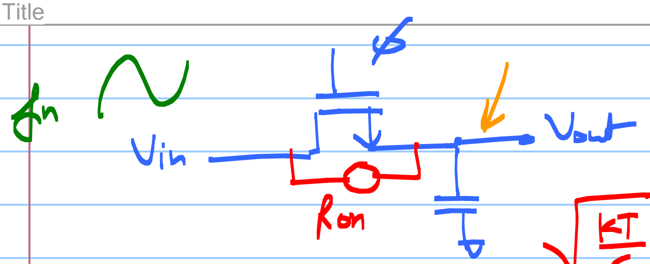
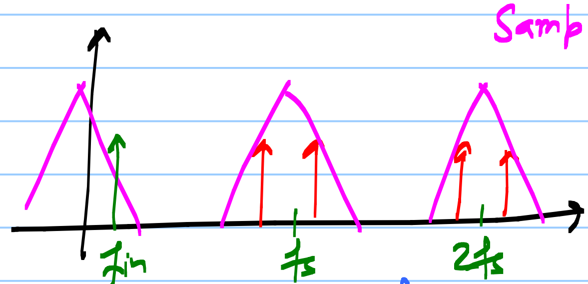
ECE 614 – Lecture 13

Note Title 10/16/2012



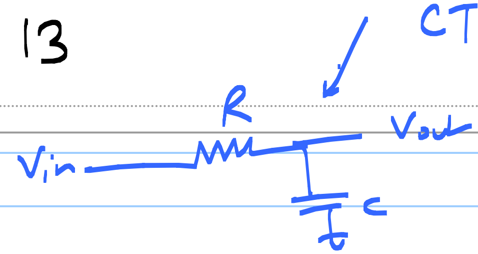
$\sqrt{\frac{kT}{C}}$

Sampling



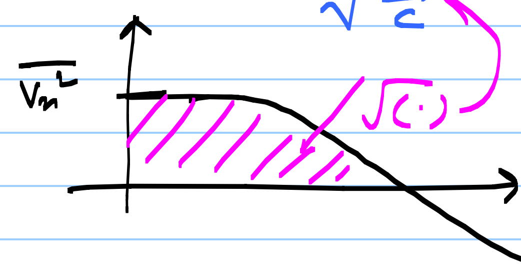
$f_s \geq 2\,BW$

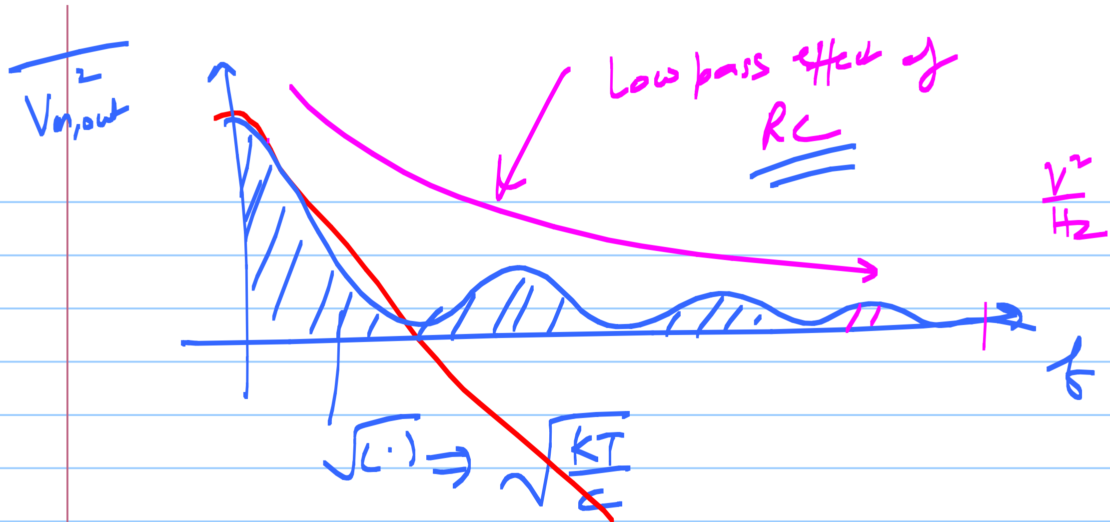
Nyquist Sampling Theorem

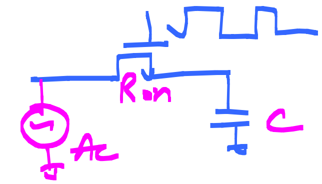


$$V_{noise,rms} = \sqrt{\int \overline{V_n^2}(f)\,df}$$

