

# Logic Circuit Design

## NOR-1

20170829

Copyright (c) 2015 - 2016 Young W. Lim.

Permission is granted to copy, distribute and/or modify this document under the terms of the GNU Free Documentation License, Version 1.2 or any later version published by the Free Software Foundation; with no Invariant Sections, no Front-Cover Texts, and no Back-Cover Texts. A copy of the license is included in the section entitled "GNU Free Documentation License".

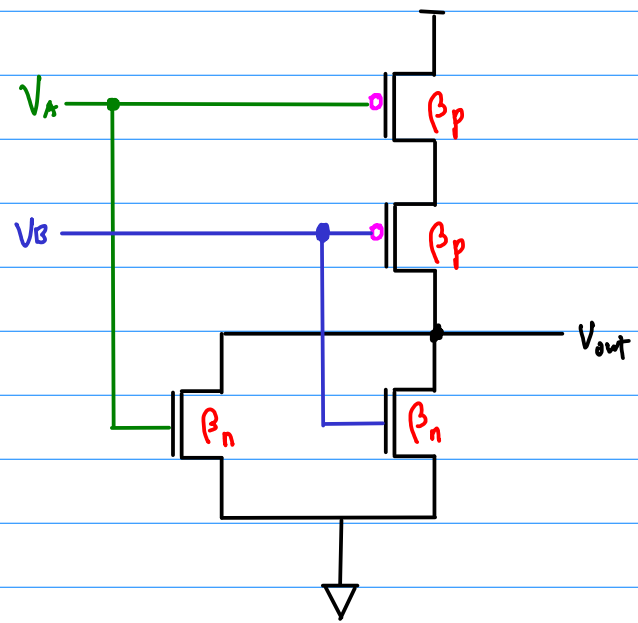
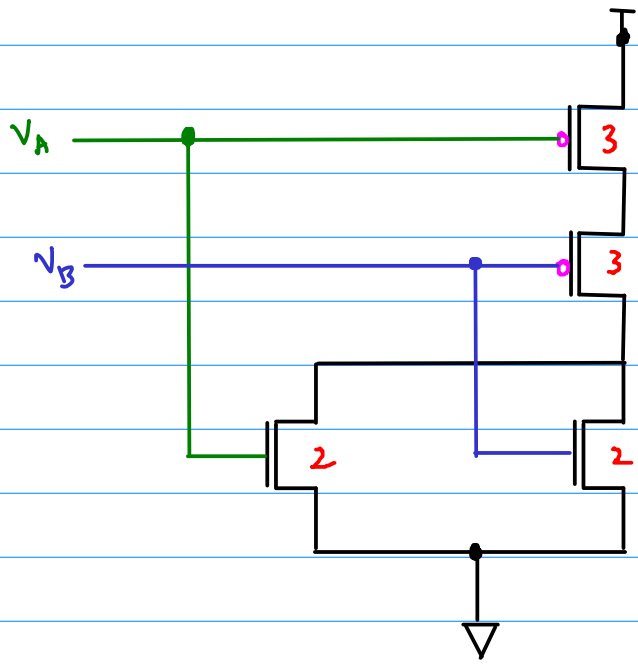
# References

