03/02/11
EE303

$$i_1 = \frac{I_T}{2} - \frac{1}{2}\sqrt{2I_T\beta}\cdot v_d\sqrt{1-\left(\frac{v_d^2\beta}{2I_T}\right)}$$

$$i_2 = \frac{I_T}{2} + \frac{1}{2}\sqrt{2I_T\beta}\, v_d\sqrt{1-\left(\frac{v_d^2\beta}{2I_T}\right)}$$

$$i_0 = i_2 - i_1 = \underbrace{\sqrt{2I_T\beta}}_{G_0}\, v_d\sqrt{1-\left(\frac{v_d^2\beta}{2I_T}\right)}$$

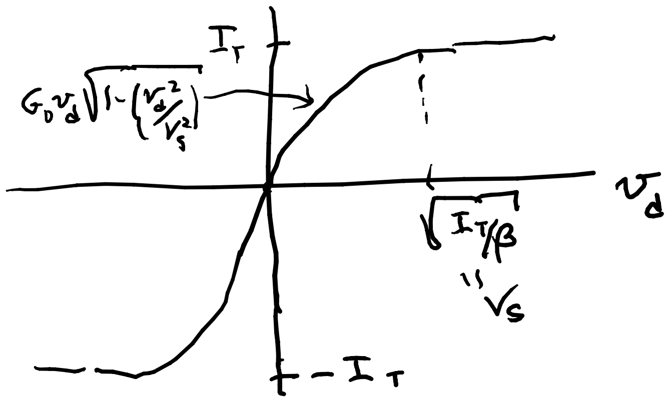
this has $\sqrt{-1}$ if v_d is very large

$$\max i_0 \Rightarrow \frac{d i_0}{d v_d} = G_0\left[\sqrt{1-\left(\frac{v_d^2\beta}{2I_T}\right)} + \frac{v_d\cdot\frac{1}{2}\left(-2v_d\beta/2I_T\right)}{\sqrt{1-\left(\frac{v_d^2\beta}{2I_T}\right)}}\right]$$

$$= \frac{G_0}{\sqrt{1-(\cdot)}}\left[1-\left(\frac{v_d^2\beta}{2I_T}\right)-\frac{v_d^2\beta}{2I_T}\right] = \frac{G_0}{\sqrt{1-(\cdot)}}\left[1-\frac{1}{1}\frac{v_d^2\beta}{I_T}\right]$$

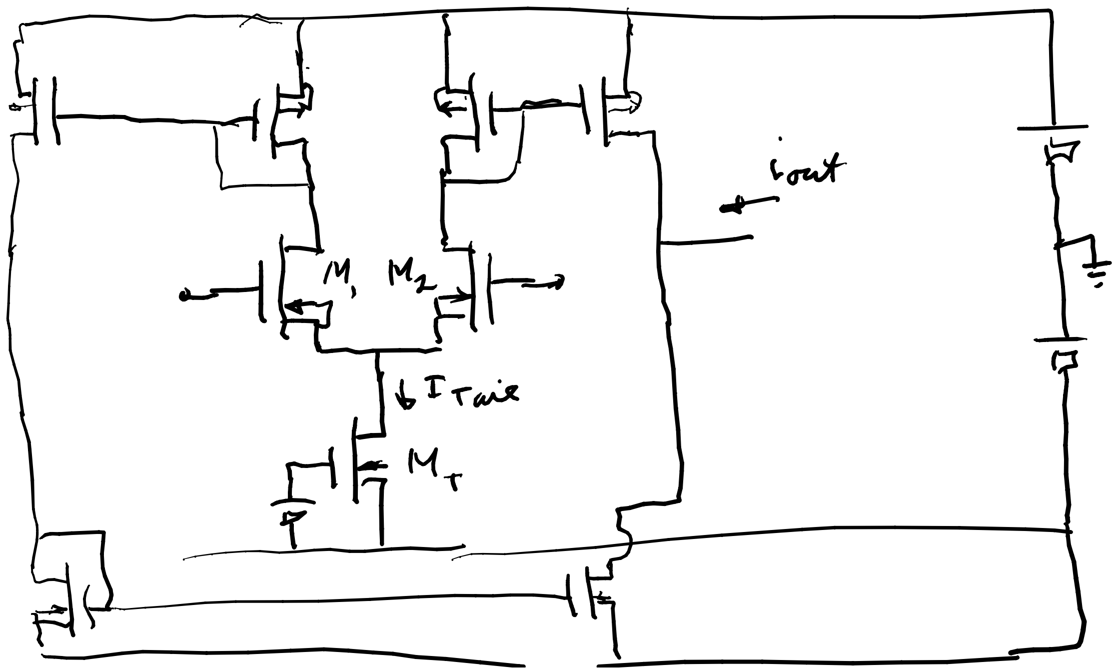
$$= 0 \Rightarrow v_d^2 = 1\frac{I_T}{\beta},\quad v_d = \pm\cancel{2}\sqrt{\frac{I_T}{\beta}}$$

