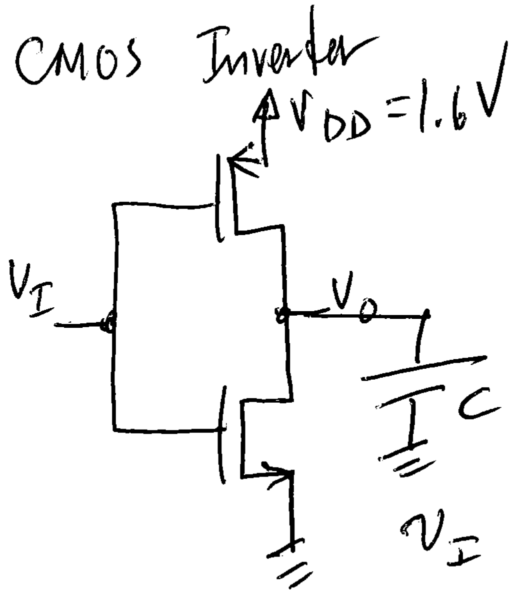
Notes on Switching Calculation Example

CMOS Inverter

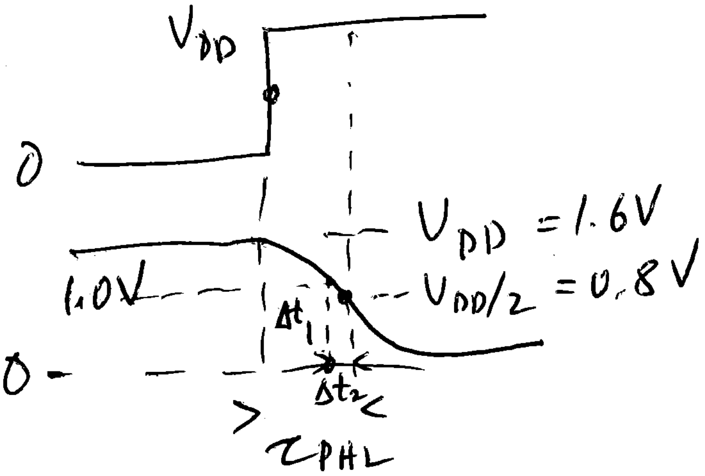


$K_n = K_p = 200\mu A/V^2$

$V_{TN} = -V_{TP} = 0.4V$

$\alpha = 0.2 \quad \lambda = 0.1 \quad C = 10pF$

Calculate τ_{PHL}



@ $t=0^+$

$V_I = 1.6V$

$V_O = 1.6V$

PMOS off, NMOS $V_{GS}=1.6V$, $V_{DS}=1.6V \Rightarrow$ saturat

$$i_{DS} = \frac{K_n}{2(1+\alpha)}(V_{GS}-V_{TN})^2 \wedge [1+\lambda(V_{DS}-V_{Dsat})] = \underbrace{\frac{200\mu A/V^2}{2(1.2)}(1.6V-0.4V)^2}_{120\mu A}\underbrace{[1+0.1}_{1.06}$$

$= 127\mu A$

NMOS saturated until $V_{DS} = V_{Dsat} = \frac{V_{GS}-V_T}{1+\alpha} = \frac{1.6-0.4}{1.2} = 1.0V$

When $V_O = V_{Dsat}$, $i_{DS} = 120\mu A$

When $V_O = V_{DD}/2 = 0.8V$ NMOS in linear/triode region ($V_{DS} \le V_{D}$

$$i_{DS} = K_n\left(V_{GS}-V_{TN}-(1+\alpha)\frac{V_{DS}}{2}\right)V_{DS} = 200\frac{\mu A}{V^2}\left(1.6-0.4-\frac{(1.2)(0.8)}{2}\right)(0.8)$$

$= 115.2\mu A$

$\Delta t_1 \quad V_o: 1.6V \Rightarrow 1.0V$

$\Delta t_2 \quad V_o: 1.0V \Rightarrow 0.8V$

$\tau_{PHL} = \Delta t_1 + \Delta t_2$

$$\Delta t_1 = \frac{C\Delta V_1}{I_{avg}^1} = \frac{(10\times10^{-12}F)(1.6V-1.0V)}{\frac{1}{2}(127.2\mu A + 120\mu A)} = \cancel{4}48.5\times10^{-9}s$$

$$= 48.5ns$$

$$\Delta t_2 = \frac{C\Delta V_2}{I_{avg}^2} = \frac{(10\times10^{-12}F)(1.0V-0.8V)}{\frac{1}{2}(120\mu A + 115.2\mu A)} = 17\ ns$$

$\underline{\tau_{PHL} = 65.5ns}$