

CMOS Power-1 (H.1)

20160405

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References

Some Figures from the following sites

[1] <http://pages.hmc.edu/harris/cmosvlsi/4e/index.html>
Weste & Harris Book Site

[2] en.wikipedia.org

[3] Digital Integrated Circuits : A Design Perspective,
Jan M. Rabaey,
(<http://bwracs.eecs.berkeley.edu/Classes/lcBook/>)

[4] Digital Electronics and Design with VHDL
Pedroni

Instantaneous Power

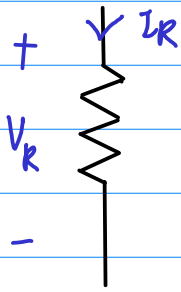
$$P(t) = I(t) V(t)$$

Energy

$$E = \int_0^T P(t) dt$$

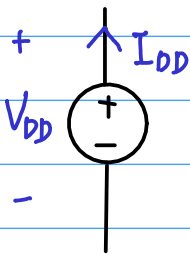
Average Power

$$P_{av} = \frac{E}{T} = \frac{1}{T} \int_0^T P(t) dt$$



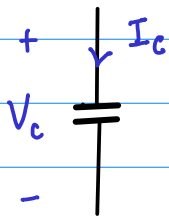
power consume

$$P(t) = I(t) V(t) = I^2(t) R = \frac{V^2(t)}{R}$$



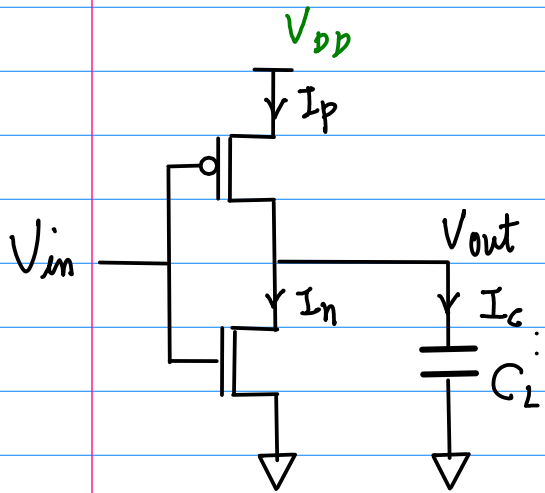
power supply

$$P(t) = I(t) V(t) = I_{pb}(t) V_{DD}$$



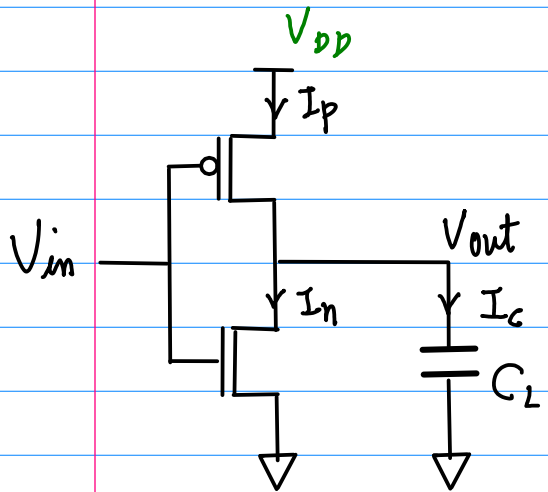
Energy stored

$$\begin{aligned} E &= \int_0^{\infty} I(t) V(t) dt = \int_0^{\infty} C \frac{dV(t)}{dt} V(t) dt \\ &= \int_0^{\infty} C V(t) \frac{dV(t)}{dt} dt = \int_0^{V_C} C V(t) dV \\ &= \left[\frac{1}{2} C V^2(t) \right]_0^{V_C} = \frac{1}{2} C V_C^2 \end{aligned}$$



Energy supply

$$\begin{aligned}
 E &= \int_0^{\infty} I(t) V_{DD} dt = \int_0^{\infty} C \frac{dV(t)}{dt} V_{DD} dt \\
 &= \int_0^{\infty} C V_{DD} \frac{dV(t)}{dt} dt = \int_0^{V_{DD}} C V_{DD} dV \\
 &= C V_{DD}^2 \quad \text{with a crossed-out asterisk}
 \end{aligned}$$



thermal energy

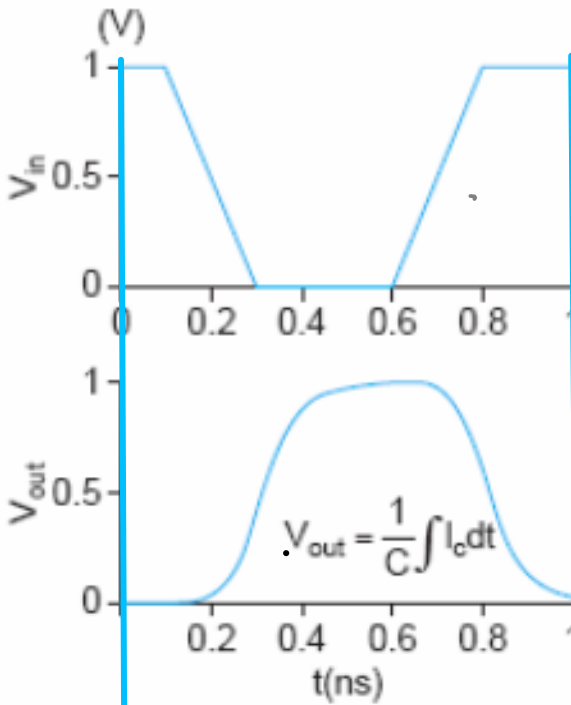
$$\left. \begin{array}{l} \frac{1}{2} C V_{DD}^2 \\ \frac{1}{2} C V_{DD}^2 \end{array} \right\} C V_{DD}^2$$

The diagram shows two terms, $\frac{1}{2} C V_{DD}^2$ (one in pink, one in blue), grouped by a green bracket to equal $C V_{DD}^2$. A wavy pink line is drawn above the first term.