$$i_0 = G_0\left[\cancel{2}\sqrt{\frac{I_T}{\beta}}\cdot\sqrt{1-\frac{1}{2}} = G_0\cdot\sqrt{\frac{I_T}{\beta}}\cdot\frac{1}{\sqrt{2}} = \sqrt{2I_T\beta}\cdot\sqrt{\frac{I_T}{\beta}}\cdot\frac{1}{\sqrt{2}} = I_T\right.$$

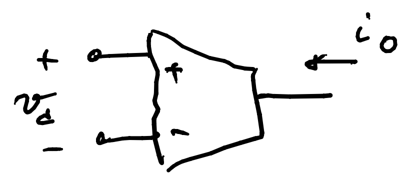


$$\beta = \frac{KP}{2}\frac{W}{L}$$

note I_T can vary with a voltage on the gate of its transistor



$\Rightarrow$



OTA

6th edition

MOS picture p. 233

ECL p. 1180

pass transistors p. 1153

BJT $\Rightarrow$ Ebers-Moll equation describe B9

$\Rightarrow$ Gummel-Poon (used by Spice) B11

MOS threshold voltage p. 324

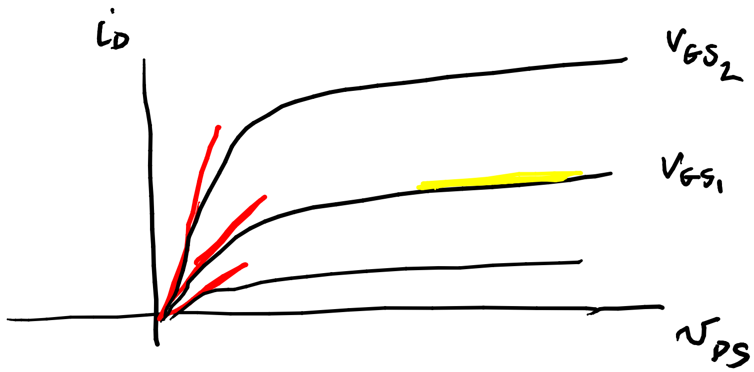
$$V_{th} = VTO + \gamma\left(\sqrt{2\phi_f + V_{SB}} - \sqrt{2\phi_f}\right)$$ n channel $2\phi_f \approx 0.6$

B = S

$$= VTO - \gamma\left(\sqrt{2\phi_f + |V_{SB}|} - \sqrt{2\phi_f}\right)$$ p channel $2\phi_f \approx 3/4$

MOS, NMOS

$$i_D = \frac{KP}{2}\frac{W}{L} \times \begin{cases} 0 & \text{cut-off. } v_{GS} < V_{th} \\ \left(2(v_{GS}-V_{th})v_{DS} - v_{DS}^2\right)(1+\lambda v_{DS}), & V_{GS} \geq V_{th},\ V_{GS}-V_{th} \geq v_{DS} \text{ ohmic} \\ (v_{GS}-V_{th})^2(1+\lambda v_{DS}) & \text{saturation, } 0 \leq v_{GS}-V_{th} \leq v_{DS} \end{cases}$$

