quad \ast .$$

c) Calculate differential gain $A_{dm} = V_{od}/V_{id}$.

Half ckt. model. X is virtual ground.



$$\frac{V_{od}}{2} = \frac{V_{id}}{2} \cdot \left(-\frac{g_m}{(+g_m R_2} [r_o(1+g_m R_2) \| R_1] \right)$$

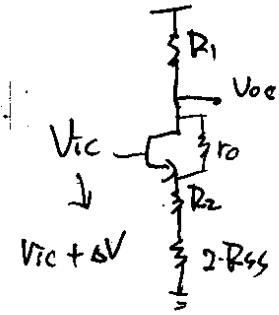
$\Rightarrow$ CS with source degeneration.

$$\therefore \frac{V_{od}}{V_{id}} = -\frac{\sqrt{K'\frac{W}{L} I_{SS}}}{1+\sqrt{K'\frac{W}{L} I_{SS}} \cdot R_2} \left(r_o(1+\sqrt{K'\frac{W}{L} I_{SS}} \cdot R_2) \| R_1 \right)$$

※

d) Common-mode gain $A_{cm} = V_{oc}/V_{ic}$.

Half ckt mode. Similar to c), except source degeneration more



$$\frac{V_{oc}}{V_{id}} = -\frac{\sqrt{K'\frac{W}{L} I_{SS}}}{1+\sqrt{K'\frac{W}{L} I_{SS}}(R_2+2R_{SS})} \left(r_o \left(1+\sqrt{K'\frac{W}{L} I_{SS}}(R_2+2R_{SS})\right) \| R_1 \right)$$

$= A_{cm}$. ※

Change in V_{ic} will cause the same voltage drop at outputs, therefore, only output common mode (V_{oc} change, not the differential mode (V_{od})!

$$\therefore V_{oc}' = V_{oc} + A_{cm} \cdot \Delta V = \frac{V_{o1}+V_{o2}}{2} - A_{cm} \cdot \Delta V$$

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