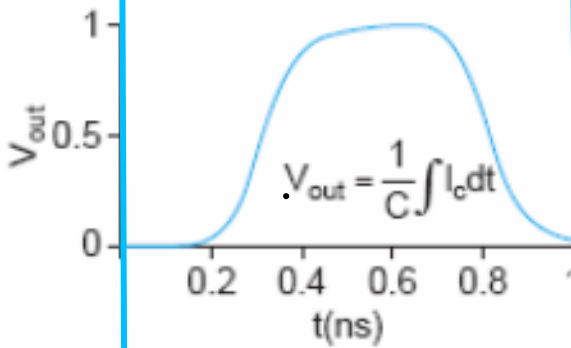
C V_{DD}

~~switching speed~~
~~tr size~~

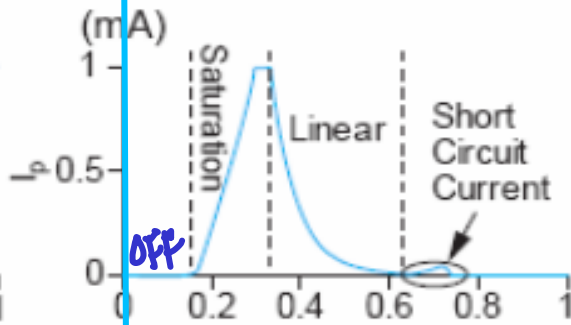
V_{in}



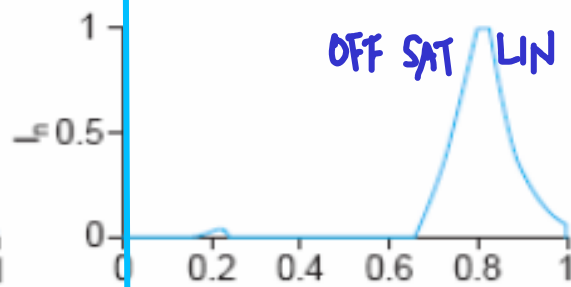
V_{out}



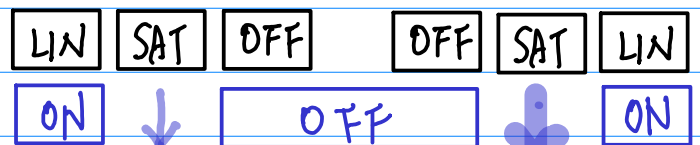
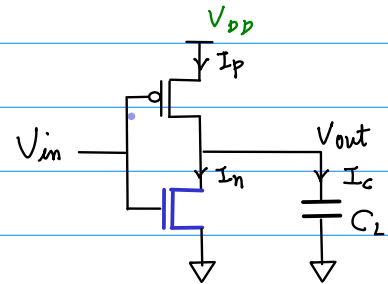
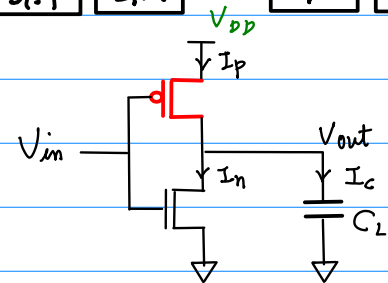
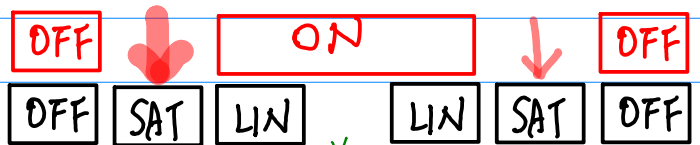
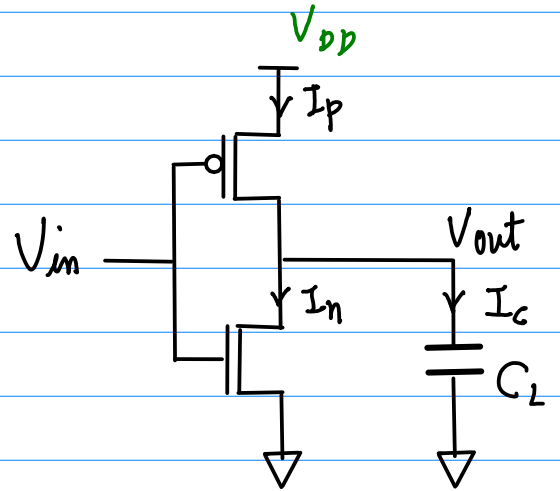
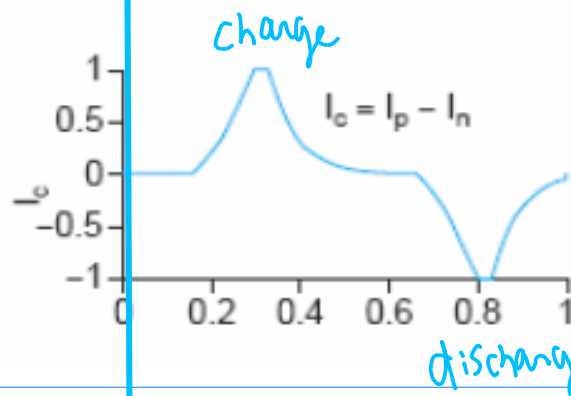
I_p



