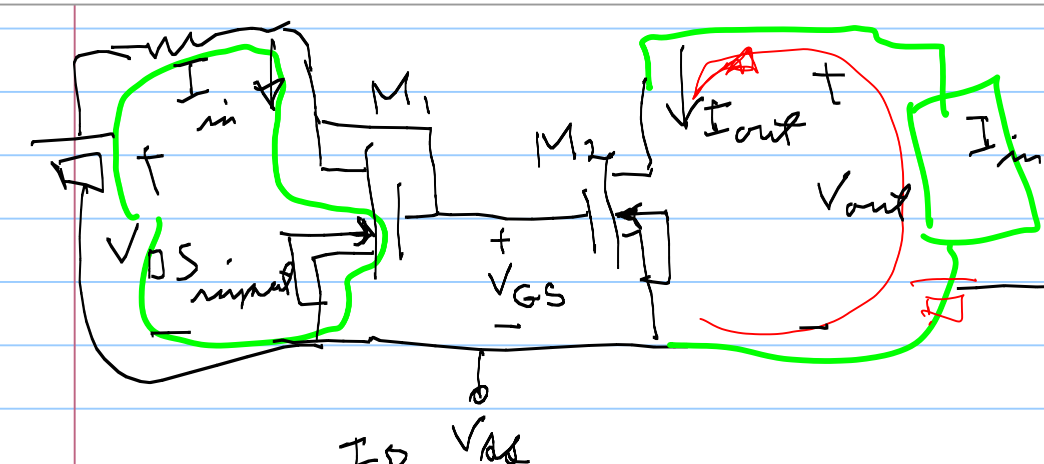
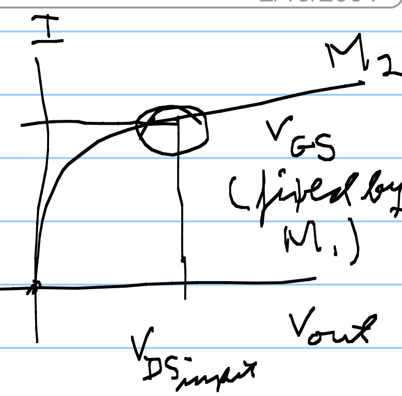
Note Title

EE 302

2/19/2004





p. 254

NMOS

p. 254 (5th edition)

to correct for slope giving the Early voltage
multiply by $(1 + \text{lambda} \cdot V_{DS})$

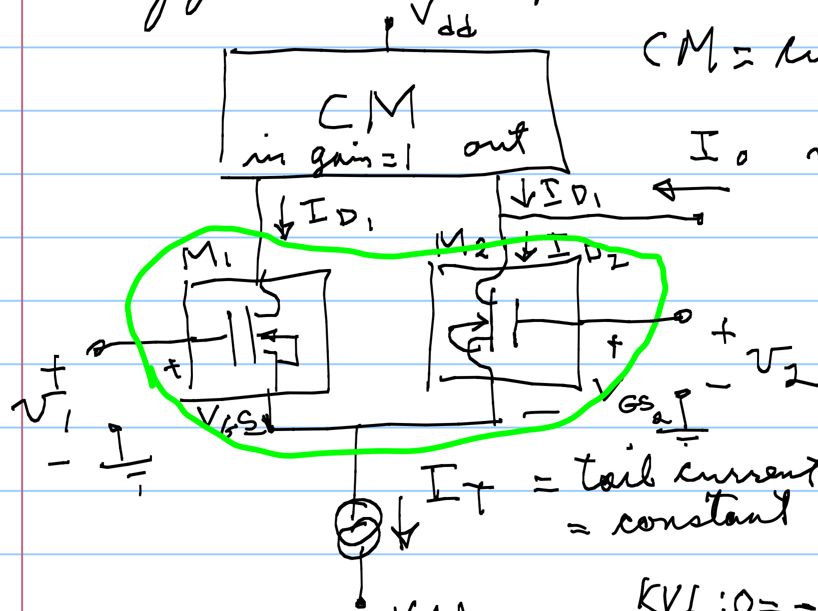
$$V_{Early} = -\frac{1}{\text{lambda}}$$

P. 258: Body effect - eq. (4.33)

$$V_{th} = VTO + \text{gamma}\left(\sqrt{2\varphi + V_{SB}} - \sqrt{2\varphi}\right)$$

$\varphi \approx 0.6$

Differential pairs.