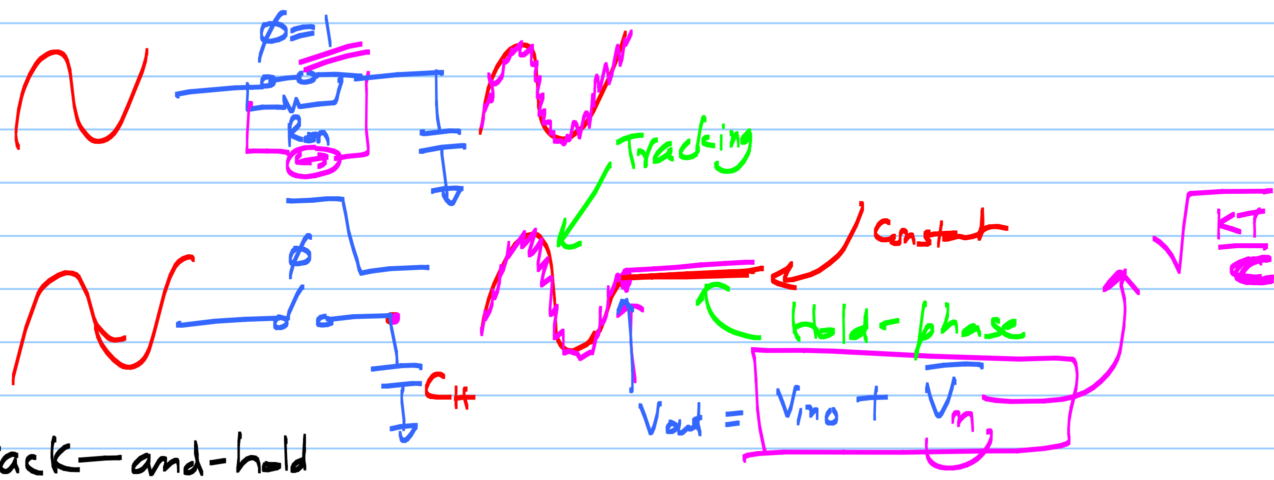
$$= \sqrt{\frac{kT}{C}}$$





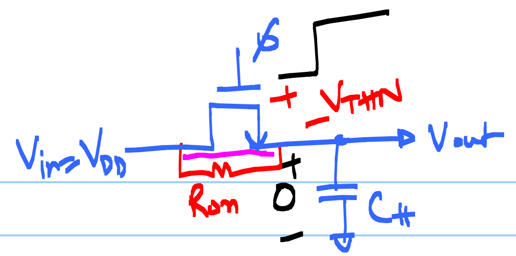


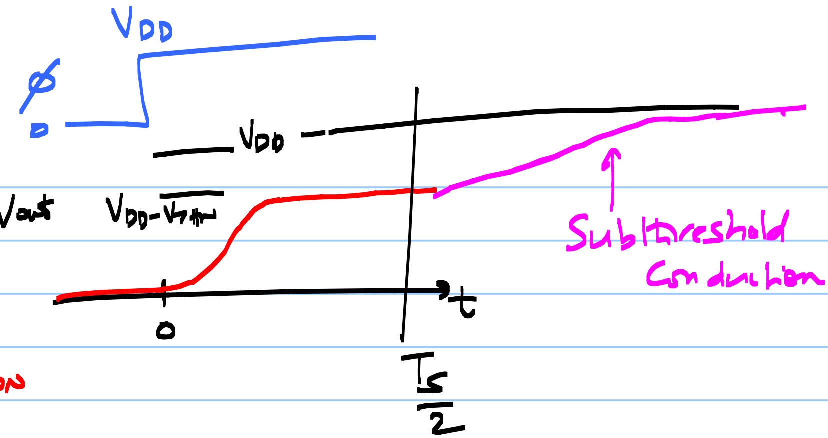
. PNoise



$V_{out} = V_{in0} + \overline{V_n}$

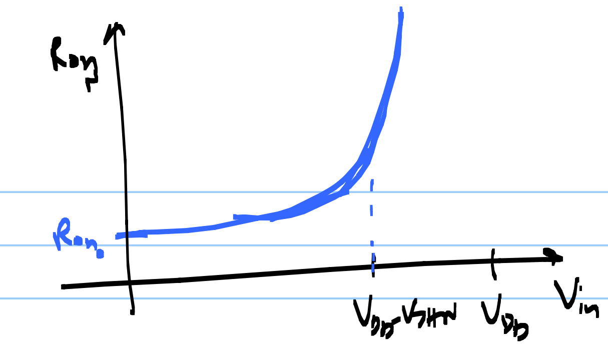
Track-and-hold circuit





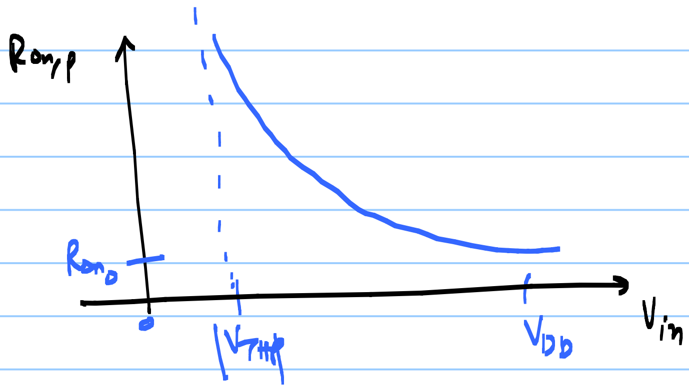
switch open ← MOSFET is off

switch closed ← MOSFET ON

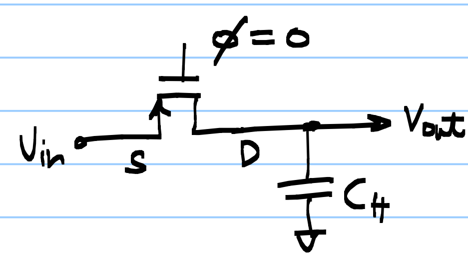