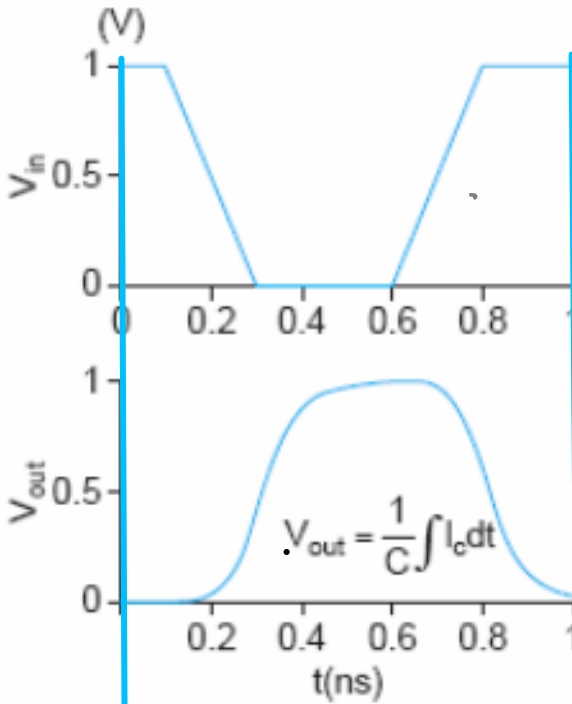
I_n



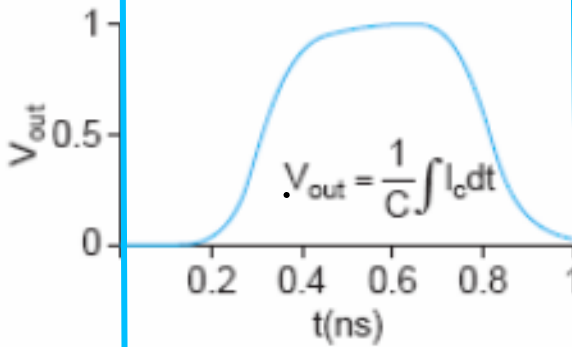
$I_c = I_p - I_n$



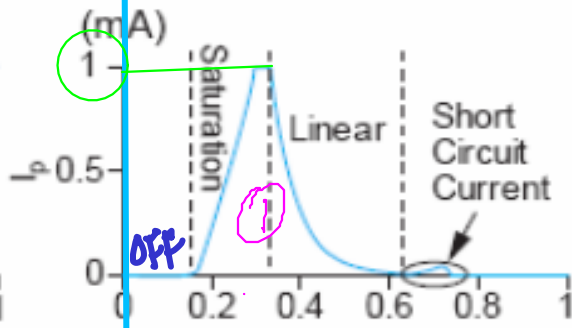
V_{in}



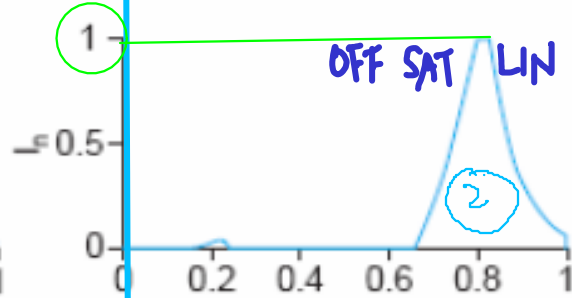
V_{out}



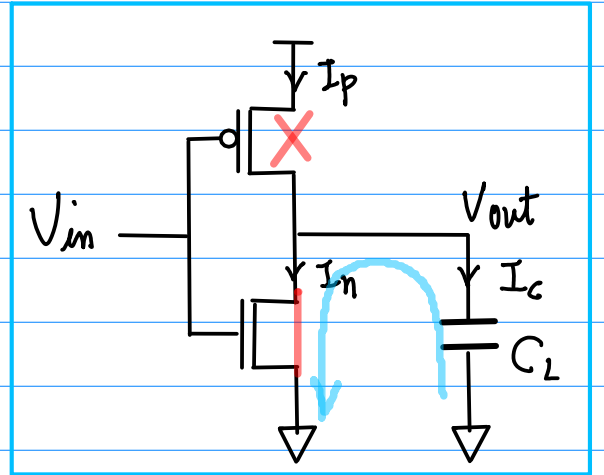
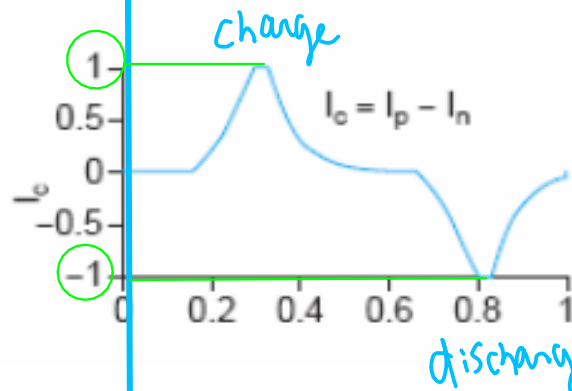
I_p



