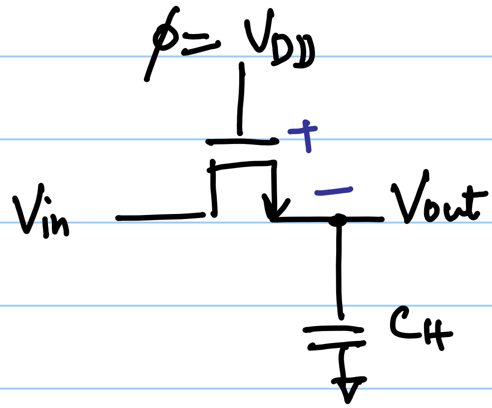
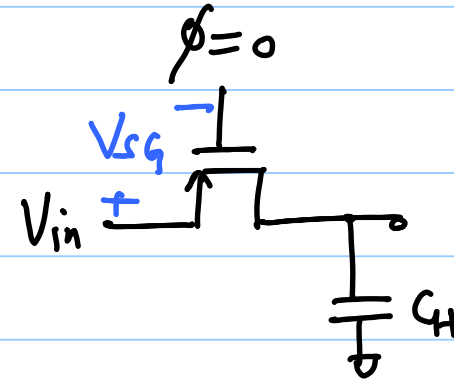
ECE 614 – Lecture 14.

