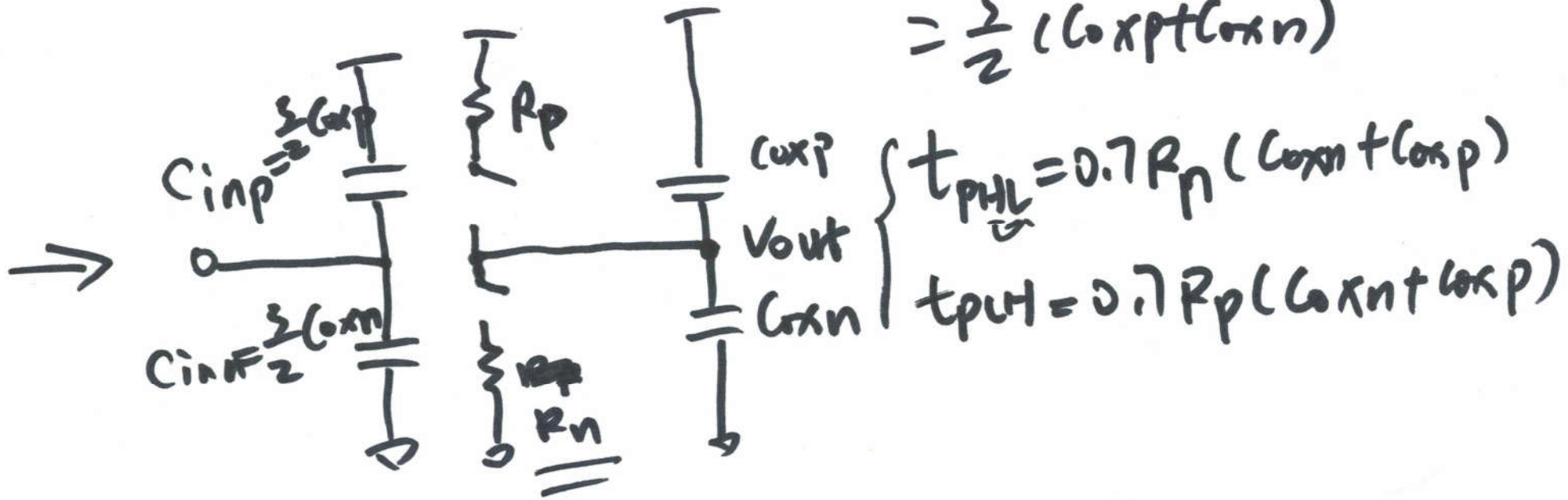
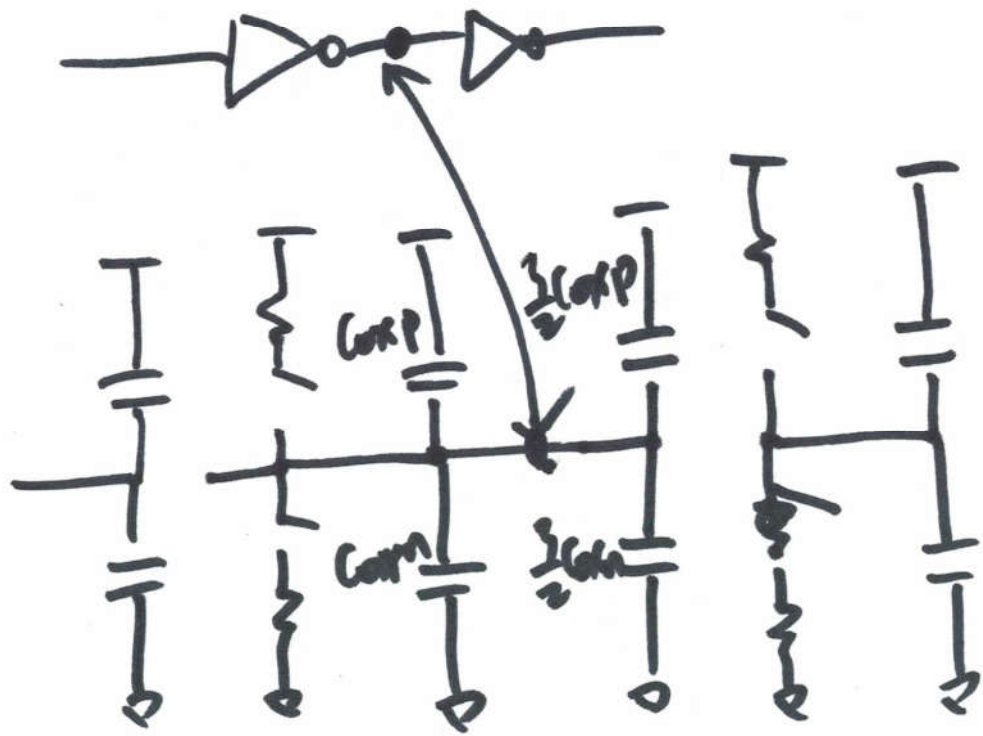


