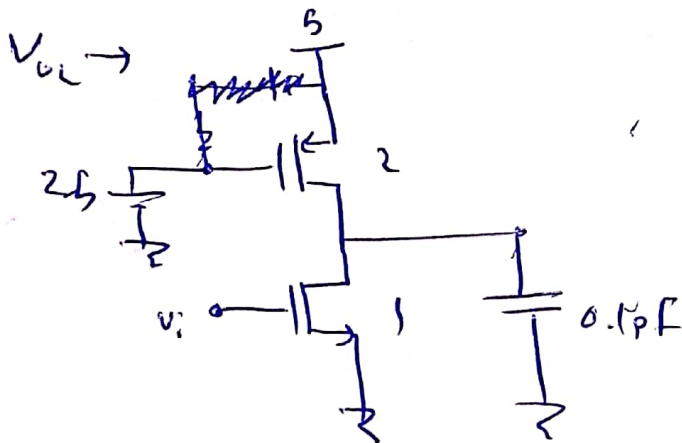


11

$$V_{th} = V_{tn} + \sqrt{\frac{\mu_p (W/L)_2}{\mu_n (W/L)_1}} \left(\frac{V_{DD}}{2} + V_{tp} \right)$$

$$V_{th} = 1 + \sqrt{\frac{K_p}{K_n}} (2.5 + (-1)) = 2.5$$



$$I_D = \frac{1}{2} \times 80 \times 10^{-6} \times ((2.5 - 5) - (-1))^2 = 90 \mu A$$

~~$$I_D = \frac{1}{2} \times 80 \times 10^{-6} \times (5 - 1)^2 = 640 \mu A$$~~

در حالت
برای، خروجی

$$V_{DS} < V_{GS} - V_{TH}$$

$$V_{OL} = I_D / I_{DS} = I_D \times \frac{1}{\mu_n C_{ox} (W/L) (V_{DD} - V_{th})} = 0.281 V$$

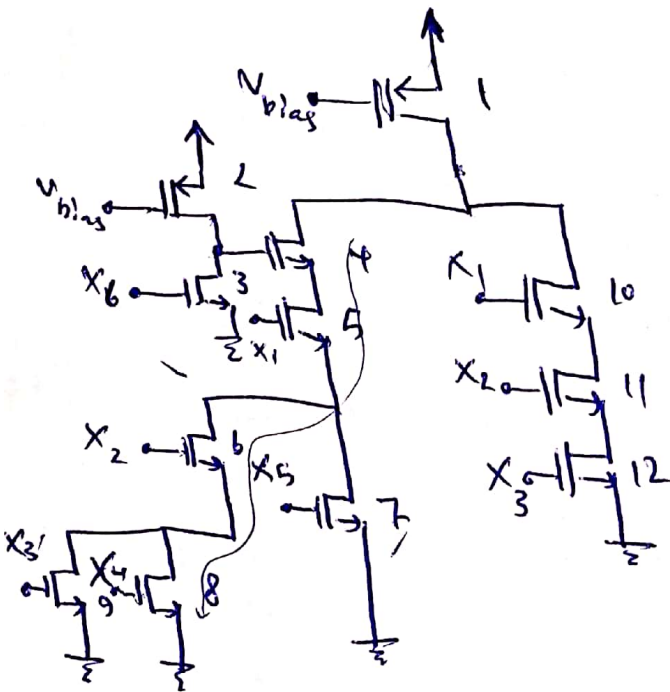
$$t_{PLH} = \frac{C_L}{I_D} \Delta V_{out} = \frac{C_L \times 3.5}{90 \times 10^{-6}} = \frac{0.1 \times 3.5 \times 10^{-12}}{90 \times 10^{-6}} = 3.89 ns$$

$$t_{PHL} \rightarrow R_{eq} = \frac{(V_{DD} - V_{th}) = V_{DS}}{\frac{\mu_n C_{ox} W/L}{C_L} (V_{DD} - V_{th})^2} = 44.4 k\Omega$$

$$t_{PHL} = 5.34 ns$$

2

$$F = X_1(X_2(X_3 + X_4) + X_5)X_6' + X_1X_2X_3$$



$$(W/L)_{eq} = \frac{1}{2} (W/L)_P$$

$$W/L_{eq} = W/L_P$$

$$(W/L)_2 = 5 \mu m / 0.8 \mu m$$

$$(W/L)_1 = 5 \mu m / 0.8 \mu m$$

$$(W/L)_i = \frac{n_i}{2} (W/L)_P$$

	$W (\mu m)$	$L (\mu m)$
1	5	0.8
2	5	0.8
3	2.5	0.8
4	5	0.8
5	5	0.8
6	5	0.8
7	7.5	0.8
8	5	0.8
9	5	0.8
10	7.5	0.8
11	7.5	0.8
12	7.5	0.8