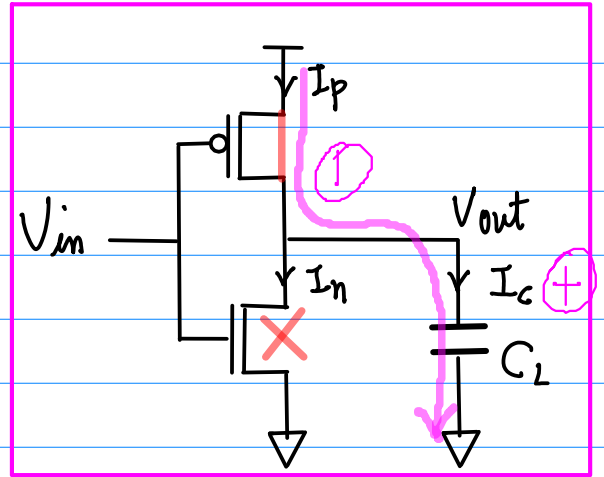
I_n



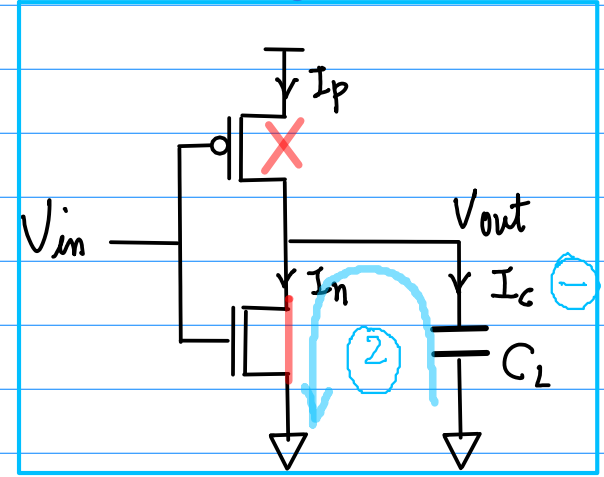
$I_c = I_p - I_n$



PMOS OFF
PMOS ON



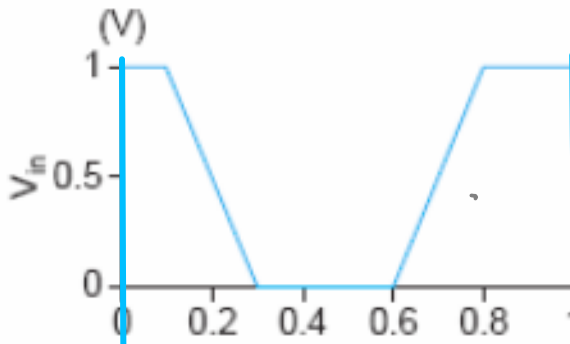
nMOS OFF
nMOS ON



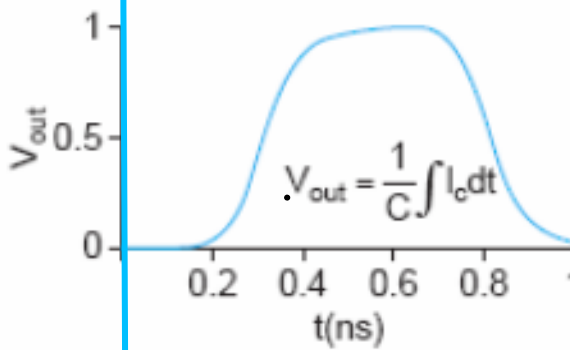
discharged

Short Circuit

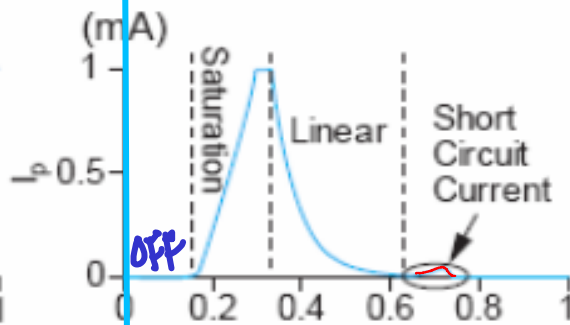
V_{in}



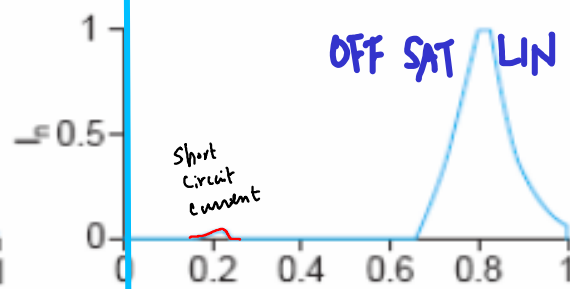
V_{out}



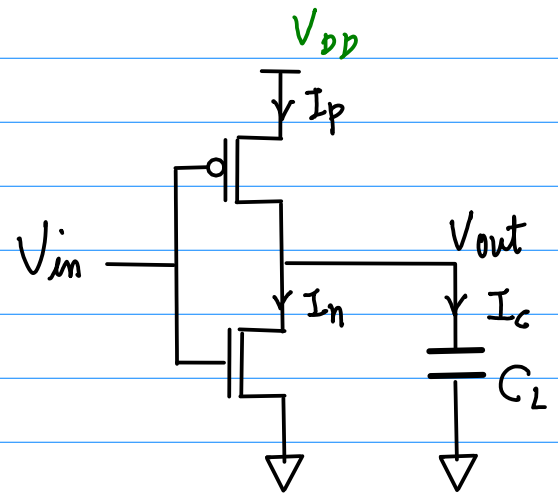
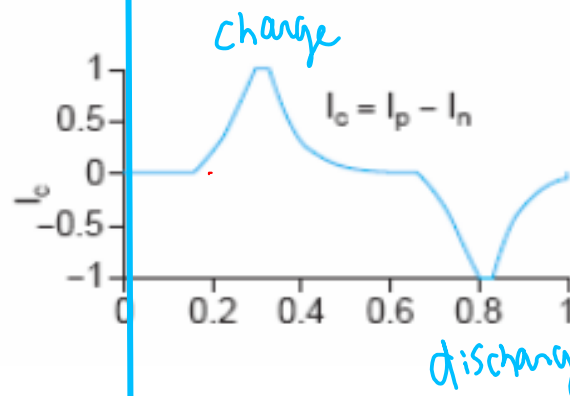
I_p



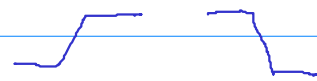
I_n



$I_c = I_p - I_n$



$$E_{sc} = C_{sc} V_{DD}^2 = R \left(a \frac{Z_{in}}{Z_{out}} + b \right)$$



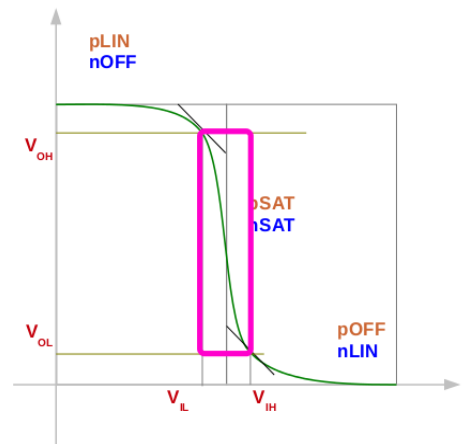
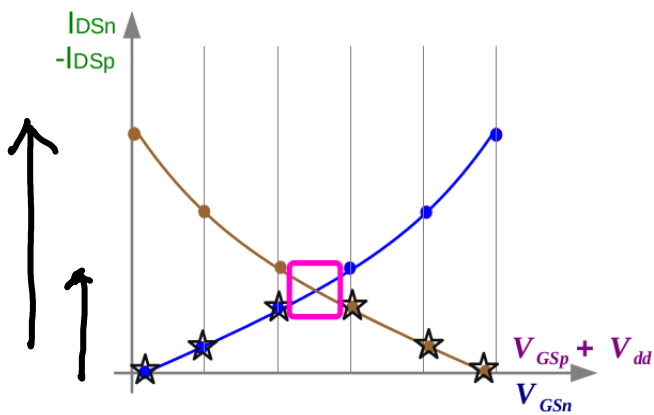
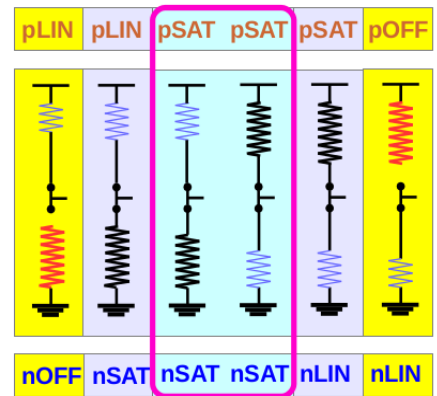
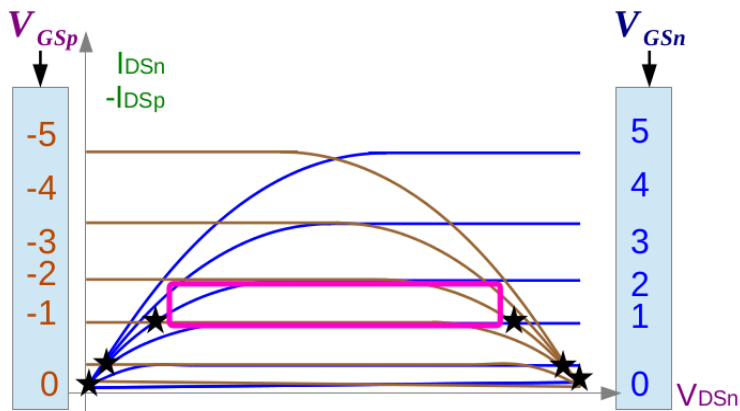
equal rate

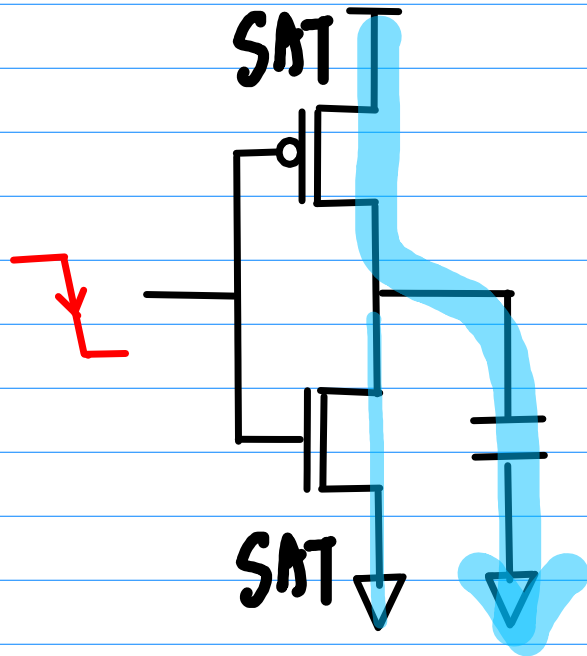
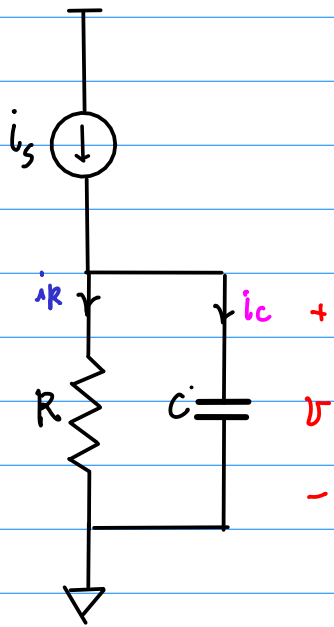
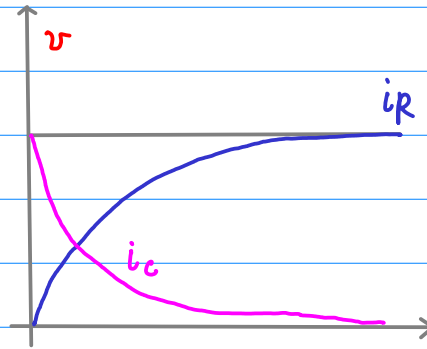
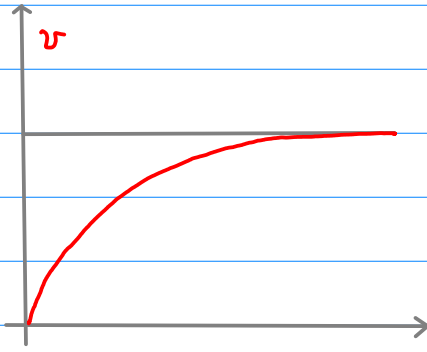
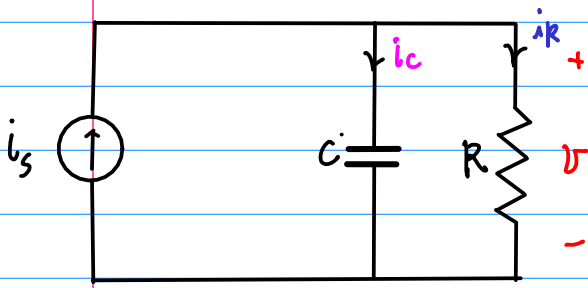
$$\frac{Z_{in}}{Z_{out}} \approx 1$$