$$C_{in} = C_{inn} + C_{inp}$$

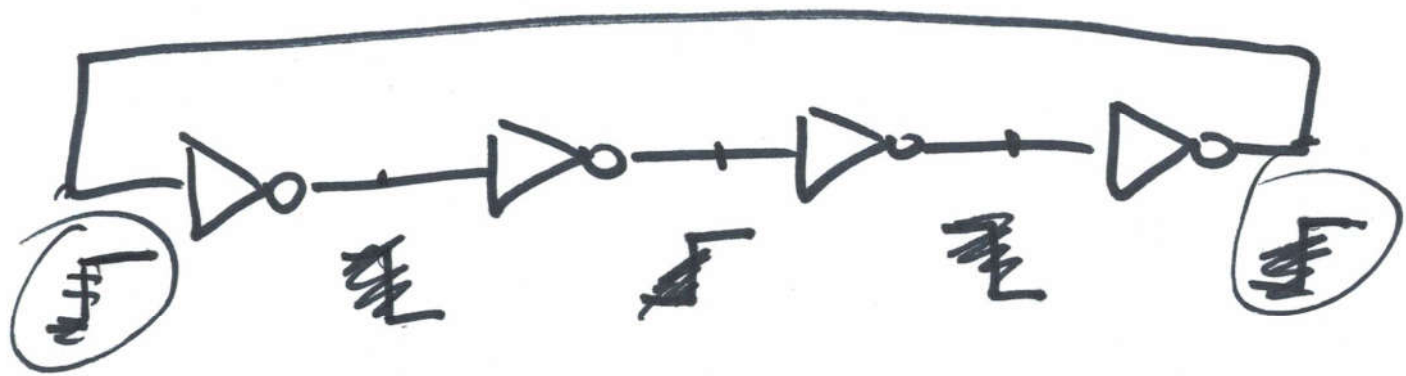
$$= \frac{3}{2} C_{oxp} + \frac{3}{2} C_{oxn}$$

$$= \frac{3}{2} (C_{oxp} + C_{oxn})$$

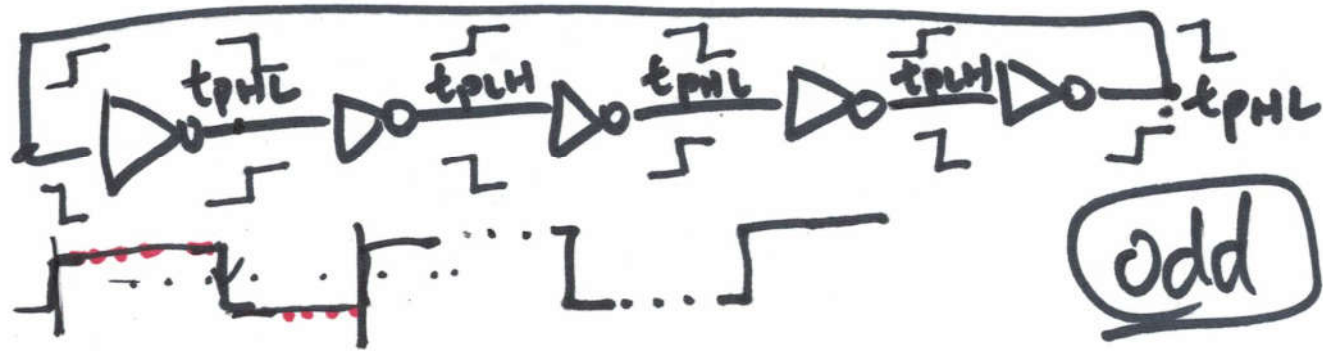




$$t_{tot} = \frac{\sum}{2} (C_{oxp} + C_{oxn})$$



Sum



$$T = 5 t_{pHL} + 5 t_{pLH}$$

$$f_{osc} = \frac{1}{T} = \frac{1}{5(t_{pHL} + t_{pLH})} = \frac{1}{N(t_{pHL} + t_{pLH})}$$