Note Title 10/9/2014





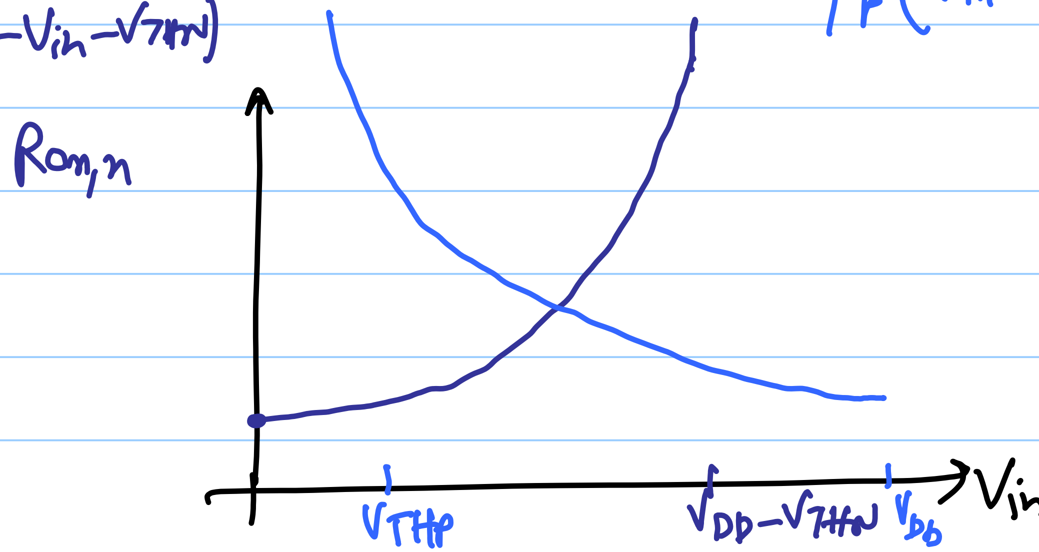
$V_{SG} = V_{in}$

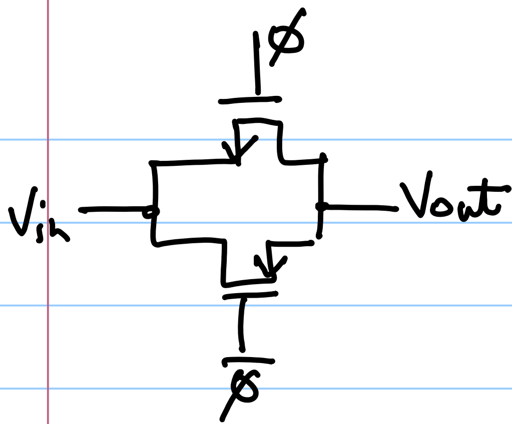
$V_{GS} = V_{DD} - V_{out}$

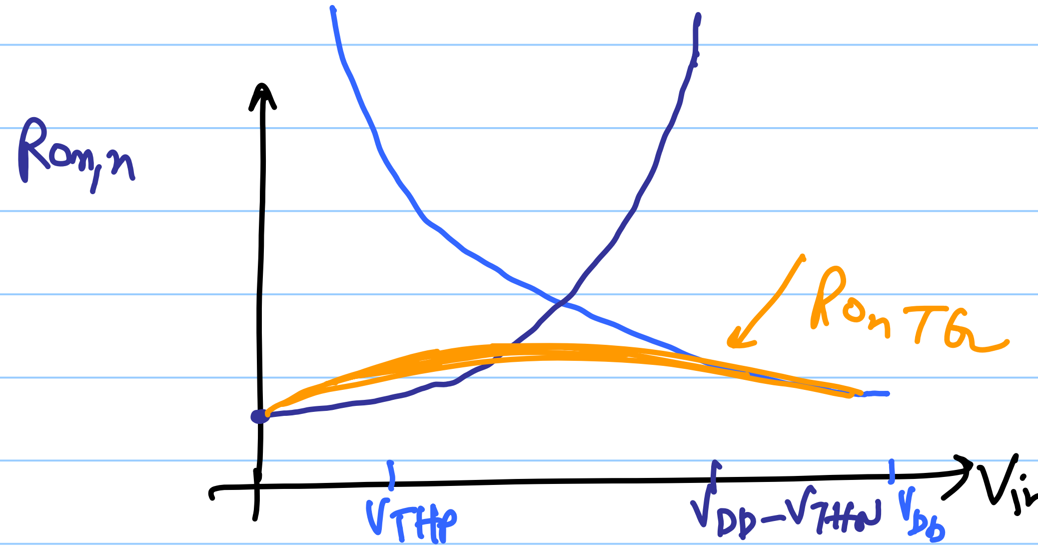
$\simeq V_{DD} - V_{in}$

$$R_{on,n} = \frac{1}{\beta_n (V_{DD} - V_{in} - V_{THN})}$$

$$R_{on,p} = \frac{1}{\beta_p (V_{in} - |V_{THP}|)}$$



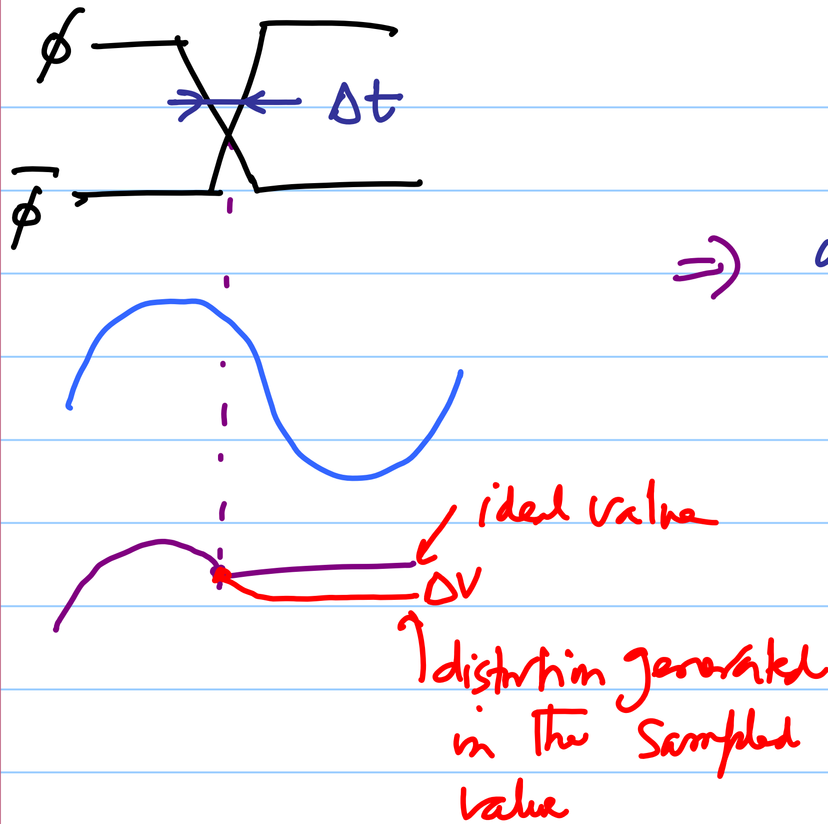




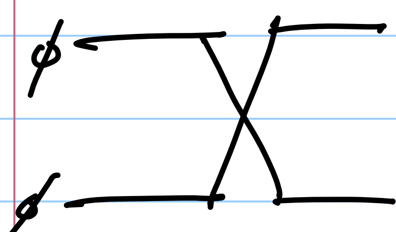
$$R_{on,eq} = R_{on,n} \parallel R_{on,p}$$