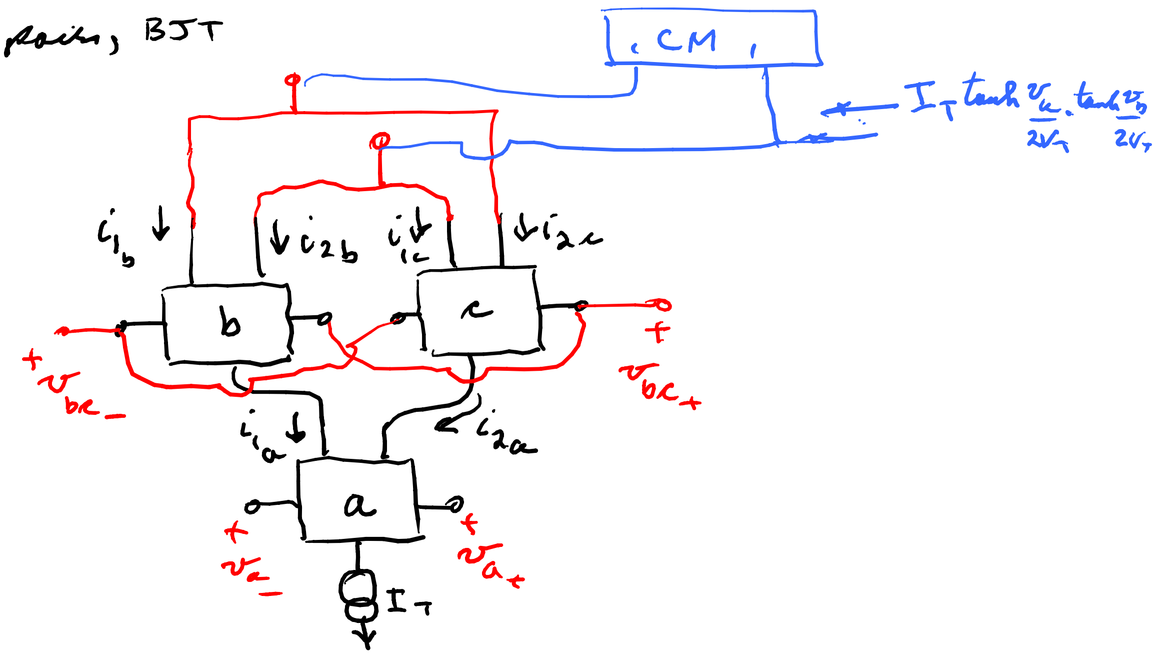


$$\left.\frac{d i_D}{\partial v_{DS}}\right|_{@ v_{DS}=0} = \frac{d}{d v_{DS}} \Rightarrow \left.\frac{KP}{2}\frac{W}{L}\left\{2(v_{GS}-V_{th}) - 2 v_{DS}^2)\right\}\right|_{v_{DS}=0}$$

$$\text{slope} = G_1 = (KP \cdot W/L)(v_{GS} - V_{th})$$

here $i_D \simeq \frac{KP}{2}\frac{W}{L}(2(v_{GS}-V_{th})v_{DS} = G_1 \cdot v_{DS}$, $v_{DS} > 0$

3-diff pairs, BJT



$$i_{2_a} - i_{1_a} = i_{o_a} = I_T \tanh(v_a/2V_T)$$

$$i_{2b} - i_{1b} = i_{o_b} = i_{1a} \tanh(v_b/2V_T) \qquad i_{2c} - i_{1c} = i_{2a} \tanh(v_c/2V_T) = i_{o_c}$$

choose $v_c = v_b = v_{bc}$

subtract $\quad i_{o_b} - i_{o_c} = (i_{1_a} - i_{2a}) \tanh(v_b/2V_T)$

$$= I_T \tanh(v_a/2V_T) \tanh(v_b/2V_T) \approx I_T \frac{v_a}{2V_T} \cdot \frac{v_b}{2V_T}$$

$$i_{o_b} - i_{o_R} = i_{2_b} - i_{1_b} - (i_{2_R} - i_{1_R}) = (i_{2_b} + i_{1_R}) - (i_{1_b} + i_{2_R})$$