$$R_{on,N} = \frac{1}{\mu_n C_{ox} \frac{W}{L} \left(V_{DD} - V_{in} - V_{THN}\right)}$$

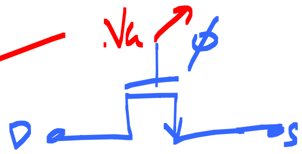
↑ Triode



$$R_{on,p} = \frac{1}{\mu_p C_{ox} \frac{W}{L} \left(V_{in} - |V_{THP}|\right)}$$

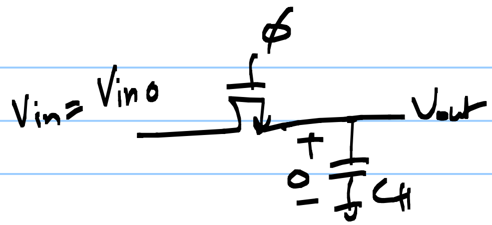


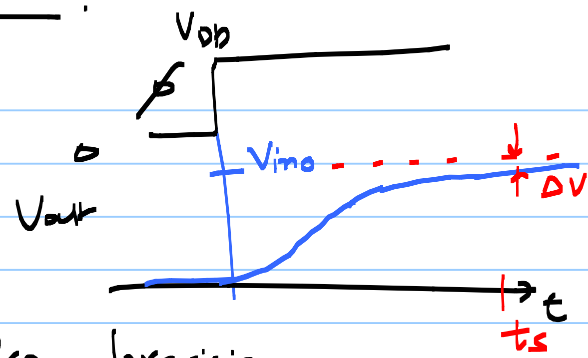
MOS
a good switch



* D & S can interchange
* V_G is unhinged from V_D, V_S
* Can be on without conducting any DC current