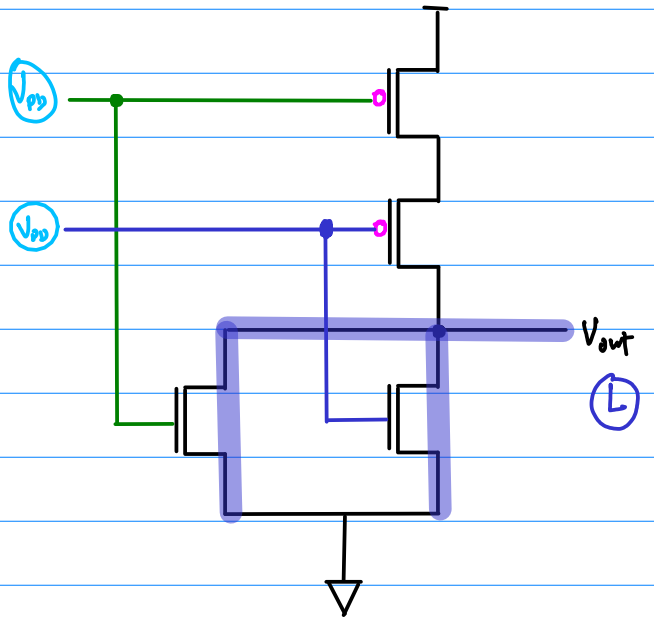
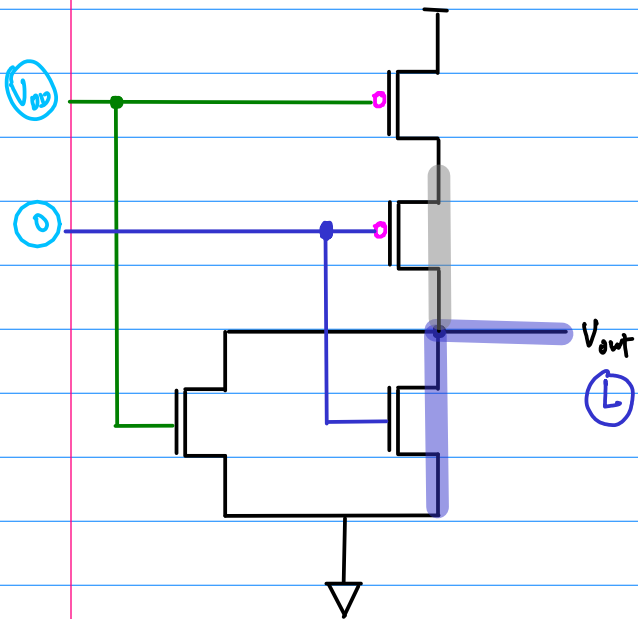
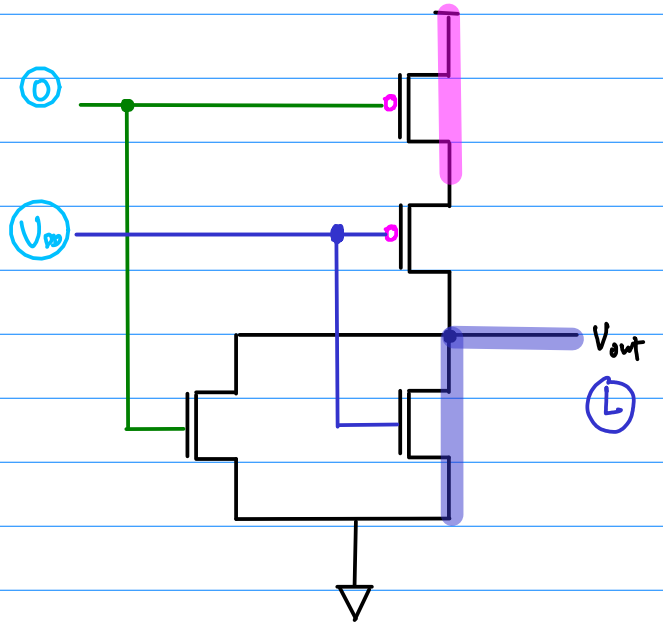
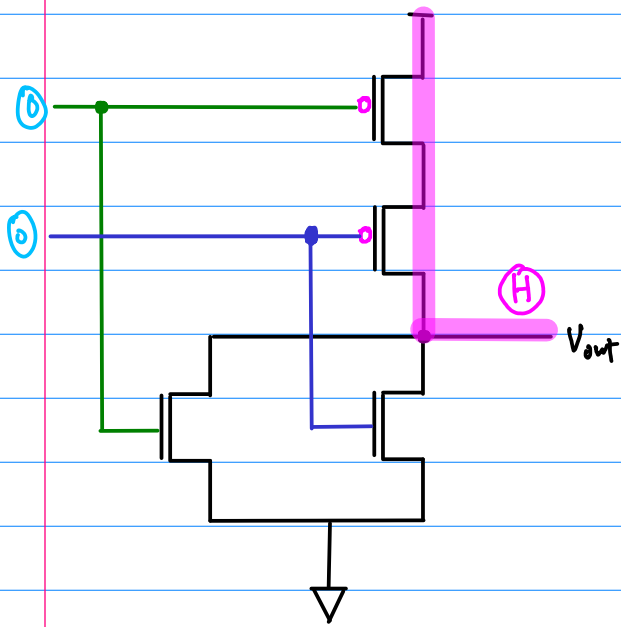
Some Figures from the following sites