Example: f_{osc} of a 11-stage ring oscillator

$$\text{NMOS: } \begin{cases} R_n = 3.4 \text{K} \\ C_{oxn} = 0.625 \text{fF} \end{cases}$$

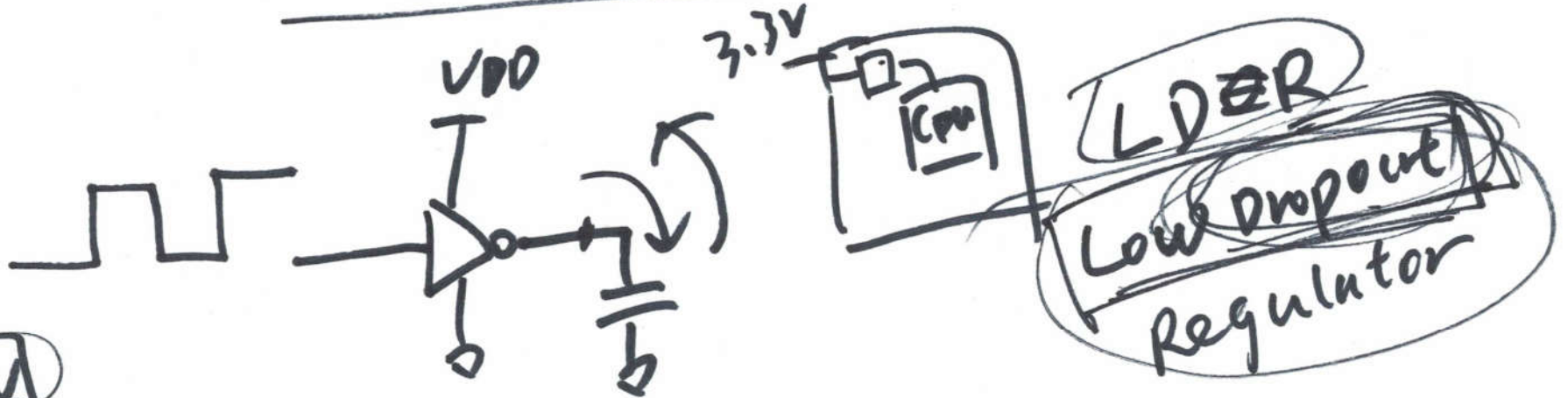
$$\begin{cases} R_p = 3.4 \text{K} \\ C_{oxp} = 1.25 \text{fF} \end{cases}$$

$$f_{osc} = \frac{1}{n(t_{pHL} + t_{pLH})}$$

$$t_{pHL} = 0.7 R_n (C_{oxn} + C_{xp})$$

$$t_{pLH} = 0.7 R_p (C_{oxn} + C_{xp})$$

Dynamic Power Dissipation

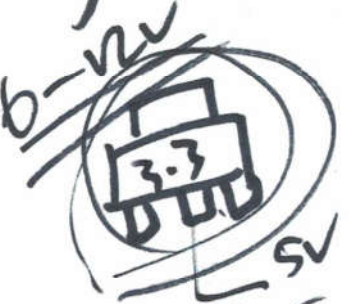


$$I_{avg} = \frac{Q_{tot}}{T} = \frac{V_{DD} \cdot C_{tot}}{T}$$

$$P_{avg} = I_{avg} \cdot V_{DD} = \frac{V_{DD}^2 \cdot C_{tot}}{T} = V_{DD}^2 \cdot C_{tot} \cdot f$$

