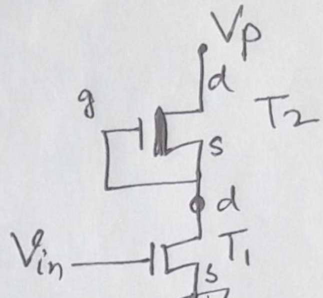
# Noise Margin (NMOS inverter with Depletion load)




when

$\boxed{V_{IL}}$

$T_1$ (enhancement) in $Sat^n$
$T_2$ (depletion) in Resistive

$$\cancel{\frac{\epsilon\mu_N}{D}} \cdot \left(\frac{W_E}{L_E}\right) \frac{1}{2} (V_{gs} - V_t)^2 = \cancel{\frac{\epsilon\mu_N}{D}} \cdot \left(\frac{W_D}{L_D}\right) \cdot \left[(V_{gs_D} - V_{tD}) V_{ds_D} - \frac{V_{ds_D}^2}{2}\right]$$

$25 \approx 30$ , $\left(\frac{W_E}{L_E}\right) / \left(\frac{W_D}{L_D}\right) = K$

$$\Rightarrow \frac{1}{2} K (v_i - V_t)^2 = (0 - V_{tD}) \cdot (V_P - V_o) - \frac{1}{2}(V_P - V_o)^2 = 0$$

$$\Rightarrow (V_P - V_o)^2 + 2V_{tD}(V_P - V_o) + K(V_i - V_t)^2 = 0$$

$$\therefore V_P - V_o = \frac{-2V_{tD} \pm \sqrt{4V_{tD}^2 - 4K(v_i - V_t)^2}}{2 \cdot 1}$$

$$= -V_{tD} \pm \sqrt{V_{tD}^2 - K(V_i - V_t)^2}$$

$$\therefore v_o = V_P + V_{tD} \pm \sqrt{V_{tD}^2 - K(V_i - V_t)^2}$$

Differentiating w.r.t. $v_i$, we get

$$\frac{dv_o}{dv_i} = 0 \pm \frac{1}{2} \cdot \frac{1 \cdot (-2K) \cdot (v_i - V_t)}{\sqrt{V_{tD}^2 - K(v_i - V_t)^2}}$$

$$\Rightarrow -1 = \pm \frac{K(V_i - V_t)}{\sqrt{V_{tD}^2 - K(v_i - V_t)^2}}$$

$$\Rightarrow V_{tD}^2 - K(V_i - V_t)^2 = K^2(V_i - V_t)^2$$

$$\therefore (K^2+K)(V_i - V_t)^2 = V_{tD}^2$$

$$\Rightarrow V_i - V_t = \frac{V_{tD}}{\sqrt{K^2+K}}$$

$$\therefore V_i = \boxed{V_t + \frac{V_{tD}}{\sqrt{K^2+K}} = V_{IL}}$$

$V_{tD} = 4$, $K = 6$, $V_{out} = 0.3$

$$V_{IL} = 1 + \frac{4}{\sqrt{6^2+6}} = 1 + \frac{4}{\sqrt{42}} = 1.617$$

$$\therefore NM(0) = 1.617 - 0.3$$

$$\boxed{NM(0) = 1.317 \text{ volt}}$$

$$\boxed{V_{OH} = V_t + \frac{2V_{tD}}{\sqrt{3K}}}$$