Microelectronics Circuit Analysis and Design Homework(12nd)

Yuejin Xie U202210333

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11.35 The bias voltages of the diff-amp shown in Figure P11.35 are $V^+ = 5\text{V}$, $V^- = -5\text{V}$. The threshold voltage of each transistor is $V_{TN} = 0.4\text{V}$ and assume $\lambda = 0$. Let $K_{n3} = K_{n4} = 0.20$ mA/V^2. The drain currents can be written as and $I_{D1} = K_{n1}(V_{GS1} - V_{TN})^2$ and $I_{D2} = K_{n2}(V_{GS2} - V_{TN})^2$.(a) Design the circuit such that $I_Q = 0.25\text{mA}$ when $v_1 = v_2 = 0$ (b) If $v_1 = v_2 = 0$ and $K_{n1} = K_{n2} = 0.120\text{mA}/N^2$, find $v_{O1} - v_{O2}$ when (i)$R_{D1} = R_{D2} = 15\text{k}\Omega$ (ii) $R_{D1} = 14.5\text{k}\Omega, R_{D2} = 15.5\text{k}\Omega$.(c) Repeat part (b) for $K_{n1} = 0.125\text{mA}/\text{V}^2$ and $K_{n2} = 0.115\text{mA}/\text{V}^2$.

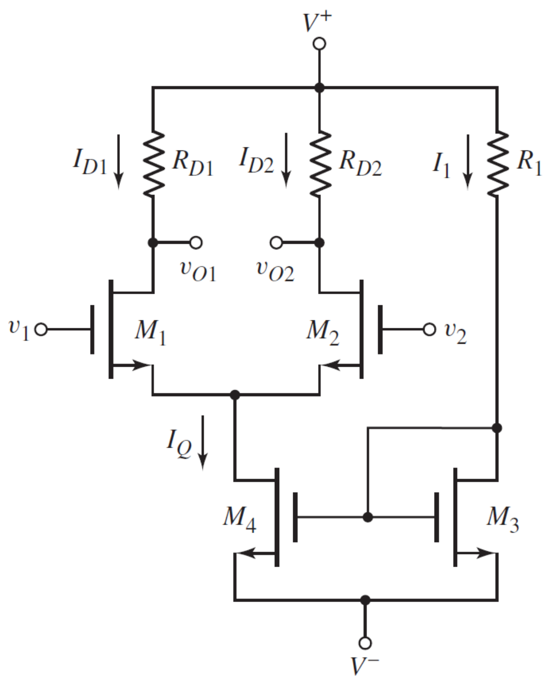

Figure 1: Problem 11.35

Solution:

(a)

$$I_Q = I_1 = K_{n3}(V_{GS3} - V_{TN})^2 \Rightarrow V_{GS3} = 1.518\text{V}$$

Therefore:

$$R_1 = \frac{V^+ - V^- + V_{GS3}}{I_1} = 33.9\text{k}\Omega$$

(b)

$$v_{O1} = V^+ - I_{D1}R_{D1}, v_{O2} = V^+ - I_{D2}R_{D2}, I_{D1} = I_{D2} = \frac{1}{2}I_Q$$

$$\Rightarrow v_{O1} - v_{O2} = I_{D2}R_{D2} - I_{D1}R_{D1}$$

(i)$R_{D1} = R_{D2} = 15\text{k}\Omega, v_{O1} - v_{O2} = 0$

(ii) $R_{D1} = 14.5\text{k}\Omega, R_{D2} = 15.5\text{k}\Omega, v_{O1} - v_{O2} = 0.125\text{V}$

(c)

$$\begin{cases} I_Q = I_{D1} + I_{D2} \\ I_{D1} = K_{n1}\left(V_{GS1} - V_{TN}\right)^2 \\ I_{D2} = K_{n2}\left(V_{GS2} - V_{TN}\right)^2 \end{cases} \Rightarrow \begin{cases} I_{D1} = 0.1302\text{mA} \\ I_{D2} = 0.1198\text{mA} \end{cases}$$

(i)$R_{D1} = R_{D2} = 15\text{k}\Omega, v_{O1} - v_{O2} = -0.156\text{V}$

(ii) $R_{D1} = 14.5\text{k}\Omega, R_{D2} = 15.5\text{k}\Omega, v_{O1} - v_{O2} = 0.031\text{V}$

11.47 Consider the circuit shown in Figure P11.47. Assume that $\lambda = 0$ for M_1 and M_2. Also assume an ideal current source I_Q. Derive the expression for the one-sided differential mode gains $A_{d1} = v_{o1}/v_d$ and $A_{d2} = v_{o2}/v_d$, and the two-sided differential-mode gain $A_d = (v_{o2} - v_{o1})/v_d$