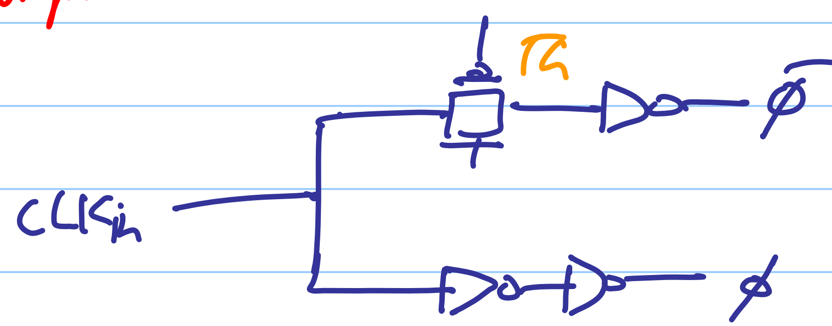
$$= \frac{1}{\beta_n (V_{DD} - V_{in} - V_{THN})} \parallel \frac{1}{\beta_p (V_{in} - |V_{THP}|)}$$

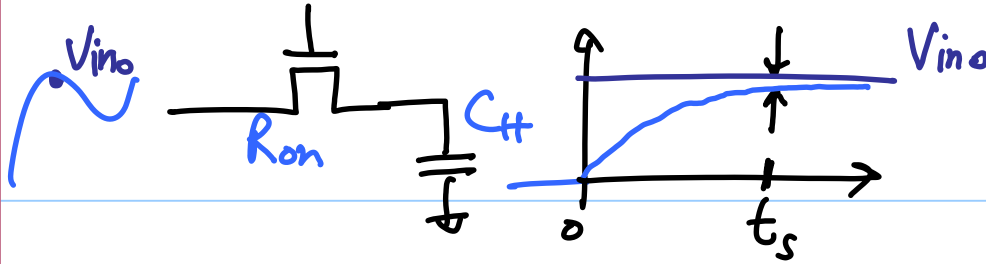
$$= \frac{1}{\beta_n (V_{DD} - V_{THN}) - [\beta_n - \beta_p] V_{in} - \beta_p |V_{THP}|}$$



$\Rightarrow$ ambiguity in the sampling instance







Time-constant

W/L

$$\tau \simeq R_{on} \cdot C_H$$

$$\frac{V_{out}}{V_{in0}} = \left(1 - e^{-t_s/\tau}\right)$$

$$V_{out} = (1-\epsilon)V_{in0}$$

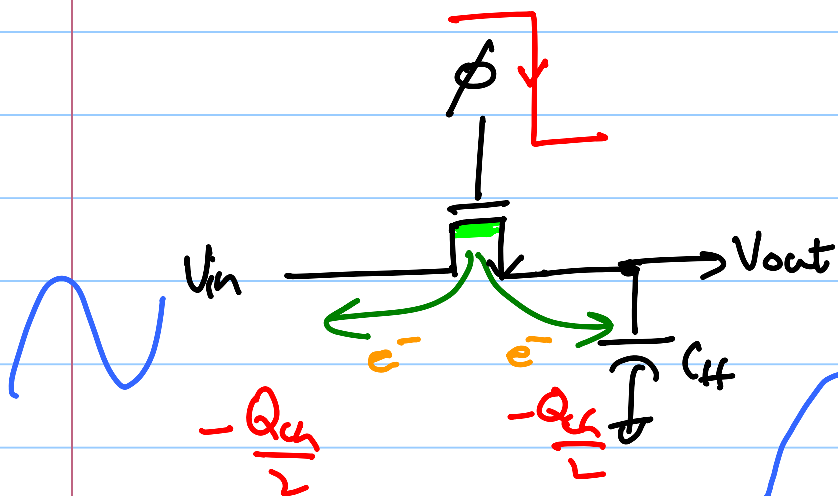
$$t_s = \tau \ln\left(\frac{1}{\epsilon}\right)$$