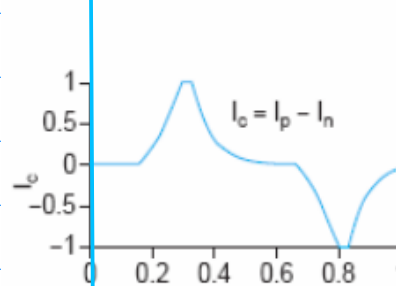
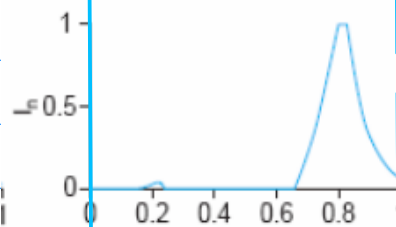
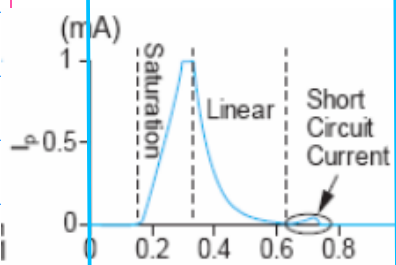
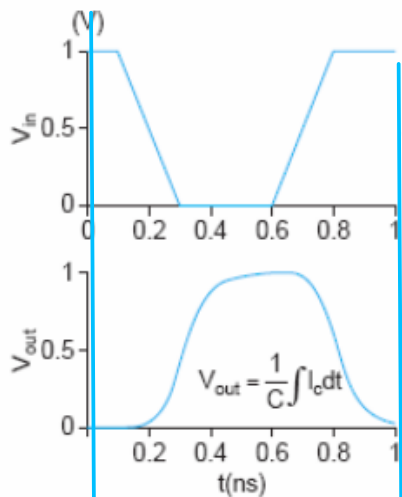
$$P_{sc} \leq 0.1 P_{dynamic}$$

$$0.15 P_{dynamic}$$

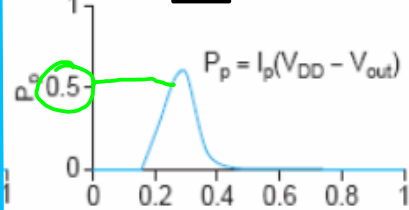
Inverter Switching Current w/o a Load



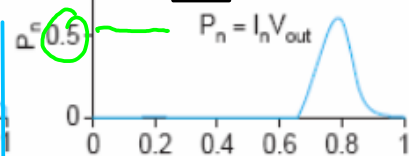




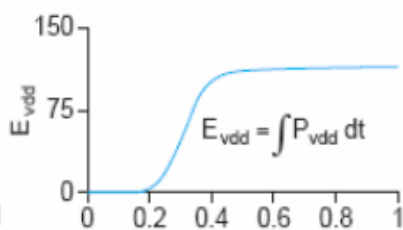
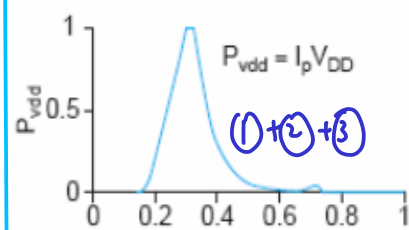
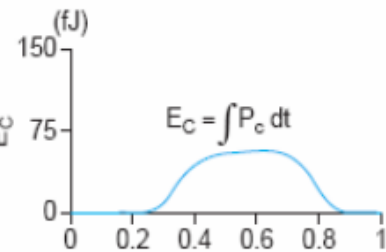
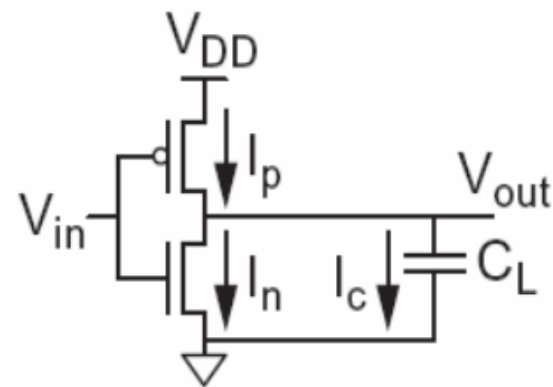
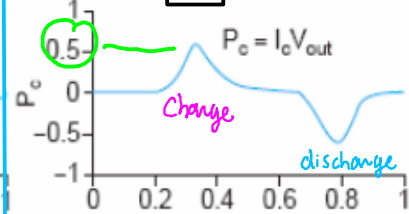
① $P_p = I_p (V_{DD} - V_{out})$



