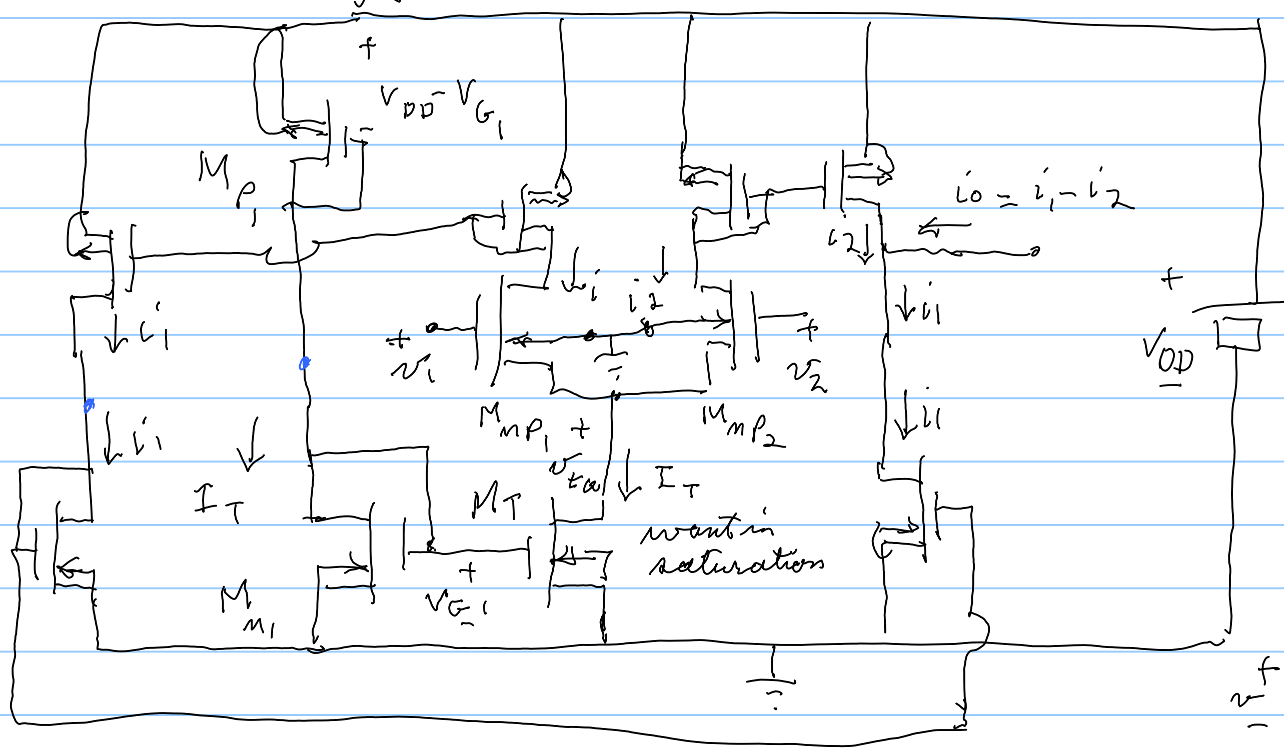
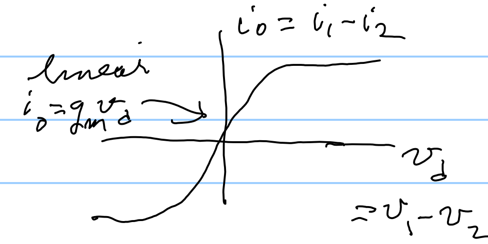
Note Title 10/1/2015

EE 303H

10/01/15

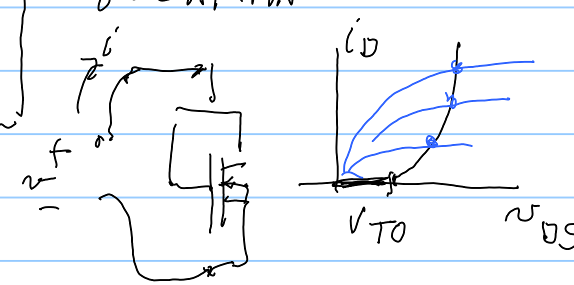
MOS differential pair





$V_{th} = V_{TO} + \gamma\left[\sqrt{v_{SB} + \phi} - \sqrt{\phi}\right]$

γ = GAMMA



$$-I_{D_{M_{p_1}}} = +I_{D_{M_{n_1}}} = \frac{KP}{2}\frac{W}{L}\Big|_n \left(V_{G_1} - V_{TO_n}\right)^2 = \frac{KP}{2}\frac{W}{L}\Big|_p \left(V_{DD} - V_{G_1} - |V_{TO_p}|\right)^2 = I_{T_{ail}}$$

$$= k_n\left(V_{G_1} - V_{TO_n}\right)^2 = k_p\left(V_{DD} - V_{G_1} - |V_{TO_p}|\right)^2$$

$$\frac{k_p}{k_n} = \frac{\left(V_{G_1} - V_{TO_n}\right)^2}{\left(V_{DD} - V_{G_1} - |V_{TO_p}|\right)^2} \Rightarrow k_p = \frac{I_T}{\left(V_{DD} - V_{G_1} - |V_{TO_p}|\right)^2}$$

desire $\frac{k_p}{k_n}$ choose $k_n \Rightarrow V_{G_1}$ for given I_T ; $V_{G_1} = V_{TO} + \sqrt{\frac{I_T}{k_n}}$