# of time-constants for settling

% error	ε	t_s/τ
10%	0.1	2.3
1%	0.01	4.6
0.1%	0.001	6.9
0.01%	0.0001	9.21

Precision Considerations:

1. channel "charge injection"
2. clock feedthrough
3. KT/C Noise



Assuming $V_{out} \simeq V_{in}$

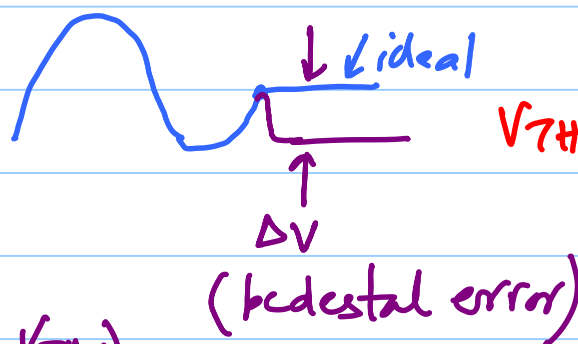
$$Q_{ch} = WLC'_{ox}(V_{GS} - V_{THN})$$

$$= WLC'_{ox}(V_{DD} - V_{in} - V_{THN})$$

$$V_{THN} = V_{THN_0} + \gamma\left(\sqrt{2\phi_B + V_{in}} - \sqrt{2\phi_B}\right)$$

$$\Delta V \simeq \frac{-Q_{ch}/2}{C_H}$$

$$\Delta V = -\frac{WLC_{ox}(V_{DD} - V_{in} - V_{THN})}{2C_H}$$



$$\Delta V = -\frac{WL\, C_{ox}\,(V_{DD} - V_{in} - V_{THN})}{2 C_H}$$

$$\Delta V \propto WL$$

$$\propto \frac{1}{C_H}$$

* Assumption of $-\frac{Q_{ch}}{2}$ being injected into C_H

↳ in reality depends upon the Z_D & Z_S at the time of clock transition

↳ no exact expression

↳ as a worst estimate, assume all of $-Q_{ch}$ is injected into C_H.