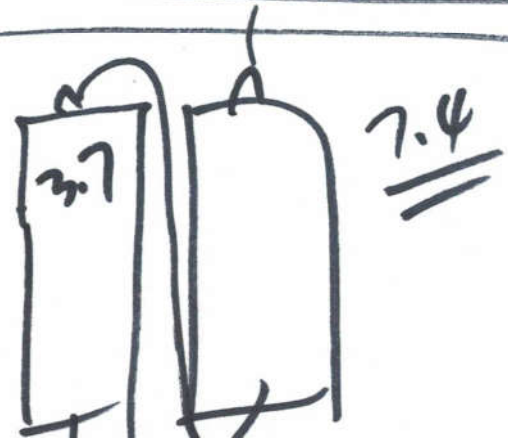
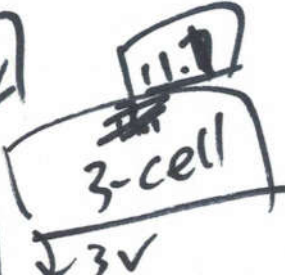
600mV

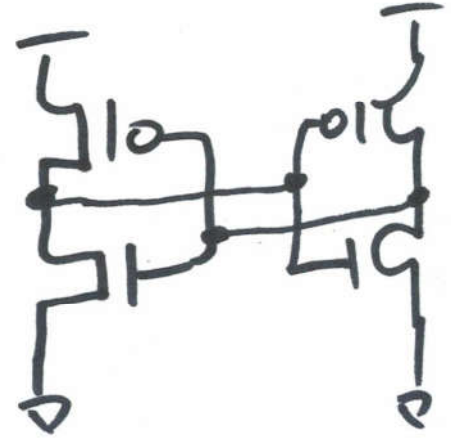
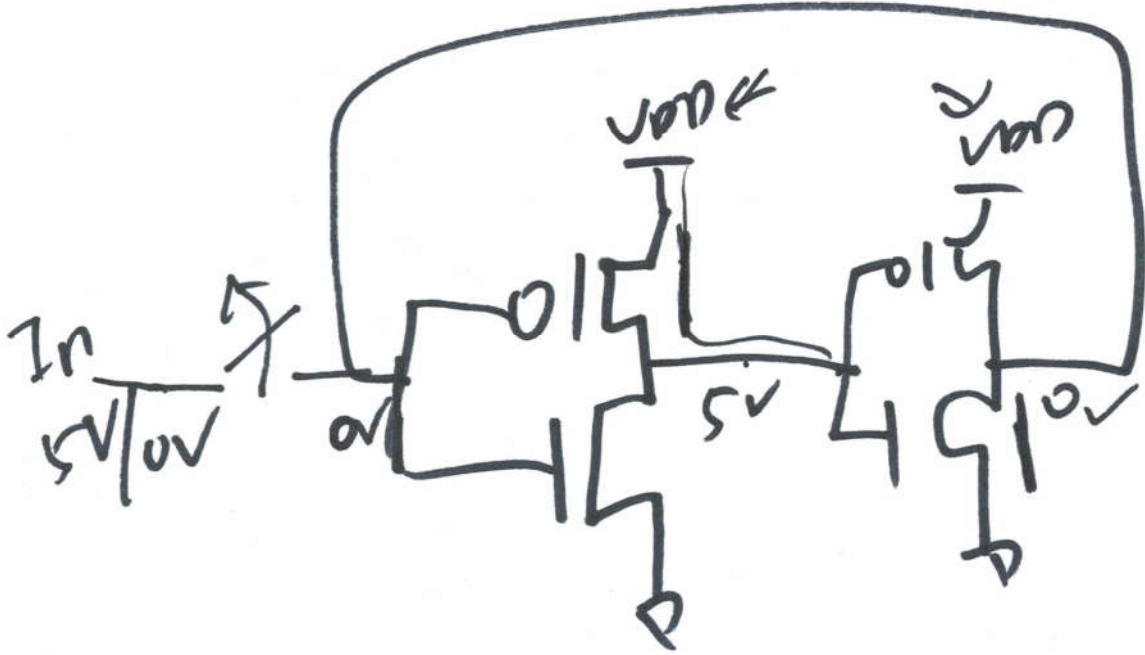
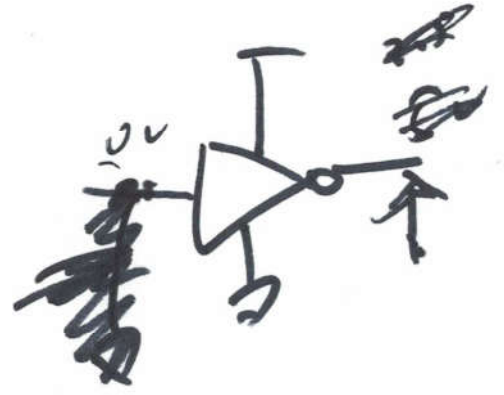
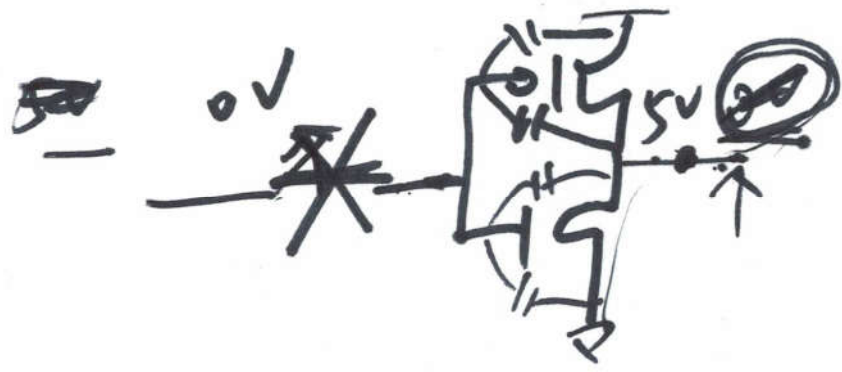
5V, 1A