Speed Considerations





$t_s < \frac{T_s}{2}$

⇒ speed spec must come from precision

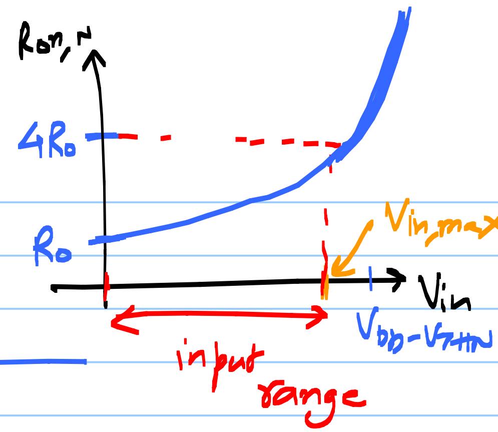
$$\tau = R_{on} \cdot C_H$$

R_{on} → Large $\frac{W}{L}$

C_H → small cap

$$R_{on} = f(V_{in})$$

If we restrict R_{on} to a range of 4 to 1

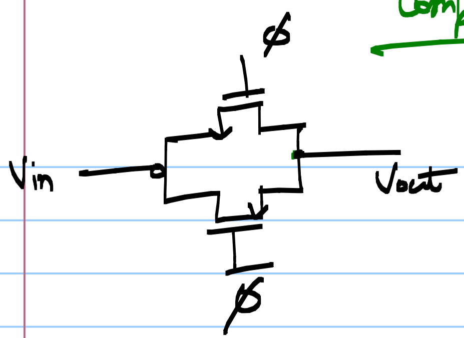


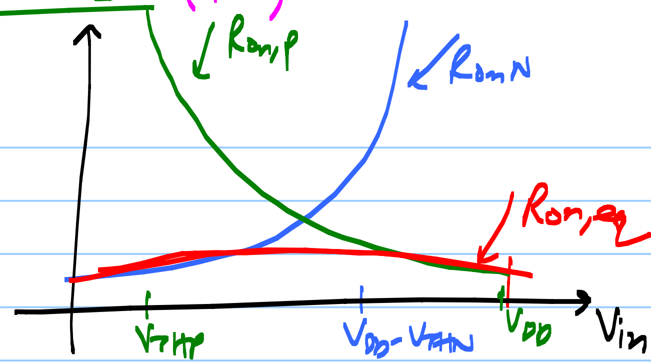
$$\underbrace{\frac{1}{\mu_n C_{ox}\frac{W}{L}(V_{DD}-V_{in,max}-V_{THN})}}_{R_{on}(V_{in,max})} = \underbrace{\frac{4}{\mu_n C_{ox}\frac{W}{L}(V_{DD}-V_{THN})}}_{4\cdot R_{on}(0)}$$

$$V_{in,max} = \frac{3}{4}(V_{DD}-V_{THN}) \simeq \frac{V_{DD}}{2}$$

↑ Severe swing limitation

Complementary switches (TG)





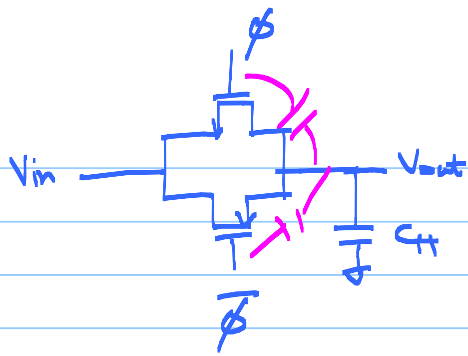
$$R_{on,eq} = R_{on,n} \parallel R_{on,p}$$

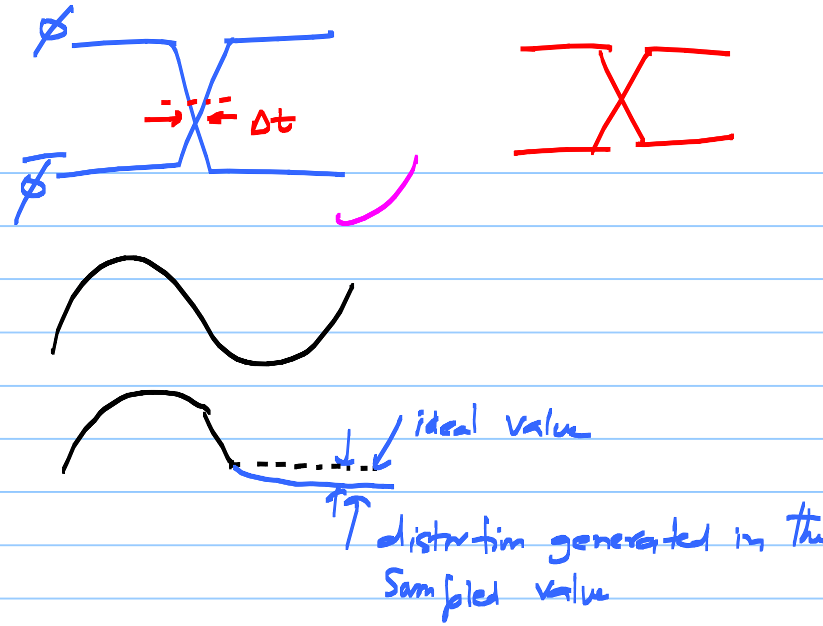
$$= \frac{1}{\mu_n C_{ox}\left(\frac{W}{L}\right)_N (V_{DD}-V_{THN}) - \left[\mu_n C_{ox}\left(\frac{W}{L}\right)_N - \mu_p C_{ox}\left(\frac{W}{L}\right)_p\right] V_{in} - \mu_p C_{ox}\left(\frac{W}{L}\right)_p |V_{THP}|}$$

