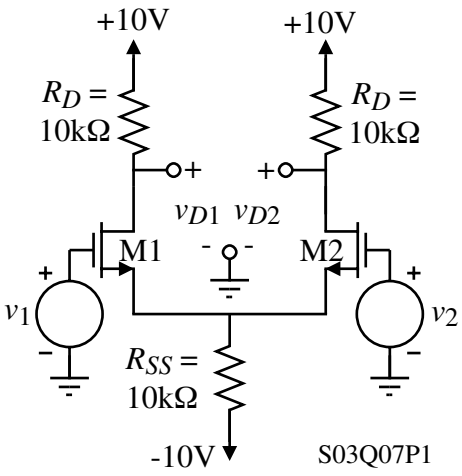
QUIZ NO. 7 - SOLUTION

(Average Score = 6.0/10 of those students taking the quiz)

Assume that M1 and M2 and the resistors R_D of the differential amplifier shown are matched. If K_n = 1mS, V_{TN} = 1V, and $\lambda_N = 0$, find (a.) the numerical value of I_{D1} and I_{D2} if $v_1 = v_2 = 0$. (b.) For this part of the problem assume that $I_{D1} = I_{D2} = 0.5$mA and find the numerical value of v_{D1}/v_{id} where $v_{id} = v_1 - v_2$. (c.) Continuing to assume that $I_{D1} = I_{D2} =$ 0.5mA, find the numerical value of v_{D1}/v_{ic} where $v_{ic} = v_1 = v_2$.



S03Q07P1

Solution

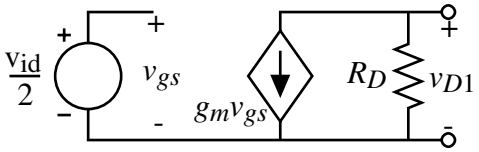
(a.) Assume that I_D is half of the current flowing through R_{SS}, we can write the following loop equation,

$$10 = V_{GS1} + 2I_{D1}R_{SS} = V_{GS1} + R_{SS}K_n(V_{GS1}-1)^2 = V_{GS1} + 10(V_{GS1}^2 - 2V_{GS1} + 1)$$

$$\therefore \quad 10V_{GS1}^2 - 19V_{GS1} = 0 \rightarrow V_{GS1} = 1.9\text{V} \rightarrow I_{D1} = I_{D2} = 0.5(0.9)^2 = \underline{0.405\text{mA}}$$

(b.) If $I_{D1} = I_{D2} = 0.5$mA, then $g_m = \sqrt{2K_n I_{D1}} = \sqrt{2 \cdot 1 \cdot 0.5}$ S = 1mS and $r_{ds} = \infty$.

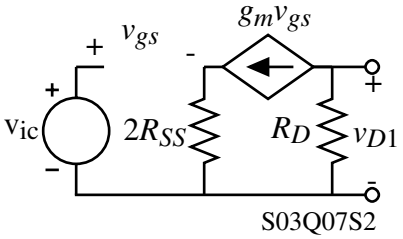
Small-signal model:



S03Q07S1

$$v_{D1}/v_{id} = \frac{-g_m R_D}{2} = \frac{-1 \cdot 10}{2} = \underline{-5\text{V/V}}$$

(c.) The small-signal model for this part is shown.



S03Q07S2

$$\frac{v_{D1}}{v_{id}} = \left(\frac{v_{D1}}{v_{gs}}\right)\left(\frac{v_{gs}}{v_{ic}}\right) = -g_m R_D \left(\frac{v_{gs}}{v_{ic}}\right)$$

$$v_{gs} = v_{ic} - v_s = v_{ic} - 2\,g_m R_{SS}\,v_{gs}$$

$$\therefore \quad \frac{v_{gs}}{v_{ic}} = \frac{1}{1 + 2\,g_m R_{SS}}$$

$$\frac{v_{D1}}{v_{id}} = \left(\frac{v_{D1}}{v_{gs}}\right)\left(\frac{v_{gs}}{v_{ic}}\right) = \frac{-g_m R_D}{1 + 2\,g_m R_{SS}} = \frac{-10}{1+20} = \underline{-0.476\text{V/V}}$$