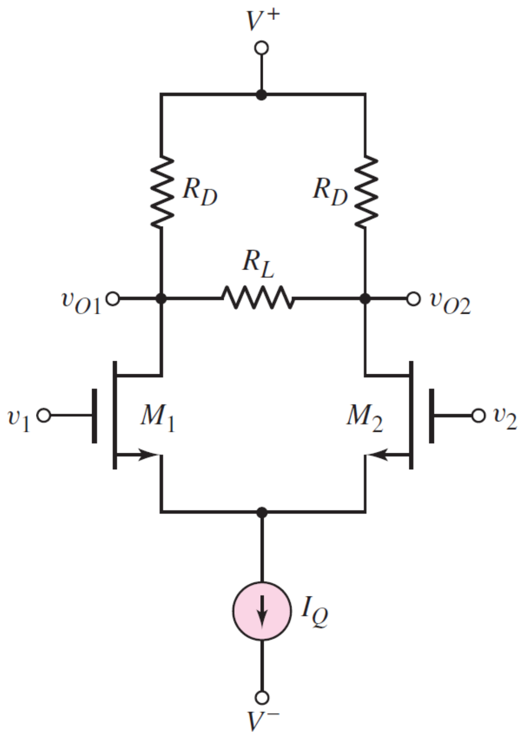

Figure 2: Problem 11.47

Solution:

$$A_{d1} = -\frac{1}{2}g_m(R_D||R_L), A_{d2} = \frac{1}{2}g_m(R_D||R_L), A_d = g_m(R_d||\frac{1}{2}R_L)$$

*D11.53 Figure P11.53 shows a two-stage cascade diff-amp with resistive loads. Power supply voltages of ±10 V are available. Assume transistor parameters of $V_{TN} = 1$V, $k'_n = 60$ μA/V^2, and $\lambda = 0$. Design the circuit such that the two-sided differential-mode voltage gain is $A_{d1} = (v_{o2} - v_{o1})/(v_1 - v_2) = 20$ for the first stage, and that the one-sided differential-mode voltage gain is $A_{d2} = v_{o3}/(v_{o2} - v_{o1}) = 30$ for the second stage. The circuit is to be designed such that the maximum differential-mode voltage swing is obtained in each stage.

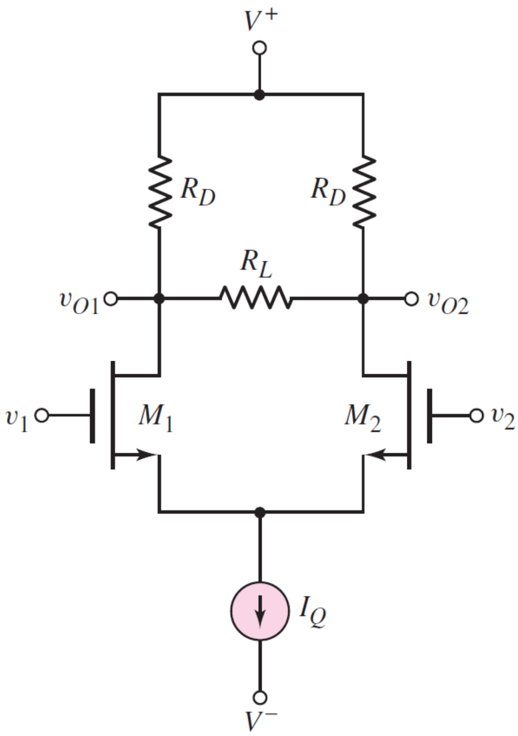

Figure 3: Problem *D11.53

Solution:

$$A_{d1} = \frac{v_{o2} - v_{o1}}{v_1 - v_2} = g_{m1}R_1 = \sqrt{2K_{n1}I_{Q1}} \cdot R_1 = 20, A_{d2} = \frac{v_{o3}}{v_{o2} - v_{o1}} = \frac{1}{2}g_{m3}R_2 = \frac{1}{2}\sqrt{2K_{n3}I_{Q2}} \cdot R_2 = 30$$

$$\frac{I_{Q1}R_1}{2} = 5V, \frac{I_{Q2}R_2}{2} = 2.5V$$

$$Let I_{Q1} = I_{Q2} = 0.1mA \Rightarrow R_1 = 100k\Omega, \quad R_2 = 50k\Omega$$

$$2\left(\frac{0.06}{2}\right)\left(\frac{W}{L}\right)_1(0.1) = \left(\frac{20}{100}\right)^2 \Rightarrow \left(\frac{W}{L}\right)_1 = \left(\frac{W}{L}\right)_2 = 6.67$$

$$2\left(\frac{0.060}{2}\right)\left(\frac{W}{L}\right)_3(0.1) = \left(\frac{2\,(30)}{50}\right)^2 \Rightarrow \left(\frac{W}{L}\right)_3 = \left(\frac{W}{L}\right)_4 = 240$$