

PART 4 ASSUMING $V_{ov} = 200\text{mV}$

* V_{G4} CONTROLS THE DRAIN VOLTAGES OF M_1 & M_3 . V_{DS3} MUST BE GREATER THAN 200mV . HOWEVER, FOR STRONG INVERSION, V_{DS3} MUST BE GREATER THAN 700mV . THEREFORE, IF $V_{th} = 500\text{mV}$, V_{G4} MUST BE AT LEAST:

$$V_{G4} \geq V_{GS3} + V_{GS4}$$

$$\boxed{V_{G4} \geq 1.4\text{V}}$$

* IN PART 2. I ASSUMED THAT $V_{DS3} = 200\text{mV}$ WHICH WOULD ACTUALLY MEAN THAT M_1 WAS NOT IN STRONG INVERSION. WITH $V_{G4} = 1.4\text{V}$, $V_{DS3} = 700\text{mV}$.

FIGURE 7:

$$V_{G3} = 700\text{mV}, V_{G4} = 1.4\text{V}, I_{REF} = 1\text{mA}, V_{ov} = 200\text{mV}, R_L = 500\Omega$$

$$V_{R1} = 200\text{mV}$$

$$R_1 = V_{R1} / I_{REF}$$

$$\boxed{R_1 = 200\Omega}$$

$$V_{G4} = V_{OV1} + V_{GS4}$$

$$V_{G4} = 900\text{mV}$$

$$\underline{V_{DS1} = 200\text{mV}}$$

$$V_A = 2.5\text{V}$$

(FROM PREVIOUS PROBLEM)

$$\begin{aligned} V_{DS4} &= V_{DD} - V_{R1} - V_{DS3} \\ &= 1.8 - (1.01 I_{REF})(500\Omega) - 200\text{mV} \\ &= 1.095\text{V} \end{aligned}$$

$$\begin{aligned} I_{REF} &= \frac{\beta}{2} \left(\frac{W}{L} \right)_1 (V_{ov})^2 \left(1 + \frac{V_{DS1}}{V_A} \right) \\ \left(\frac{W}{L} \right)_1 &= 144.68 \end{aligned}$$

$$\begin{aligned} 1.01 I_{REF} &= \frac{\beta}{2} \left(\frac{W}{L} \right)_4 (V_{ov})^2 \left(1 + \frac{V_{DS4}}{V_A} \right) \\ \left(\frac{W}{L} \right)_4 &= 109.74 \end{aligned}$$

$$\boxed{W_1 = 36.17\mu\text{m}, L_1 = 0.25\mu\text{m}}$$

$$\boxed{W_4 = 27.45\mu\text{m}, L_4 = 0.25\mu\text{m}}$$

$$\begin{aligned} I_{REF} &= \frac{\beta}{2} \left(\frac{W}{L} \right)_2 (V_{ov})^2 \left(1 + \frac{V_{DS2}}{V_A} \right) \\ \left(\frac{W}{L} \right)_2 &= 130.21 \end{aligned}$$

$$\begin{aligned} V_{DS2} &= 700\text{mV} - 200\text{mV} \\ V_{DS2} &= 500\text{mV} \end{aligned}$$

$$\boxed{W_2 = 32.55\mu\text{m}, L_2 = 0.25\mu\text{m}}$$

$$\begin{aligned} 1.01 I_{REF} &= \frac{\beta}{2} \left(\frac{W}{L} \right)_3 (V_{ov})^2 \left(1 + \frac{V_{DS3}}{V_A} \right) \\ \left(\frac{W}{L} \right)_3 &= 146.12 \end{aligned}$$

$$\begin{aligned} V_{DS3} &= V_{G4} - V_{GS4} \\ V_{DS3} &= 200\text{mV} \end{aligned}$$

* M_1, M_2, M_3, M_4 ARE ALL IN STRONG INVERSION & SATURATION

$$\boxed{W_3 = 36.53\mu\text{m}, L_3 = 0.25\mu\text{m}}$$