② $P_n = I_n V_{out}$

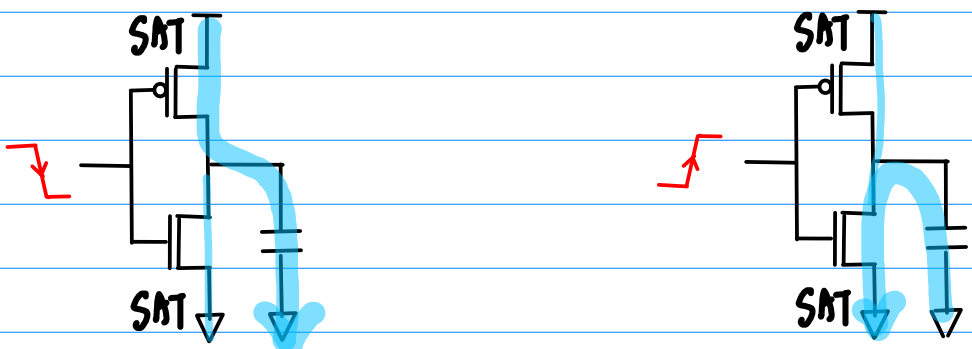
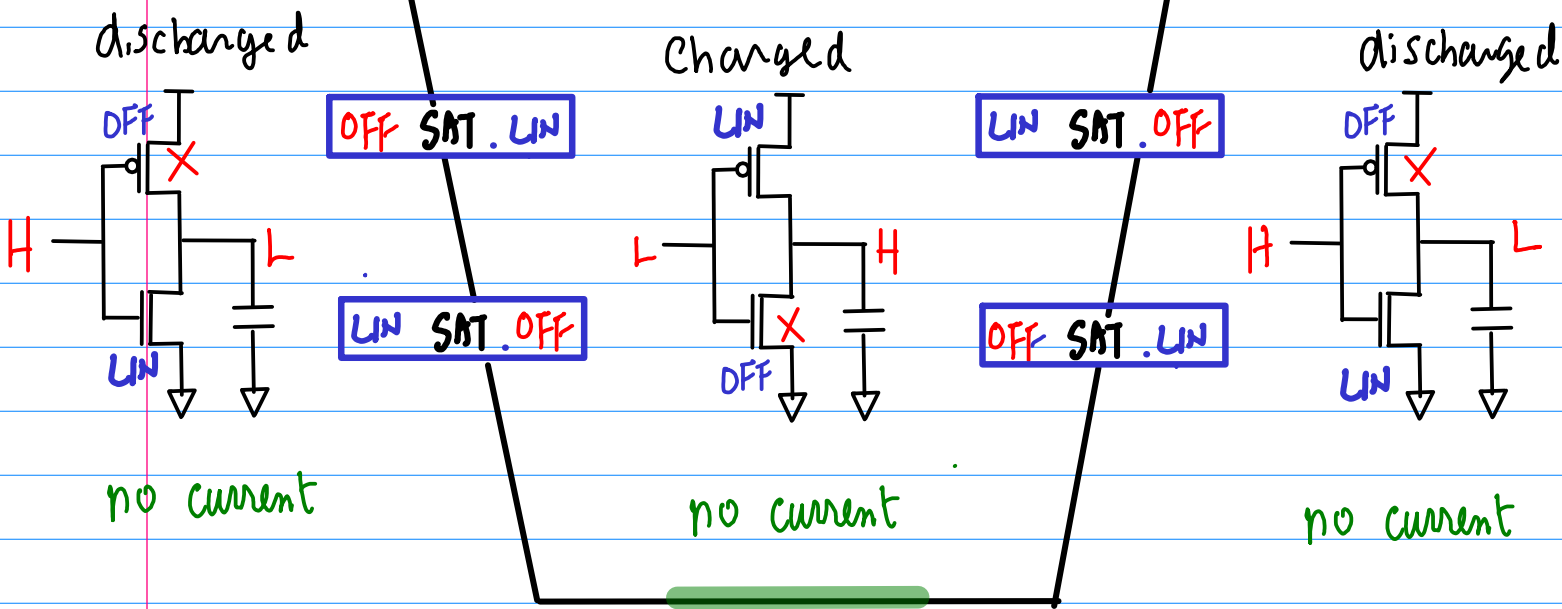


③ $P_c = I_c V_{out}$



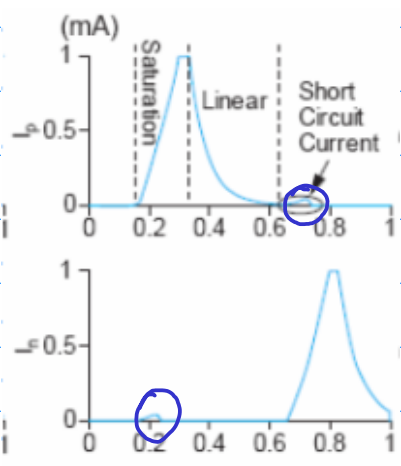
$P_{VDD} = I_p V_{DD}$

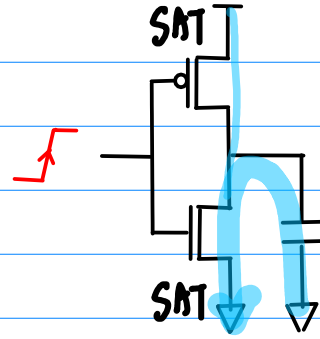
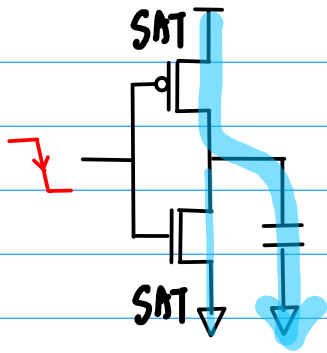
V_{in}



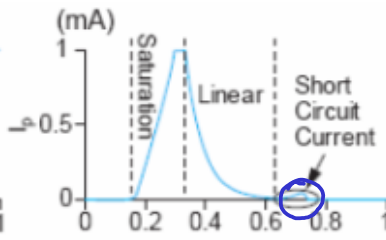
pMos

nMos

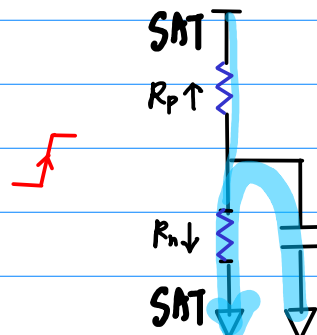
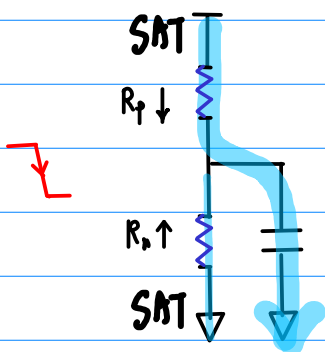
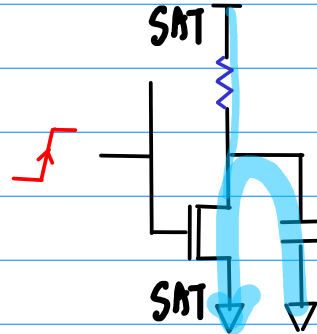
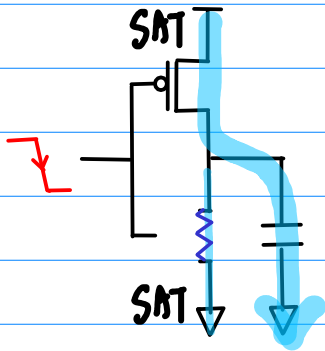
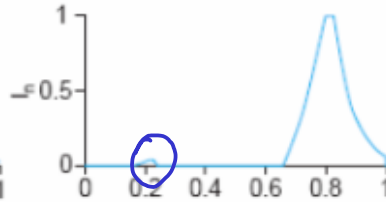