Impact of C.I. on precision

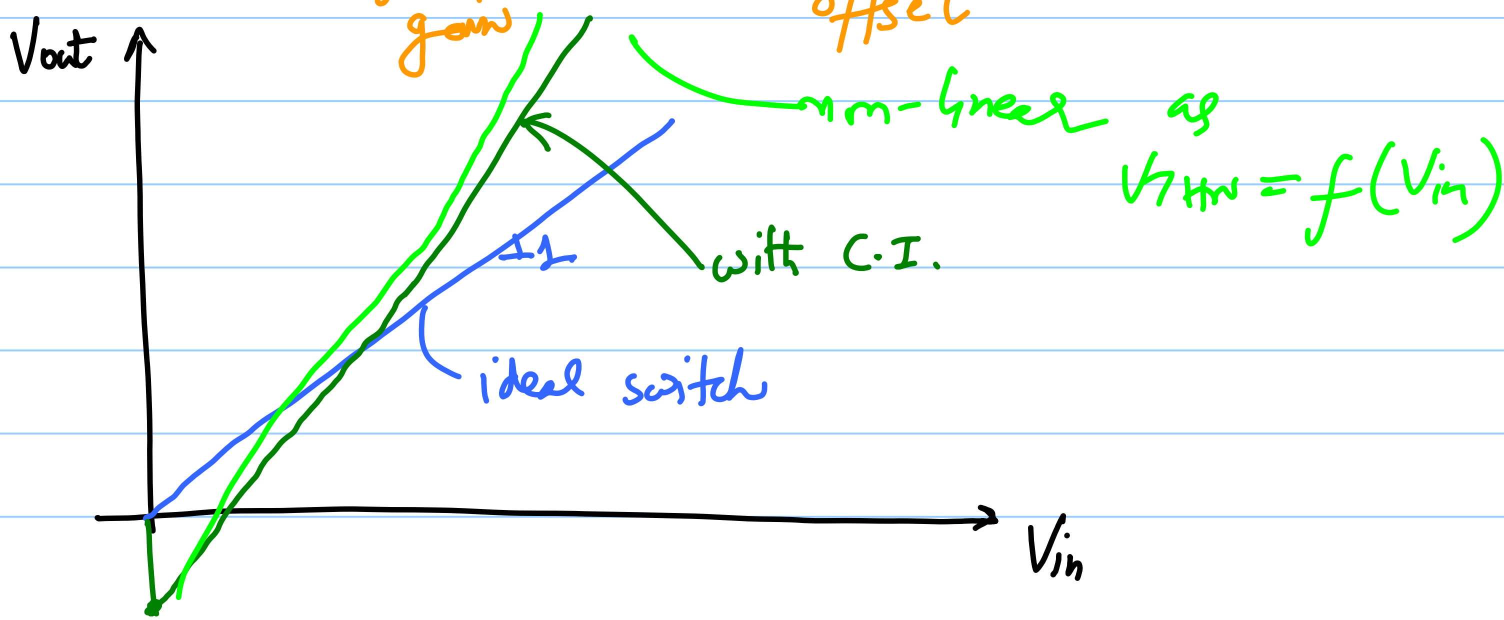
$C_{ox} \triangleq C'_{ox}$

$$V_{out} \simeq V_{in} - \Delta V$$

$$= V_{in} - \frac{WLC_{ox}(V_{DD} - V_{in} - V_{THN})}{C_H}$$

neglecting the phase shift b/w V_{in} & V_{out}

$$\Rightarrow V_{out} = \underbrace{V_{in}\left(1 + \frac{WLC_{ox}}{C_H}\right)}_{\text{gain}} - \underbrace{\frac{WLC_{ox}}{C_H}(V_{DD} - V_{THN})}_{\text{offset}}$$



$$V_{out} = V_{in}\left(1+\frac{WLC_{ox}}{C_H}\right) + \gamma\frac{WLC_{ox}}{C_H}\sqrt{2\phi_B + V_{in}}$$

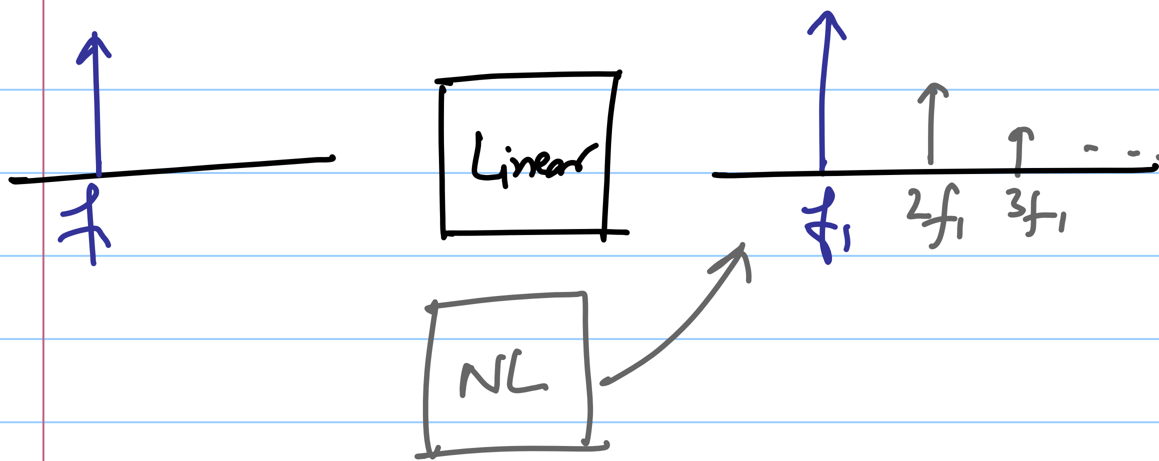
$$\underbrace{- \frac{WLC_{ox}}{C_H}\left(V_{DD} - V_{THN0} + \gamma\sqrt{2\phi_B}\right)}_{\text{fixed}}$$

