1 Two-stage operational amplifier design

Using the following transistor parameters solve the problem 9.18 from the textbook (Razavi).

Transistor parameters: $V_{DD} = 3\, \text{V}$, $V_{TN} = |V_{TP}| = 0.7\, \text{V}$, $\lambda_n = 0.1\, \text{V}^{-1}$, $\lambda_p = 0.2\, \text{V}^{-1}$, $\mu_n C_{ox} = 134\, \mu\text{A}/\text{V}^2$, $\mu_p C_{ox} = 38\, \mu\text{A}/\text{V}^2$. The small signal transistor schematics includes $g_m$ and $r_0$ only.

9.18. In this problem, we design a two-stage op amp based on the topology shown in Fig. 9.68. Assume a power budget of $6\, \text{mW}$, a required output swing of $2.5\, \text{V}$, and $L_{eff} = 0.5\, \mu\text{m}$ for all devices.

![Figure 9.68](image)

(a) Allocating a current of $1\, \text{mA}$ to the output stage and roughly equal overdrive voltages to $M_5$ and $M_6$, determine $(W/L)_S$ and $(W/L)_X$. Note that the gate-source capacitance of $M_5$ is in the signal path whereas that of $M_6$ is not. Thus, $M_6$ can be quite larger than $M_5$.

(b) Calculate the small-signal gain of the output stage.

(c) With the remaining $1\, \text{mA}$ flowing through $M_7$, determine the aspect ratio of $M_1$ (and $M_4$) such that $V_{GS5} = V_{GS5}$. This is to guarantee that if $V_{in} = 0$ and hence $V_X = V_Y$, then $M_7$ carries the expected current.

(d) Calculate the aspect ratios of $M_1$ and $M_2$ such that the overall voltage gain of the op amp is equal to $500$. 

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