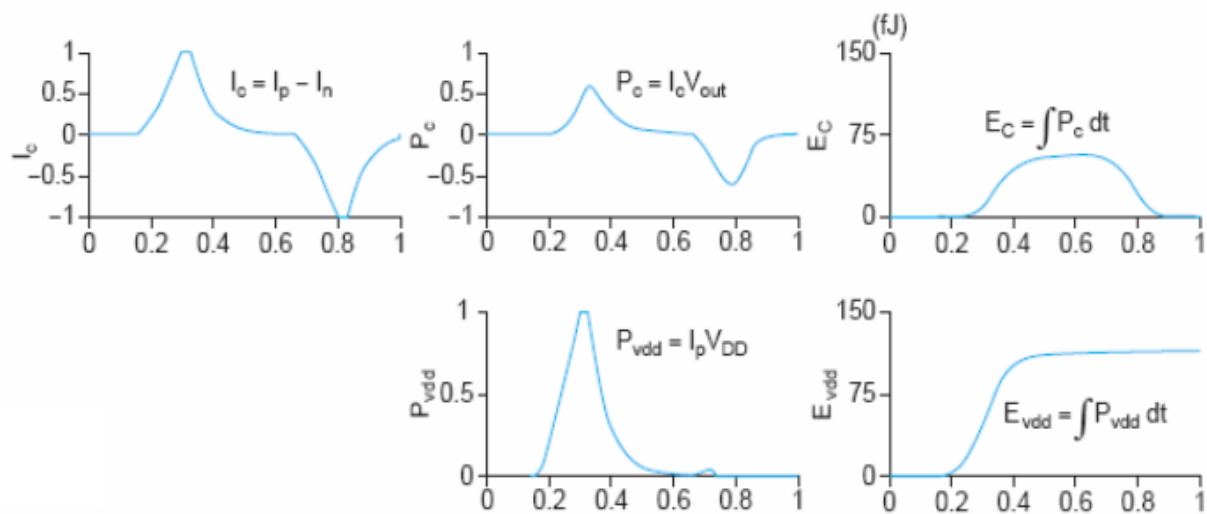
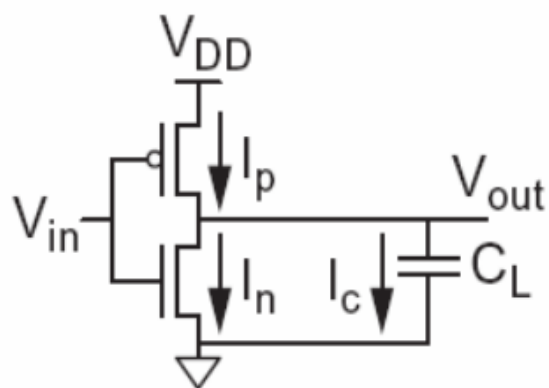
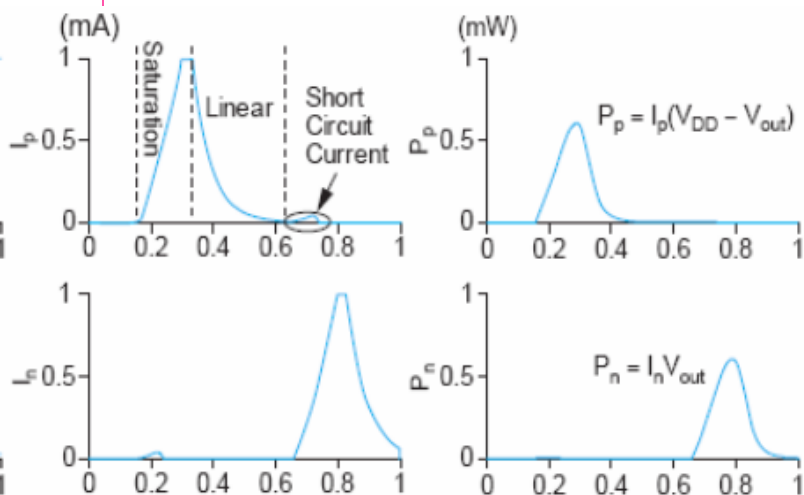


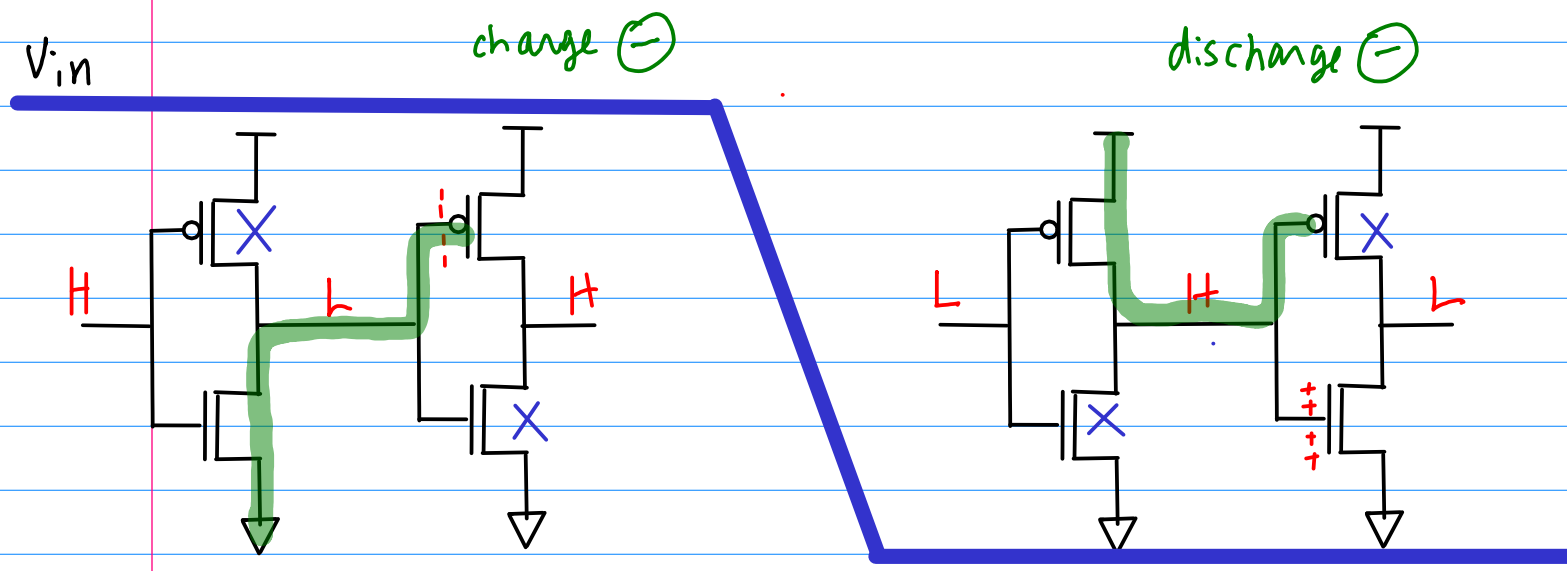
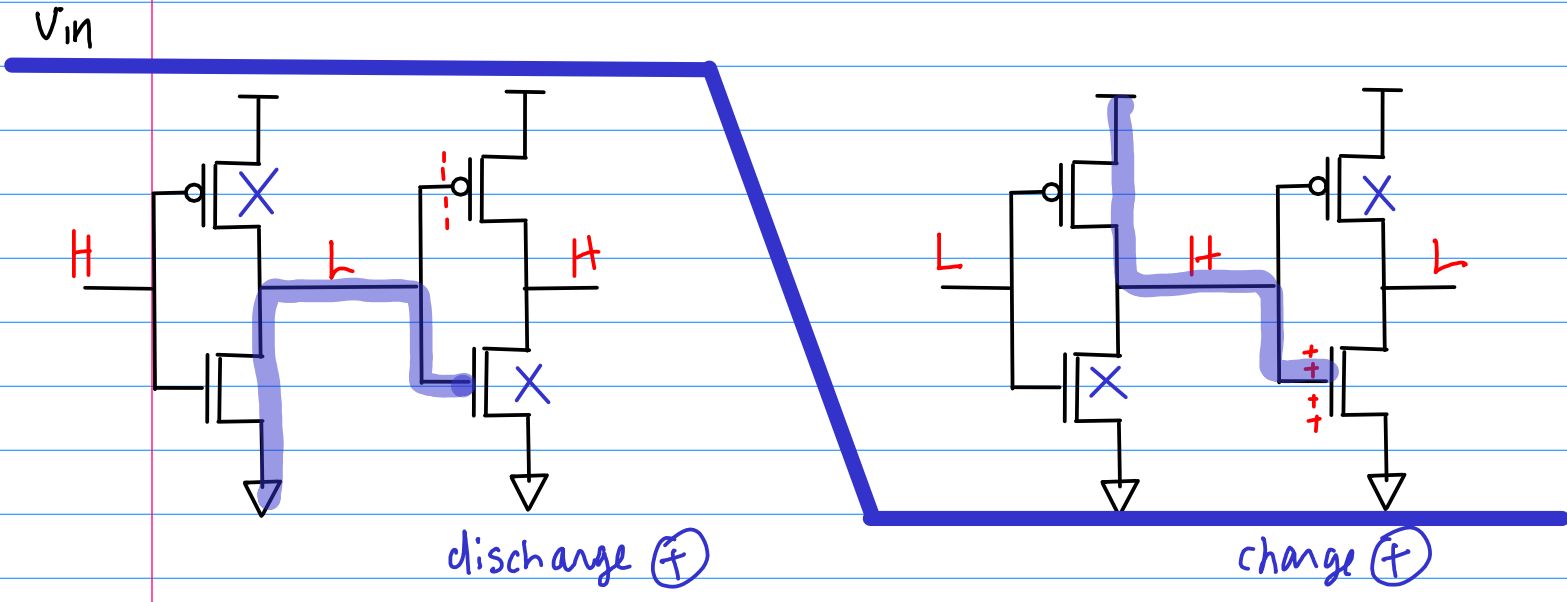
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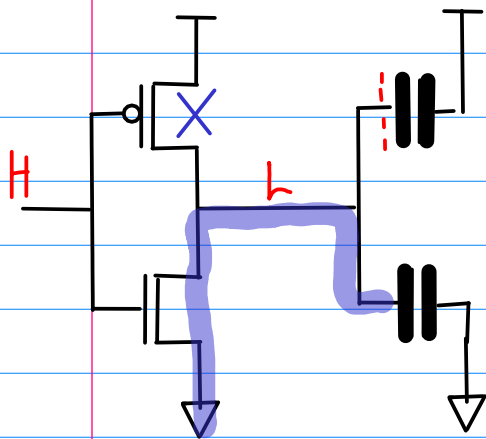