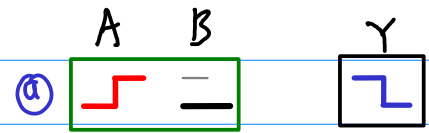
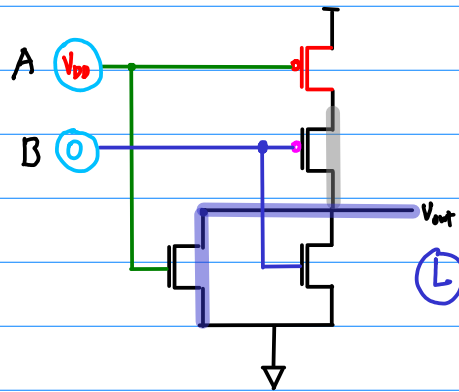
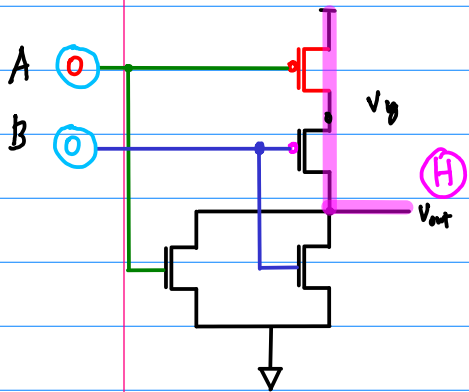
[1] <http://pages.hmc.edu/harris/cmosvlsi/4e/index.html>  
Weste & Harris Book Site

[2] Introduction to VLSI Circuits and Systems, Uyemura

[2] [en.wikipedia.org](http://en.wikipedia.org)



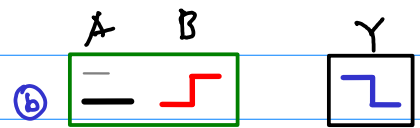
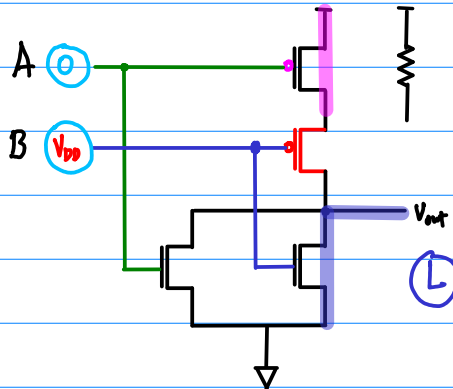
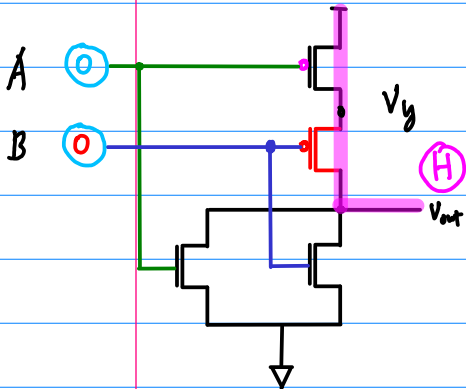




Weak PDN

PMA : resistor

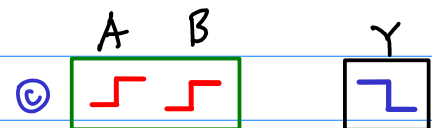
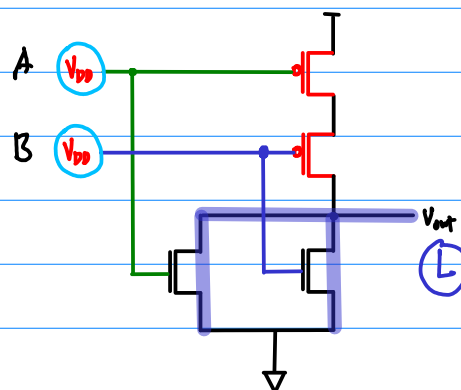
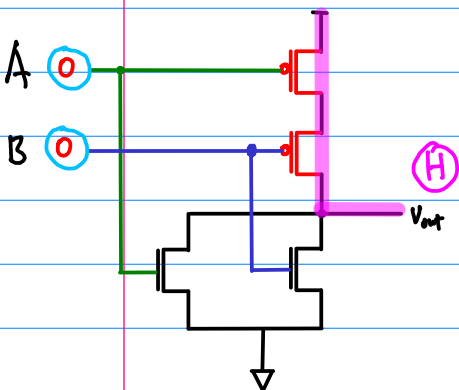
PMB : ~~Body Effect~~