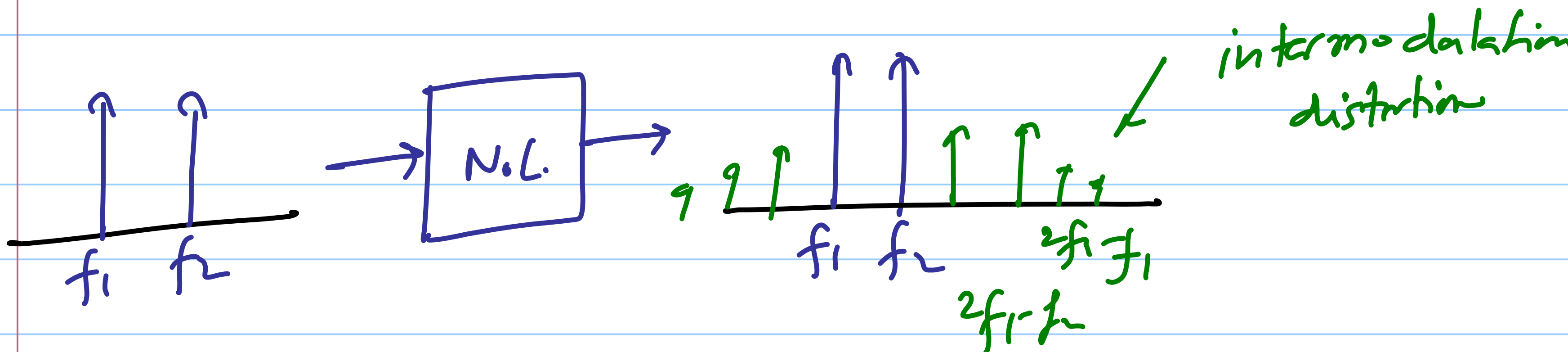
* Nonlinearity in the input-output characteristics

Charge-injection contributes errors in S/C circuits

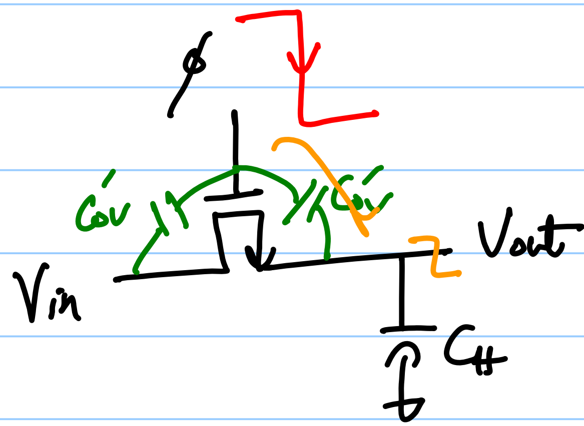
↳ gain error
↳ DC offset } can tolerate using circuit techniques

↳ non-linearity } cannot be tolerated


f
Linear
NL
f_1
$2f_1$
$3f_1$


f_1
f_2
N.L.
$2f_1$
f_1
$2f_1 - f_2$
intermodulation distortion

② Clock feedthrough :



Capacitive Divider

overlap Cap

$$\Delta V = V_{clk} \cdot \frac{\underbrace{W C_{ov}'}_{\text{overlap Cap}}}{W C_{ov}' + C_H}$$

$C_{ov}' \Leftarrow$ overlap cap per unit width

$\Delta V \Leftarrow$ indep of V_{in}

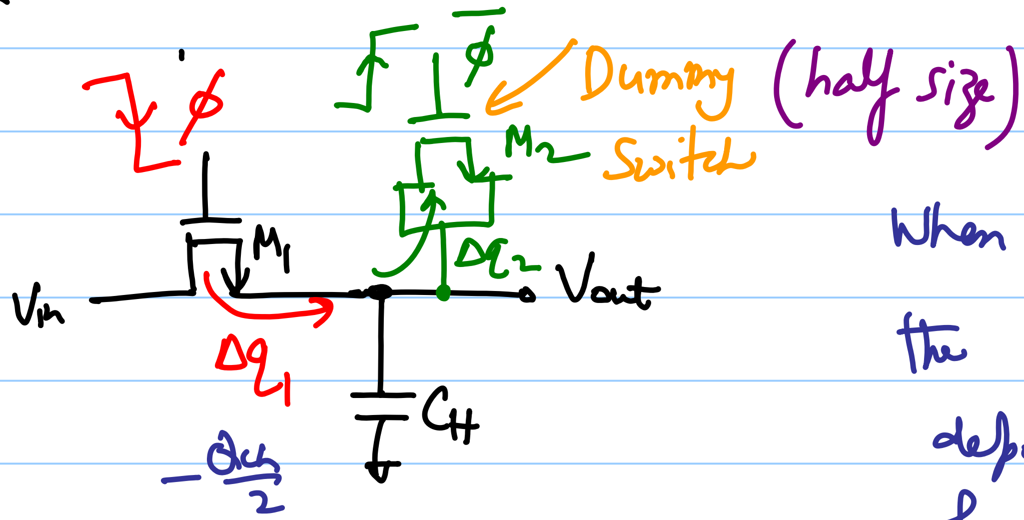
$\hookrightarrow$ introduces a constant offset in the sampled output