3

$$V_{OH} = 3.3$$

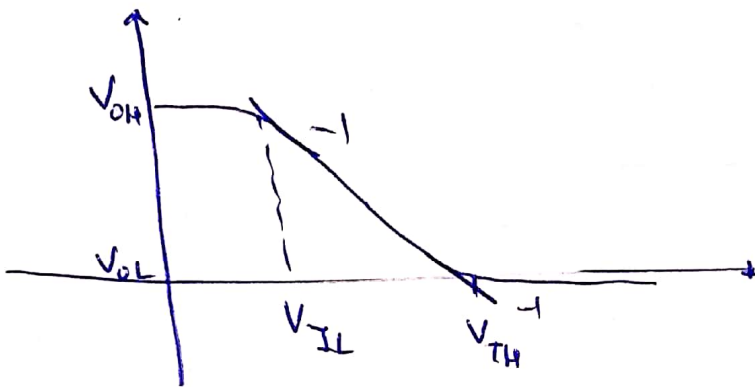
$$V_{OL} = 0$$

$$V_{IH} \rightarrow$$

$$\frac{1}{2} K_n (2(V_{AS} - V_{th})V_{DS} - V_{DS}^2) = \frac{1}{2} K_p (V_{AS} - V_{tp})^2$$

$$\frac{1}{2} K_n (2(V_{in} - V_{th})V_{out} - V_{out}^2) = \frac{1}{2} K_p ((V_{in} - V_{DD}) - V_{tp})^2$$

$$\frac{1}{2} K_n (2V_{out} + 2(V_{in} - V_{th}) \frac{dV_{out}}{dV_{in}} - 2V_{out} \frac{dV_{out}}{dV_{in}}) = \frac{1}{2} K_p (V_{in} - V_{DD} - V_{tp})$$



~~Vout~~

$$V_{IH} = 1.2$$

$$V_{IL} = 1.17$$

$$\frac{1}{2} K_p (2(V_{in} - V_{DD} - V_{tp})(V_{out} - V_{DD}) - (V_{out} - V_{DD})^2) = \frac{1}{2} K_n (V_{in} - V_{th})^2$$

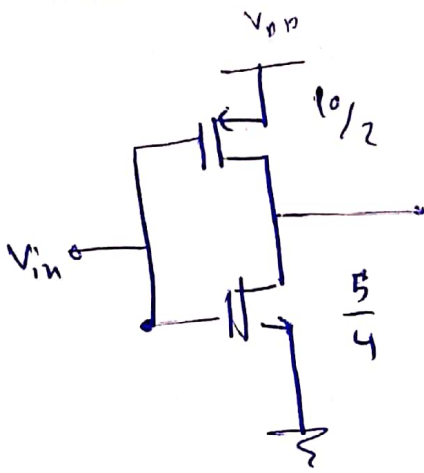
$$\frac{1}{2} K_p (2(V_{out} - V_{DD}) + 2(V_{in} - V_{DD} - V_{tp}) \frac{dV_{out}}{dV_{in}} - 2(V_{out} - V_{DD}) \frac{dV_{out}}{dV_{in}}) = K_n (V_{in} - V_{th})$$

V_{in}

$$NM_H = 3.3 - 1.2 = 2.1$$

$$NM_L = 1.17 - 0 = 1.17$$

4



$$V_{D1} = V_{G1} = V_{D2} = V_{G2}$$

$$V_{SD1} = V_{SG1} \rightarrow V_{SD1} > V_{SG1} - V_{thp}$$

$$V_{DS2} = V_{GS2}$$

$$V_{DS2} > V_{GS2} - V_{thn}$$

$$I_{D1} = I_{D2}$$

$$\frac{\mu_p C_{ox}}{2} [V_{SG1} - |V_{thp}|]^2 = \frac{\mu_n C_{ox}}{2} [V_{GS2} - V_{thn}]^2$$

$$V_{G2} = V_{thn} \approx 1.32$$