Weak PDN

PMA : resistor

PMB : Body Effect

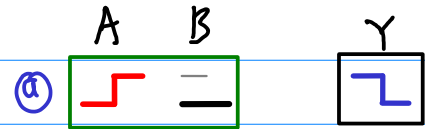
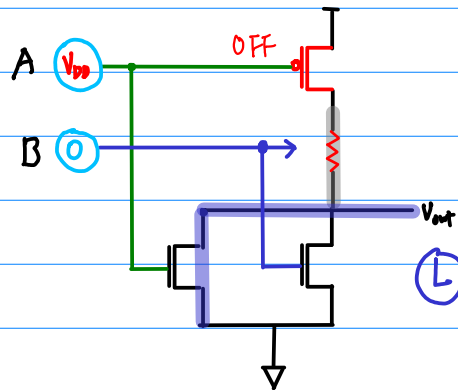


Strong PDN

{ small R  
 { large C (load)

{ small voltage drop  
 { slow change

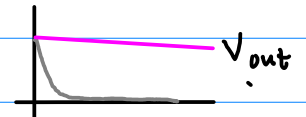
small effect on VTC



Weak PPN

pMA : resistor

pMB : ~~Body Effect~~



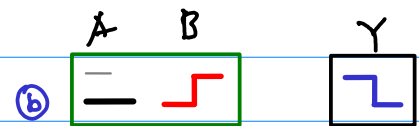
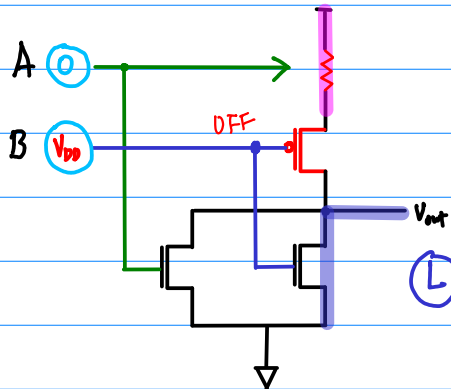
{ small R  
 { small C (load)

{ large voltage drop  
 { immediate change

increase  $V_T$

→ hard to turn ON nMB

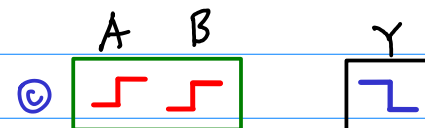
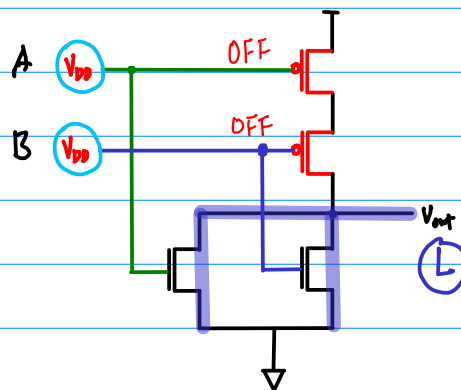
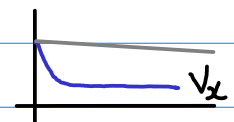
→ VTC shifted to the right