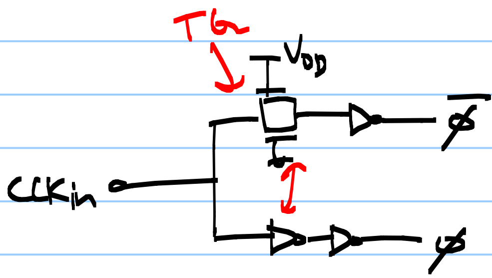
V_{THN}: $f(\sqrt{V_{in}})$

$\left[\mu_n C_{ox}\left(\frac{W}{L}\right)_N - \mu_p C_{ox}\left(\frac{W}{L}\right)_p\right] \Rightarrow \approx 0$ → mostly independent of input level

$|V_{THP}|$: $f(\sqrt{V_{in}})$

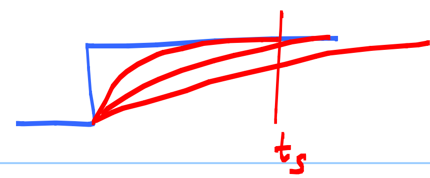




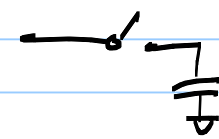


simple circuit

$\tau = R_{on,eq} \cdot C_H$



$$\frac{V_{out}}{V_{in_0}} = \left(1 - e^{-t_s/\tau}\right)$$



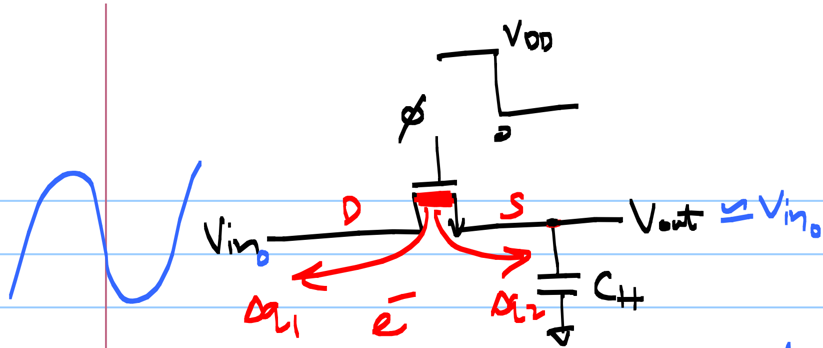
$\Rightarrow \quad V_{out} = (1-\epsilon) V_{in_0}$

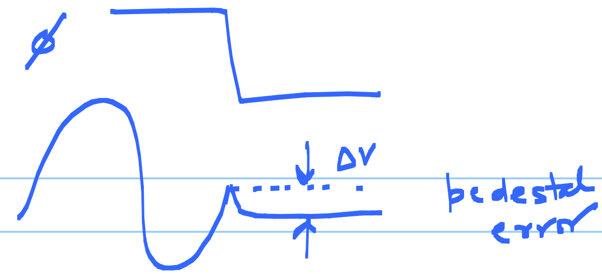
(ϵ ← error)

$\Rightarrow \quad t_s = \tau \ln(1/\epsilon)$

Precision Consideration

1. Channel "Charge injection"
2. Clock feedthrough
3. $\frac{KT}{C}$ Noise $\left(\sqrt{\frac{kT}{C}}\right)$





Triode

$Q_{ch} = WL\, C_{ox} (V_{DD} - V_{in} - V_{THN})$

Total channel charge

$V_{THN} = V_{THN0} + \gamma\left(\sqrt{2\phi_B + V_{in}} - \sqrt{2\phi_B}\right)$

Assuming that $\frac{Q_{ch}}{2}$ is injected into C_H

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

(negative)