$W \uparrow \Rightarrow \Delta V \uparrow$

Could use $C_H \gg W C_{ov}'$

Charge injection Cancellation

①



When M_1 turns off & M_2 turns on the channel charge Δq_1 deposited on C_H is absorbed by M_2 to create its channel (Δq_2)

for perfect cancellation

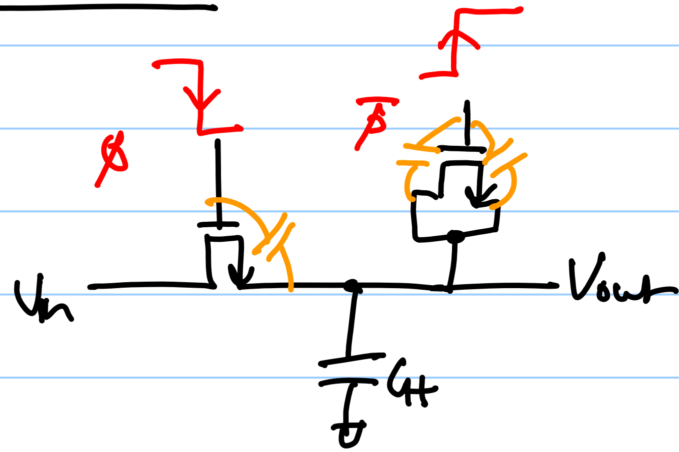
$$\Delta q_1 = \Delta q_2$$

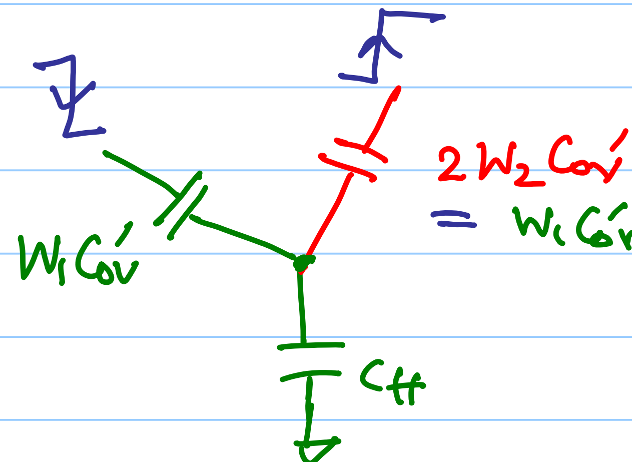
$$\frac{W_1 L_1 C_{ox}}{2}(V_{CLK} - V_{in} - V_{THN1}) = W_2 L_2 C_{ox}(V_{CLK} - V_{in} - V_{THN2})$$

for $W_2 = \frac{W_1}{2}$ & $L_2 = L_1$ it could work!