Weak PPN

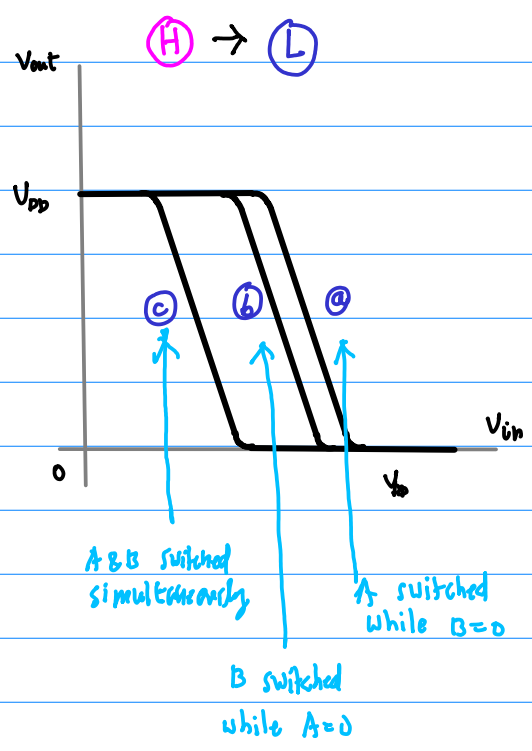
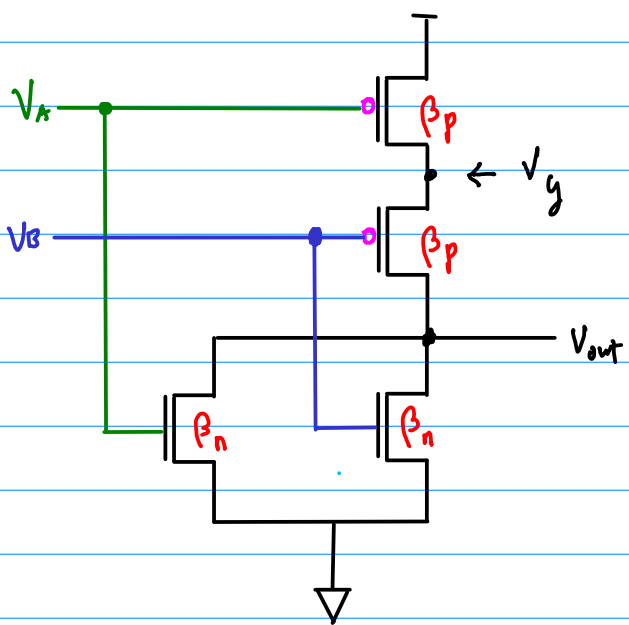
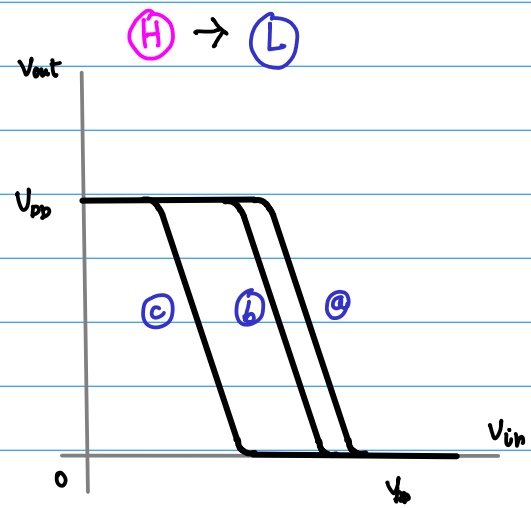
pMA : resistor

pMB : Body Effect



Strong PPN

	$V_A$	$V_B$	$V_{out}$
	0	0	$V_{DD}$
(b)	0	$V_{DD}$	0
(a)	$V_{DD}$	0	0
(c)	$V_{DD}$	$V_{DD}$	0

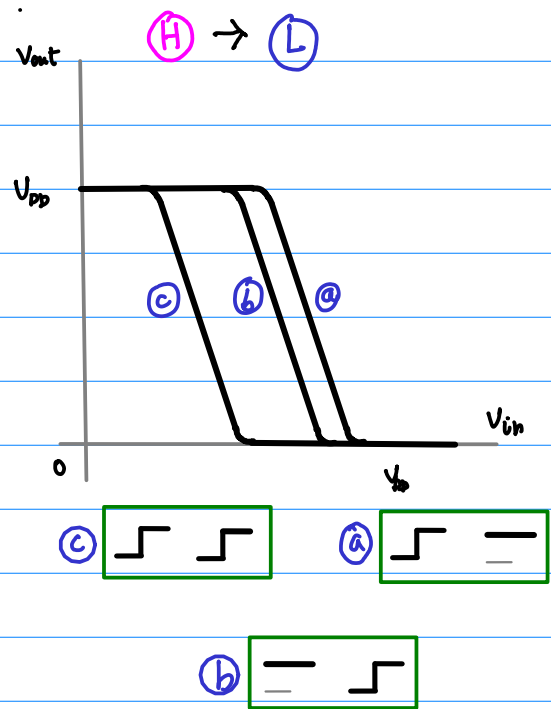
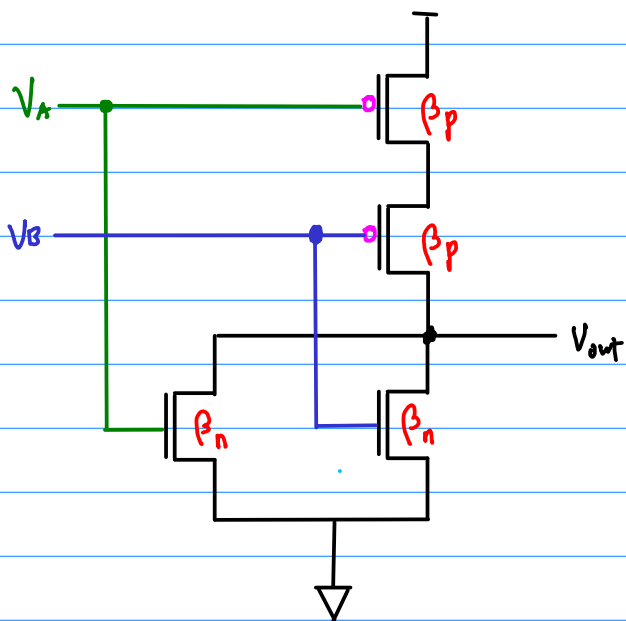