$\Rightarrow k_p$ from $k_p = \dfrac{I_T}{\left(V_{DD} - V_{G_1} - |V_{TO_p}|\right)^2}$

$k_n = \frac{KP_n}{2}\left(\frac{W}{L}\right)_n \Rightarrow k_p = \frac{KP_p}{2}\left(\frac{W}{L}\right)_p$ know all about M_{p_1}

to get $i_0 = f(v_d)$:

$$I_T = i_1 + i_2 \,, \quad i_0 = i_1 - i_2$$

$$i_1 = k_n\left(v_1 - v_{ta} - V_{th}\right)^2 \quad i_2 = k_n\left(v_2 - v_{ta} - V_{th}\right)^2 \;; \quad v_d = v_1 - v_2$$

$$+\sqrt{i_1/k_n} = v_1 - v_{ta} - V_{th} \qquad +\sqrt{i_2/k_n} = v_2 - v_{ta} - V_{th}$$

$$\sqrt{\frac{i_1}{k_n}} - \sqrt{\frac{i_2}{k_n}} = \left[(v_1) - (V_{ta} + V_{th})\right] - \left[(v_2) - (V_{ta} + V_{th})\right] = v_1 - v_2 = v_d$$

$$\Rightarrow \sqrt{\frac{i_1}{k_n}} = \sqrt{i_2/k_n} + v_d \qquad \text{also} \qquad \sqrt{\frac{i_2}{k_n}} = \sqrt{i_1/k_n} - v_d$$

$$\frac{i_1}{k_n} = \frac{i_2}{k_n} + v_d^2 + 2v_d\sqrt{\frac{i_2}{k_n}} \qquad \frac{i_2}{k_n} = i_1/k_n + v_d^2 - 2v_d\sqrt{i_1/k_n}$$

$$\frac{i_0}{k_n} = v_d^2 + 2v_d\sqrt{\frac{i_2}{k_n}} \qquad \frac{-i_0}{k_n} = v_d^2 - 2v_d\sqrt{i_1/k_n}$$

also $I_T = i_1 + i_2 \Rightarrow \frac{I_T}{k_n} = \frac{i_1}{k_n} + \frac{i_2}{k_n}$

$$\Rightarrow \frac{i_2}{k_n} = \left(\frac{\frac{i_0}{k_n} - v_d^2}{2v_d}\right)^2 \qquad \frac{i_1}{k_n} = \left(\frac{i_0/k_n + v_d^2}{2v_d}\right)^2$$

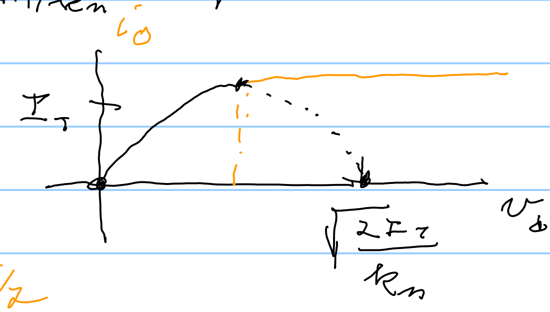
$$\frac{I_T}{k_n} = \frac{(i_0/k_n)^2 + v_d^4 + \cancel{2v_d}^{2}\, i_0/k_n}{4v_d^2} + \frac{(i_0/k_n)^2 + v_d^4 - \cancel{2}v_d^2\, i_0/k_n}{4v_d^2}$$

$$= \left[(i_0/k_n)^2 + v_d^4\right] / 2v_d^2$$

$$\left(\frac{i_o}{k_n}\right)^2 = 2v_d^2 \cdot \frac{I_T}{k_n} - v_d^4 \Rightarrow \frac{i_o}{k_n} = \pm\sqrt{2v_d^2 \cdot \frac{I_T}{k_n} - v_d^4}$$

$$\Rightarrow i_o = k_n \cdot \sqrt{\frac{2I_T}{k_n}} \cdot v_d \sqrt{1 - \frac{v_d^2}{2I_T/k_n}} = \sqrt{2k_n I_T} \cdot v_d \sqrt{1 - \left(\frac{v_d}{\sqrt{\frac{2I_T}{k_n}}}\right)^2}$$

$$i_o = 2I_T \cdot \underbrace{\left[\left(\frac{v_d}{\sqrt{\frac{2I_T}{k_n}}}\right)\sqrt{1 - \left(\frac{v_d}{\sqrt{\frac{2I_T}{k_n}}}\right)^2}\right]}_{\max = 1/2}$$



$$= 2x\sqrt{1-x^2}, \quad x = \frac{v_d}{\sqrt{2I_T/k_n}}$$

$$\frac{d\,x\sqrt{1-x^2}}{dx} = \sqrt{1-x^2} + x\left(\frac{1}{2}\frac{1}{\sqrt{1-x^2}} \times (-2x)\right) = \frac{1-x^2-x^2}{\sqrt{1-x^2}} = 0 \text{ at max}$$

$$1-2x^2 = 0 \Rightarrow x = 1/\sqrt{2} \Rightarrow x\sqrt{1-x^2} = \frac{1}{\sqrt{2}}\sqrt{1-\frac{1}{2}} = \frac{1}{\sqrt{2}\sqrt{2}} = 1/2$$

$$i_o\Big|_{max} = I_T$$