400mV

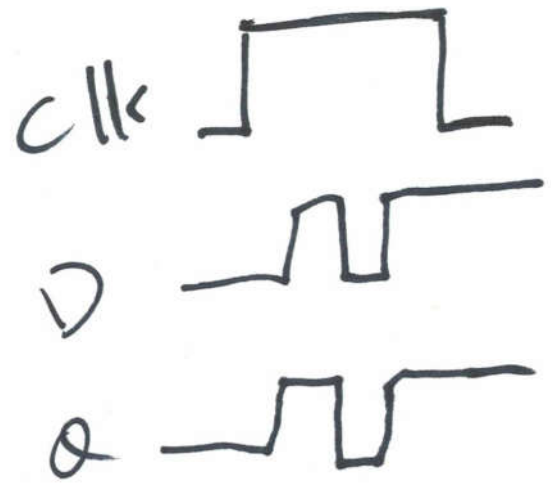
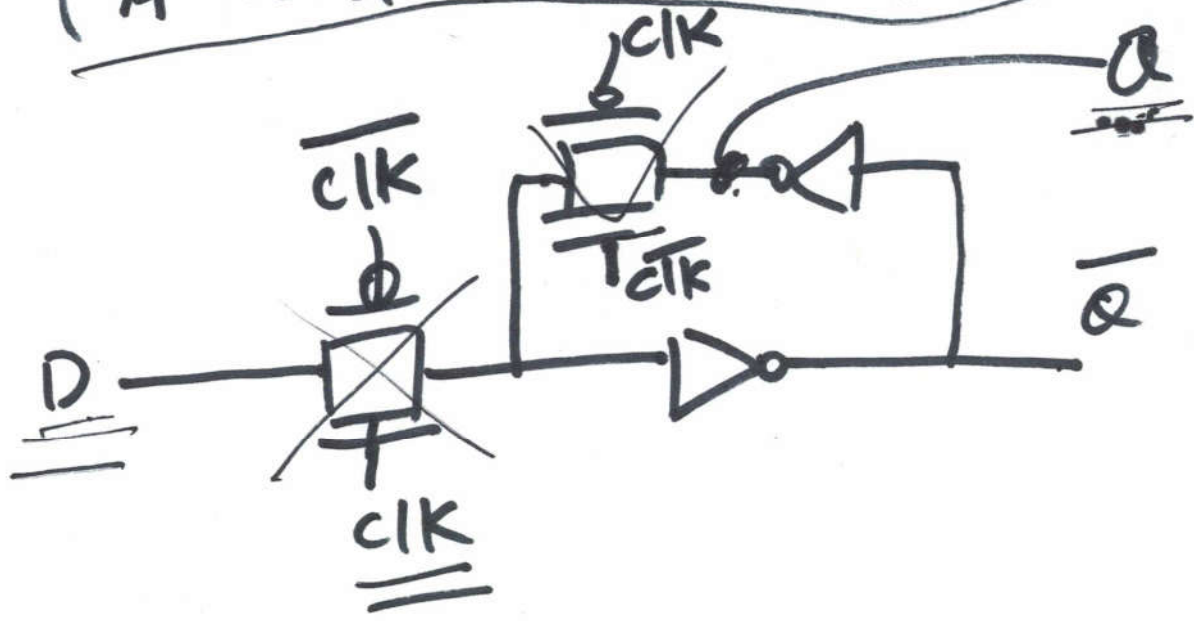
7.4V