$Q_{ch} \propto WL$

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

$V_{out} = ?$

$V_{out} = V_{in} - |\Delta V|$ ← C.I. error

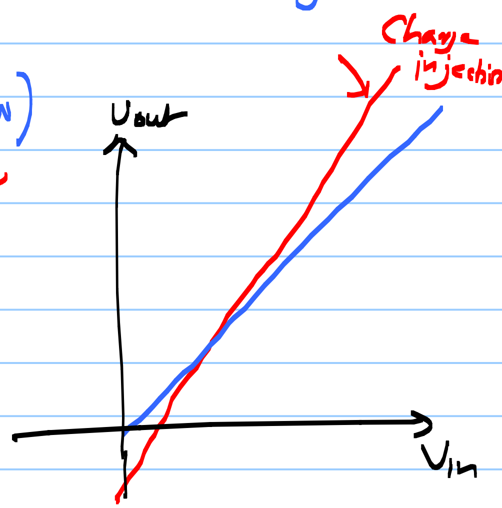
$\Rightarrow V_{out} = V_{in} - \dfrac{WLC_{ox}(V_{DD} - V_{in} - V_{THN})}{C_H}$

= "V_{in}" ideally

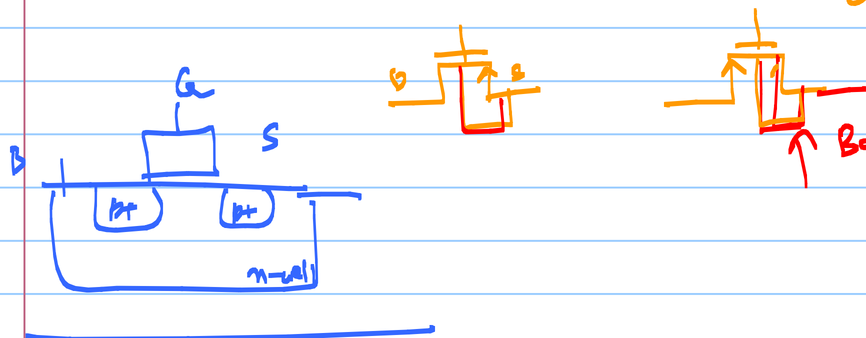
$= V_{in}\left(1 + \dfrac{WLC_{ox}}{C_H}\right) - \dfrac{WLC_{ox}}{C_H}(V_{DD} - V_{THN})$

gain > 1 DC offset

* all Q_{ch} is injected into C_H
  ↳ worst case analysis



⇒ PMOS ⇒ D & S can interchange



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

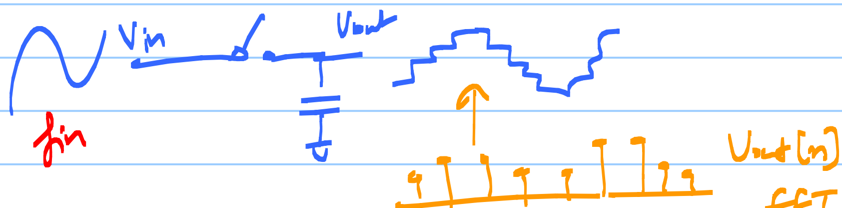
gain error

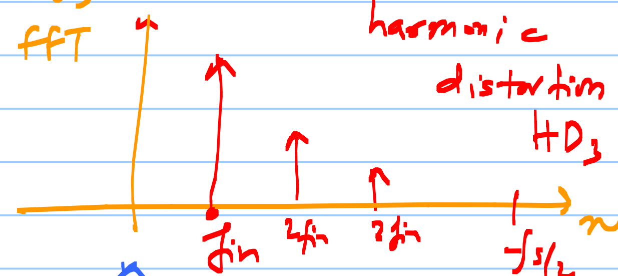
due to body effect

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

DC offset

$$(1+x)^{1/2} = 1 + a_0 x + a_2 x^2 + a_3 x^3 + \dots \infty$$

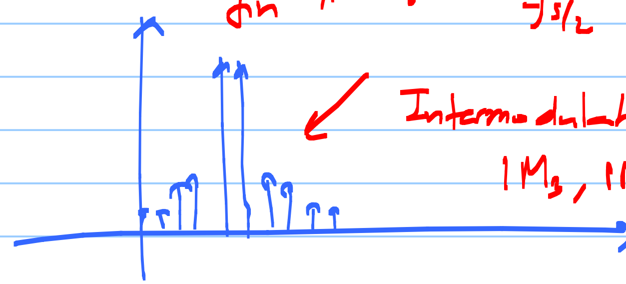




harmonic distortion

HD_3

input has two tones



Intermodulation

IM_3, IM_5