nMos

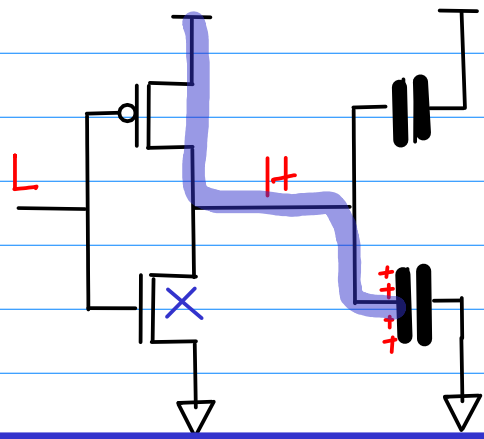




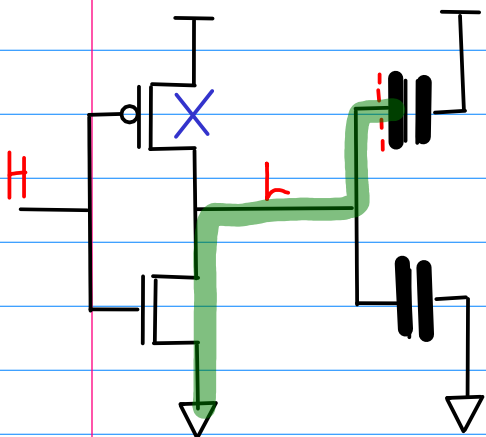




discharge (+)

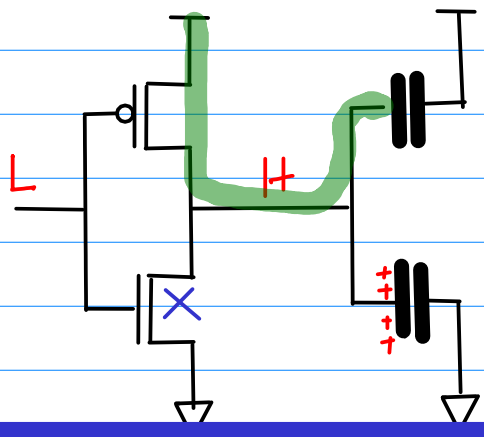


charge (+)



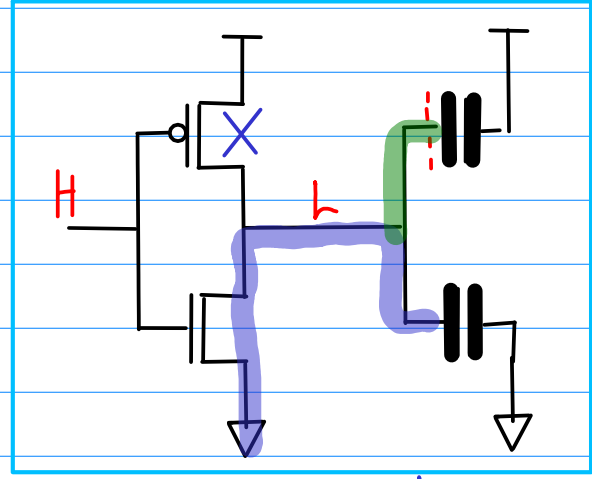
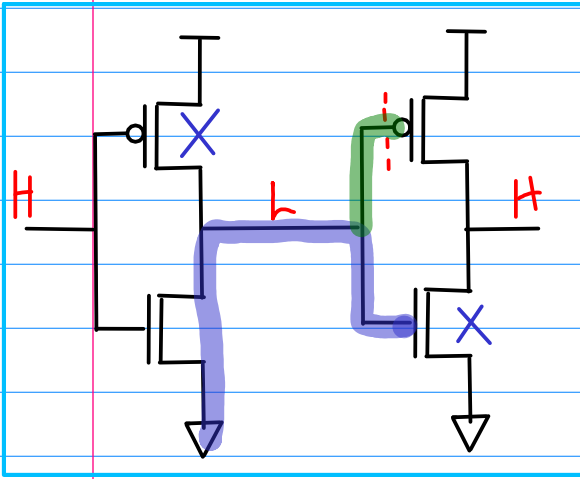
charge (-)

discharge (+)



discharge (-)

charge (+)



discharge (f)

