Lab 10a.

1. Differential Amplifier with Resistive Load

(a) Theory

$V_{DD} = 10V$ Gain > 12 dB

$V_{in,cm(min)} = 3.5V$

$5V < V_{out,cm} < 7V$

(i) We need them in saturation region.

I in $M_3 = I_{tail}$

$$V_{in,cm(min)} = V_{GS_1} + V_{dsat\,3}$$

$$V_{in,cm(min)} = V_{TH_1} + \sqrt{\frac{I_{tail}}{K_{n_1}}} + \sqrt{\frac{2I_{tail}}{K_{n_3}}}$$

from given file

$\Rightarrow K_{n_1}$ = given = 106u $V_{TH_1} = 0.45$

$$3.5 = 0.45 + \sqrt{\frac{I_{tail}}{\frac{106u}{0.53m}}} + \sqrt{\frac{2I_{tail}}{\frac{106u}{0.53m}}}$$

$$\Rightarrow I_{tail} = 0.84591\ mA$$

(ii) $A_V = g_{m_1} * R_2 = \sqrt{I_{tail} K_{n_1}} * R_2$

Let $R_2 = 10k\Omega = 10^4\ \Omega$

$$\Rightarrow 20\log A_V = 20\log\left(\sqrt{0.84591 \times 10^{-3} \times \frac{0.53}{106} \times 10^{-3}} * 10^4\right)$$

$$= 16.515\ dB$$

(iii) $V_{out,cm} = V_{DD} - \frac{I_{tail} R_2}{2}$

$= 10 - \frac{0.84591 \times 10^{-3} \times 10^4}{2}$

$= 5.77045$

(iv) $I_{DQ} = \frac{1}{2} K_n (V_{GS} - V_{th})^2$

$\Rightarrow 0.84591 \times 10^{-3} = \frac{1}{2} \times 0.53 \times 10^{-3} (V_{GS} - 0.45)^2$

$\Rightarrow 0.58091 \times 10^{-3} = (V_{GS} - 0.45)^2$

$\Rightarrow 0.58091 = (V_{GS} - 0.45)^2$

$\Rightarrow 1.2121 = V_{GS}$ for M_4

$R_1 = \frac{V_{DD} - V_{GS}}{I_{DQ}} = \frac{10 - 1.2121}{0.84591 \times 10^{-3}} = 10.38 \text{ k}\Omega$

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2. Differential Amplifier with active load.

$V_{out,dc} = 6V \qquad V_{dd} = 10V$

$V_{out,dc} = V_{DD} - \sqrt{\frac{I_D}{K_{n3}}} - V_{tn3}$

$\Rightarrow \quad 6 = 10 - \sqrt{\frac{I_D}{K_{n3}}} - V_{tn}$

$\Rightarrow \quad I_D = 1.96\ mA$

$V_{in,cm(min)} = \sqrt{\frac{2I_D}{K_{n1,2}}} + \sqrt{\frac{I_D}{K_{n1}}} + V_{tn}$

$\Rightarrow \quad V_{in,cm(min)} = 5.0926V$

$V_{in,cm(min)} = V_{out,dc} + V_{tn} = 6 + 0.45 = 6.45$

$V_g = 3.17V \qquad R_D = \frac{V_{DD} - V_g}{I_D} = 3484.69\ \Omega$

$\Rightarrow \quad R_D = 3.48\ k\Omega$

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