### Body Effect

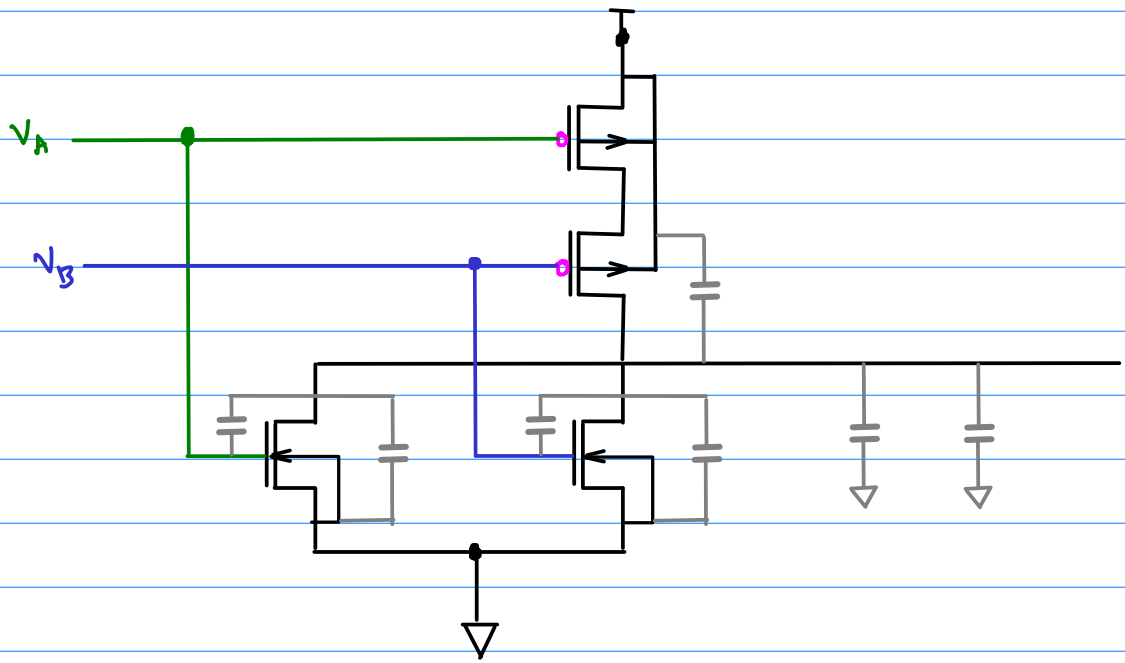
B is more difficult to be turned on than A

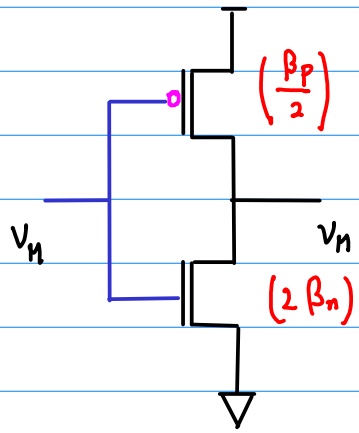
	$V_A$	$V_B$	$V_{out}$
	0	0	$V_{DD}$
(b)	0	$V_{DD}$	0
(a)	$V_{DD}$	0	0
(c)	$V_{DD}$	$V_{DD}$	0