CM = current mirror

I_0 vs $(v_1 - v_2) = v_i$

$I_0 = I_{D_2} - I_{D_1}$

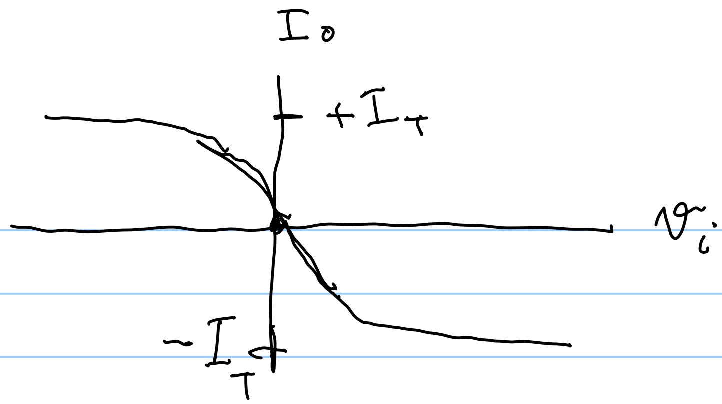
$I_T = I_{D_2} + I_{D_1}$

I_T = tail current = constant

assume $M_1 = M_2$

KVL : $0 = -v_1 + V_{GS_1} - V_{GS_2} + v_2$

$v_1 - v_2 = V_{GS_1} - V_{GS_2} = v_i$



assume M_1 & M_2 in saturation & no Early effect

$I_{D_1} = \beta(V_{GS_1} - V_{th})^2$, $I_{D_2} = \beta(V_{GS_2} - V_{th})^2$

$= \beta(V_{GS_1} - v_i - V_{th})^2$

$\beta = \frac{KP}{2} \times \frac{W}{L}$

let $x = V_{GS_1} - V_{th}$

$I_o = \beta(x - v_i)^2 - \beta(x)^2$; $I_T = \beta(x - v_i)^2 + \beta x^2$

$\frac{I_T}{\beta} = 2x^2 - 2v_i x + v_i^2 \Rightarrow 0 = x^2 - v_i x + [v_i^2 - I_T/\beta]/2$

$$x = +\frac{v_i}{2} \pm \frac{1}{2}\sqrt{v_i^2 - 4\left[v_i^2 - I_T/\beta\right]/2}$$

$$= \frac{1}{2}\left[v_i \pm \sqrt{\frac{2I_T}{\beta} - v_i^2}\,\right] \quad \text{if} \quad \sqrt{\frac{2I_T}{\beta}} \geq |v_i|$$

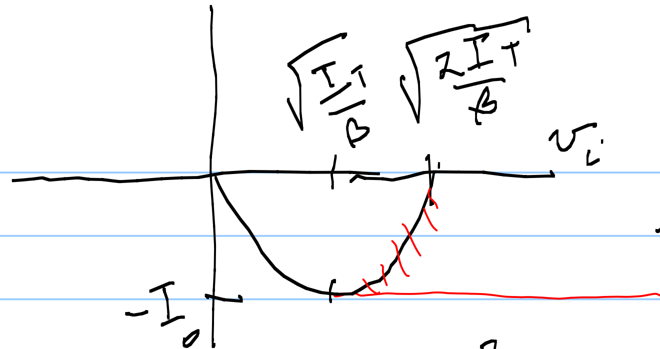
$$x - v_i = -\frac{1}{2}v_i \pm \frac{1}{2}\sqrt{\frac{2I_T}{\beta} - v_i^2}$$

$$\frac{I_0}{\beta} = (x - v_i)^2 - x^2 = -2v_i x + v_i^2$$

$$= \cancel{-2v_i \cdot \frac{v_i}{2}} \mp v_i\sqrt{\frac{2I_T}{\beta} - v_i^2} \cancel{+ v_i^2}$$

$$I_0 = \mp \beta v_i \sqrt{\frac{2I_T}{\beta} - v_i^2} \quad ; \quad |v_i| \leq \sqrt{\frac{2I_T}{\beta}}$$

by physical reasoning



strange!

let $k = 2I_T/\beta$

$$\frac{d}{dv_i}\left[-\beta v_i \sqrt{k - v_i^2}\right] = -\beta\sqrt{k - v_i^2} - \frac{\beta v_i(-\cancel{2}v_i)}{\sqrt{k - v_i^2}} \times \frac{1}{\cancel{2}} = 0$$

for the "peak"

$$-(k - v_i^2) + v_i^2 = 0 \Rightarrow 2v_i^2\Big|_{peak} = k$$

$$v_i\Big|_{peak} = \sqrt{\frac{k}{2}} = \sqrt{\frac{I_T}{\beta}} \; ; \; I_0\Big|_{peak} = -\beta\sqrt{\frac{I_T}{\beta}}\cdot\sqrt{\frac{2I_T}{\beta} - \frac{I_T}{\beta}} = -I_0$$

$$I_o = \begin{cases} -I_T & \text{if } v_i \geq \sqrt{I_T/\beta} \\ -\beta v_i \sqrt{\dfrac{2I_T}{\beta} - v_i^2} & -\sqrt{\dfrac{I_T}{\beta}} \leq v_i \leq \sqrt{\dfrac{I_T}{\beta}} \\ +I_T & \text{if } v_i \leq -\sqrt{\dfrac{I_T}{\beta}} \end{cases}$$