the assumption of ½ way splitting makes it less robust

However



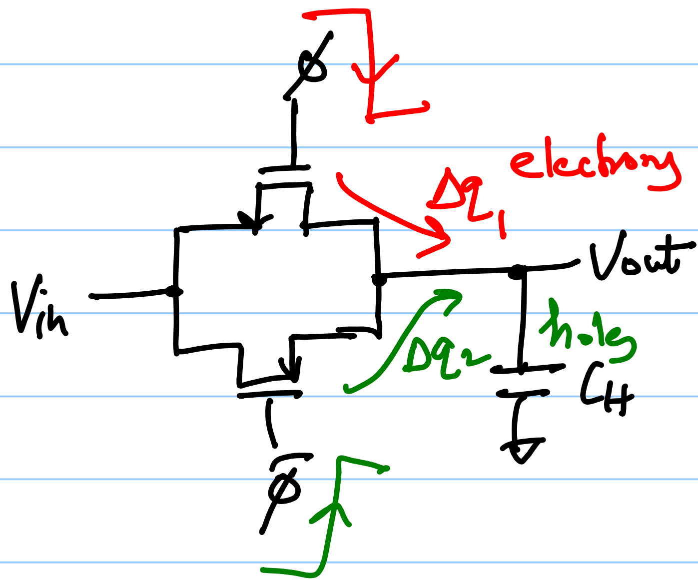


⇒ Clock feedthru is cancelled using this scheme

⇒ Soln' use ½-size dummy to absorb injected charge.

②
Complementary Switches

NMOS & PMOS
↳ inject opposite charge packets



for $\Delta q_1 = \Delta q_2$

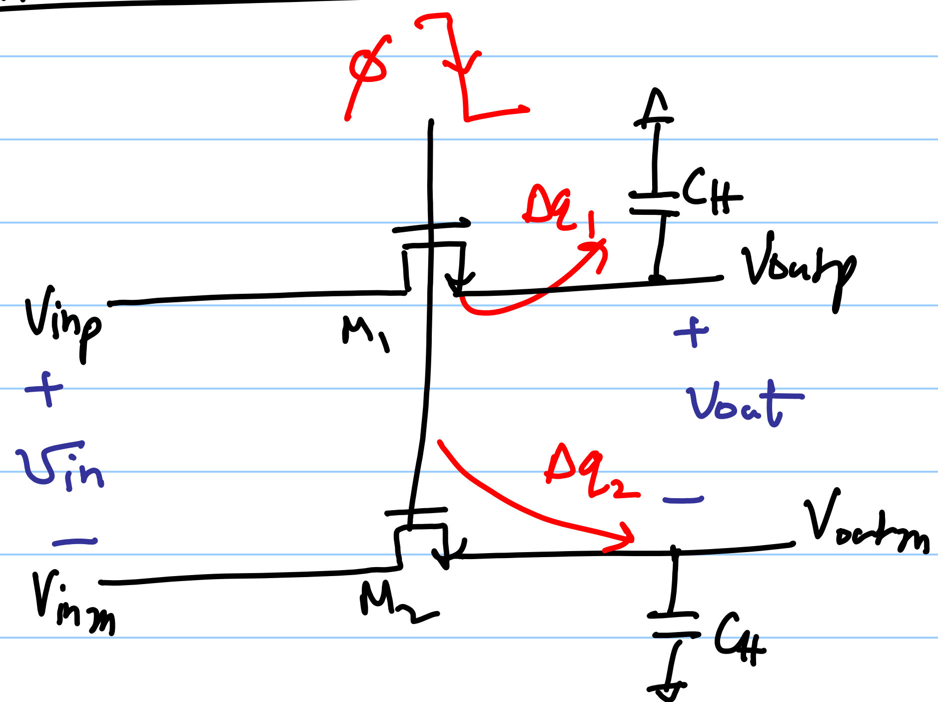
We must have

$$W_1 L_1 C_{ox} (V_{clk} - V_{in} - V_{THN}) = W_2 L_2 C_{ox} (V_{in} - |V_{THP}|)$$

Cancellation only works for one input value :(

* Don't provide clock feedthru cancellation as $C_{ov,n} \neq C_{ov,p}$

③ Differential Circuits.



Differential error charge

$$\Delta q = \Delta q_1 - \Delta q_2 = WLC_{ox}\left[-(V_{inp}-V_{inm}) + (V_{THN_2} - V_{THN_1})\right]$$

$$= WLC_{ox}\Big[\underbrace{-(V_{inp}-V_{inm})}_{1^{st}\text{ order}} + \gamma\underbrace{\left(\sqrt{2\phi_B+V_{inm}} - \sqrt{2\phi_B+V_{inp}}\right)}_{\text{Odd function.}}\Big]$$

* No DC offset due to C.I.

* non-linear terms $\Rightarrow$ odd-order distortion remains

All even-order distortion is cancelled