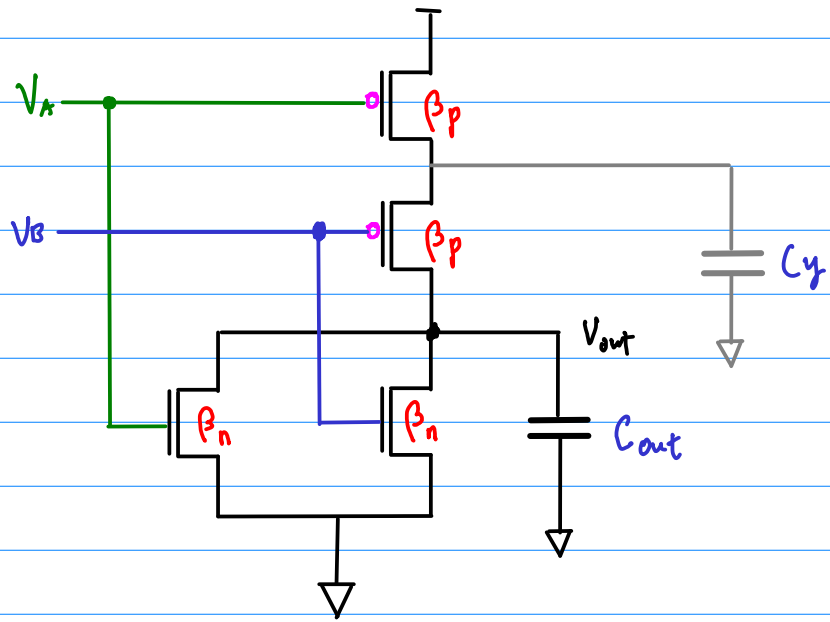
	$V_A$	$V_B$	$V_{out}$
(a)			
(b)			
(c)			