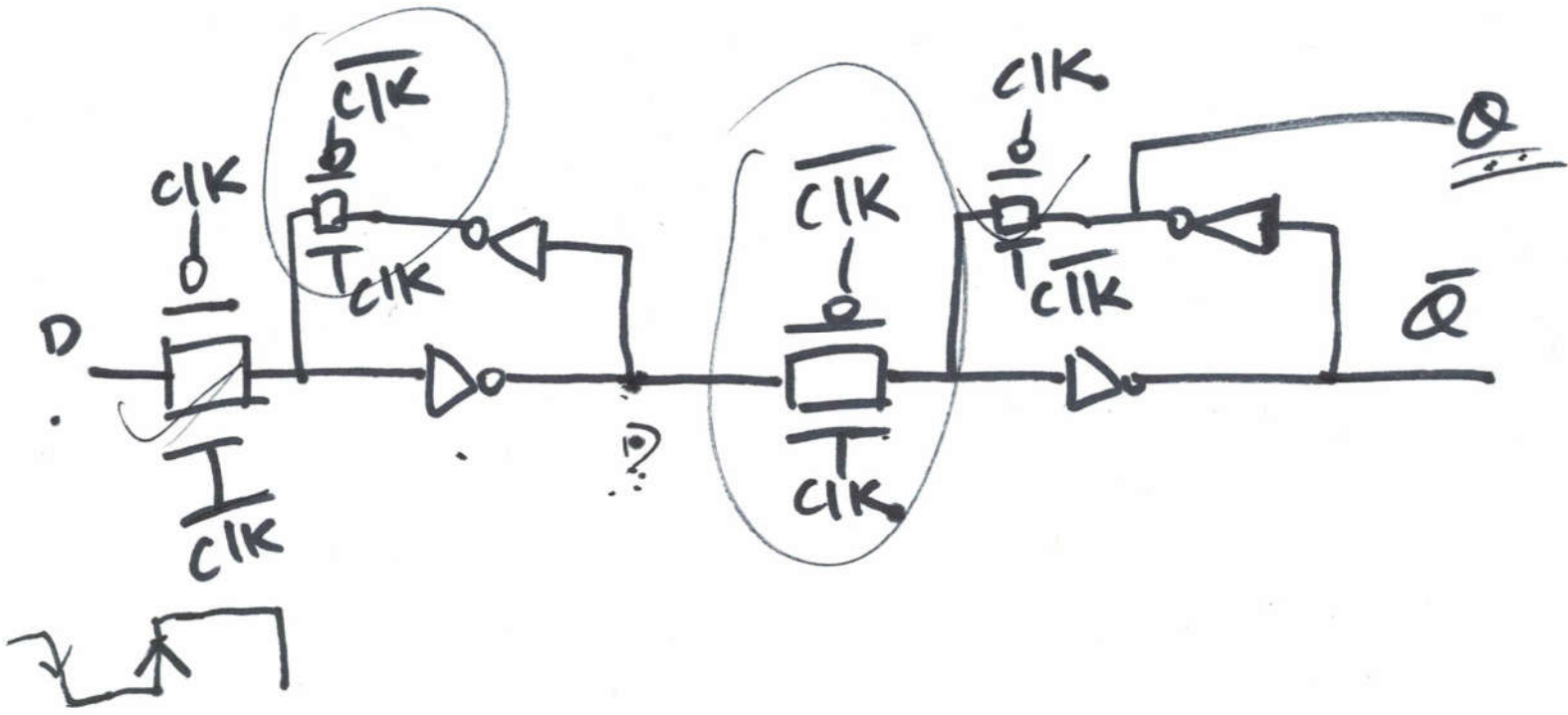




(5)

A level-sensitive latch





①