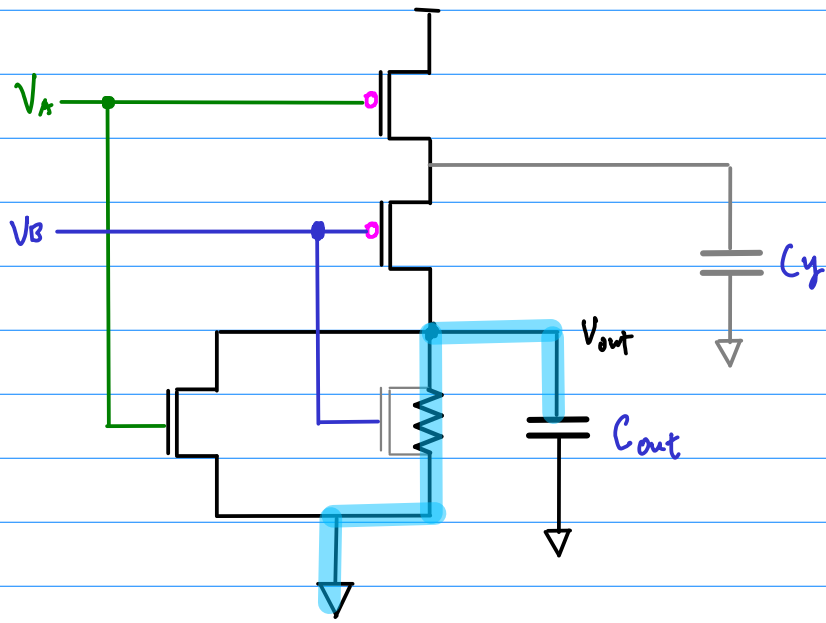


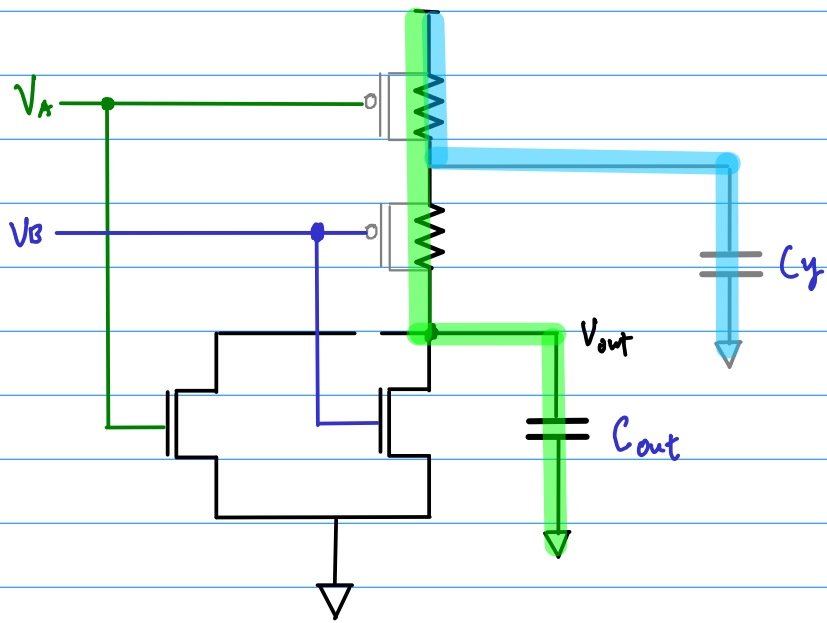












$$C_{out} = C_{FET} + C_L$$

$$C_{FET} = 2C_{Dn} + C_{Dp}$$

$$R_p = \frac{1}{\beta_p (V_{DD} - |V_{Tp}|)} \quad R_n = \frac{1}{\beta_n (V_{DD} - V_{Tn})}$$

# Simultaneous Switching

$$V_{GS,1} = V_{GS,2} = V_{th} = V_{DS,1} = V_{DS,2}$$

$$\begin{aligned} I_D &= I_{D,1} + I_{D,2} \\ &= \beta_n (V_{th} - V_{T0n})^2 \end{aligned}$$

$$V_{th} - V_{T0n} = \sqrt{\frac{I_D}{\beta_n}}$$

$$V_{SG,3} = V_{DD} - V_{th}$$

$$V_{SG,4} = V_{DD} - V_{th} - V_{SD,3}$$

$$V_{DD} - V_{th} = V_{SD,3} + V_{SG,4}$$

$$\begin{aligned} I_D &= \frac{\beta_p}{2} (2(V_{DD} - V_{th} - |V_{T0p}|) V_{SD,3} - V_{SD,3}^2) \\ &= \frac{\beta_p}{2} (V_{DD} - V_{th} - |V_{T0p}| - V_{SD,3})^2 \end{aligned}$$

$$\sqrt{\frac{2I_D}{\beta_p}} = V_{DD} - V_{th} - |V_{T0p}|$$

$$V_{th} = \frac{V_{T0n} + \frac{1}{2} \sqrt{\frac{\beta_p}{\beta_n}} (V_{DD} - |V_{T0p}|)}{1 + \frac{1}{2} \sqrt{\frac{\beta_p}{\beta_n}}}$$

$$V_{th} = \frac{V_{DD} + V_{T0}}{3}$$

# Single Switching

$$I_D = I_{D,S} = \frac{\beta_n}{2} (V_{th} - V_{T0n})^2$$

$$V_{S_{G,3}} = V_{DD}$$

$$V_{S_{G,4}} = V_{DD} - V_{th} - V_{SD,3}$$

$$V_{DD} - V_{th} = V_{SD,3} + V_{SD,4}$$

$$I_D = \frac{\beta_p}{2} [2(V_{DD} - |V_{T0p}|) V_{SD,3} - V_{SD,3}^2]$$

$$= \frac{\beta_p}{2} (V_{DD} - V_{th} - |V_{T0p}| - V_{SD,3})^2$$

$$V_{SD,3} = (V_{DD} - |V_{T0p}| - V_{th}) - \sqrt{\frac{2I_D}{\beta_p}}$$

$$2\left(\frac{2I_D}{\beta_p}\right) = (V_{DD} - |V_{T0p}|)^2 - V_{th}^2 - 2\sqrt{\frac{2I_D}{\beta_p}} V_{th}$$

$$\begin{aligned} & \left[1 + 2\left(\frac{\beta_n}{\beta_p} + \sqrt{\frac{\beta_n}{\beta_p}}\right)\right] V_{th}^2 - 2V_{T0n} \left[2\left(\frac{\beta_n}{\beta_p}\right) + \sqrt{\frac{\beta_n}{\beta_p}}\right] V_{th} \\ & - \left[(V_{DD} - |V_{T0p}|)^2 - 2\left(\frac{\beta_n}{\beta_p}\right) V_{T0n}^2\right] = 0 \end{aligned}$$

$$V_{th} = 0.6 V_{T0} + 0.2 \sqrt{5V_{DD}^2 - 10V_{DD} V_{T0} + 4V_{T0}^2}$$