EE303

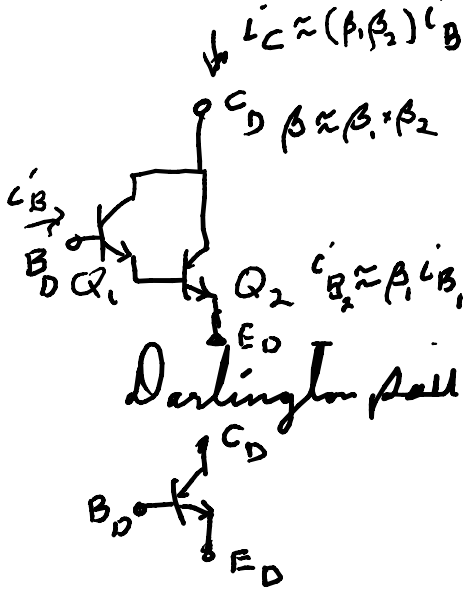
10/04/12

Note Title 10/4/2012

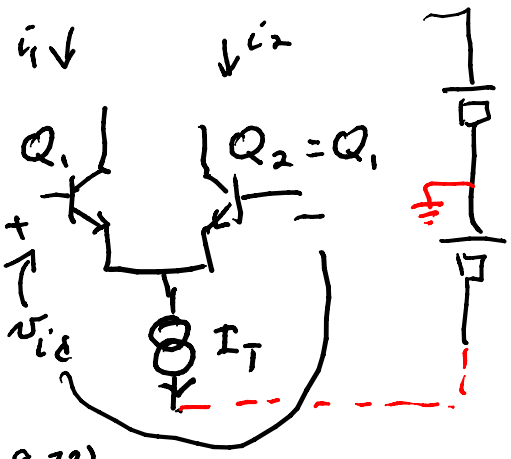
Darlington pairs p. 549, Fig 7.40

Latch, p. 1205, Figs 15.1, 2

Pass transistors, p. 1153, Fig. 14.6



Diff pair, BJT:



by KCL

$i_1 + i_2 = I_T$

$$i_1 = \frac{I_T}{1 + e^{-v_{id}/V_T}} \qquad (8.73)$$

$$i_2 = \frac{I_T}{1 + e^{v_{id}/V_T}}$$

$$i_1 - i_2 = I_T \left\{ \frac{1}{1 + e^{-v_{id}/V_T}} - \frac{1}{1 + e^{v_{id}/V_T}} \right\}$$

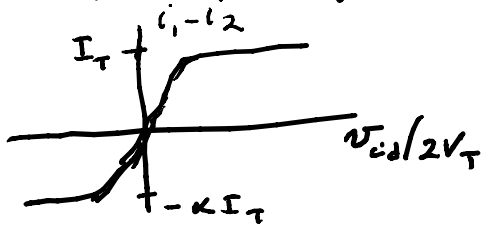
$$= I_T \left\{ \frac{e^{v_{id}/V_T} - e^{-v_{id}/V_T}}{(1 + e^{-v_{id}/V_T})(1 + e^{v_{id}/V_T})} \right\}$$

$$= I_T \cdot e^{v_{id}/V_T} \frac{(1 - e^{-2v_{id}/V_T})}{(1 + e^{-v_{id}/V_T})(1 + e^{v_{id}/V_T})}$$

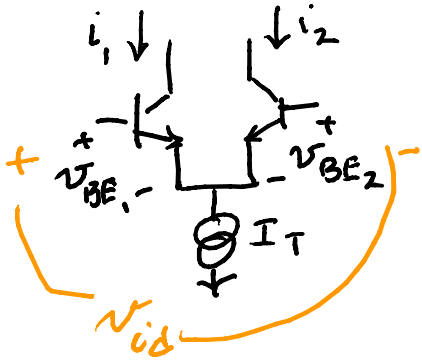
$$= I_T e^{v_{id}/V_T} \frac{(1 - e^{-v_{id}/V_T})(1 + e^{-v_{id}/V_T})}{(1 + e^{-v_{id}/V_T})(1 + e^{v_{id}/V_T})}$$

$$= I_T \frac{e^{v_{id}/2V_T}}{e^{v_{id}/2V_T}} \frac{(e^{v_{id}/2V_T} - e^{-v_{id}/2V_T})}{(e^{-v_{id}/2V_T} + e^{v_{id}/2V_T})}$$

$$i_1 - i_2 = I_T \cdot \tanh\left(\frac{v_{id}}{2V_T}\right)$$



To get $i_1 + i_2 = I_T$



KVL

$$v_{id} = v_{BE_1} - v_{BE_2}$$

here assume $i_C \approx \alpha I_S e^{v_{BE}/V_T}$

$$i_1 = \alpha I_S e^{v_{BE_1}/V_T}$$

$$i_2 = \alpha I_S e^{v_{BE_2}/V_T}$$

$$i_1 + i_2 = I_T = \alpha I_S \left(e^{v_{BE_1}/V_T} + e^{\frac{v_{BE_1} - v_{id}}{V_T}} \right) = \alpha I_S e^{v_{BE_1}/V_T} \left(1 + e^{-v_{id}/V_T}\right)$$

$$= i_1 \times \left(1 + e^{-v_{id}/V_T}\right) \Rightarrow i_1 = \frac{I_T}{1 + e^{-v_{id}/V_T}}$$

by symmetry $i_2 = \dfrac{I_T}{1 + e^{+v_{id}/V_T}}$

$$G_m = \left.\frac{\partial i_{out}}{\partial v_{in}}\right| = \left.\frac{\partial (i_1 - i_2)}{\partial v_{id}}\right| = I_T \cdot \frac{1}{2V_T} \left.\frac{\partial \tanh v_{id}/2V_T}{\partial v_{id}/2V_T}\right|_{v_{id}=0} = \frac{I_T}{2V_T} \cdot 1$$

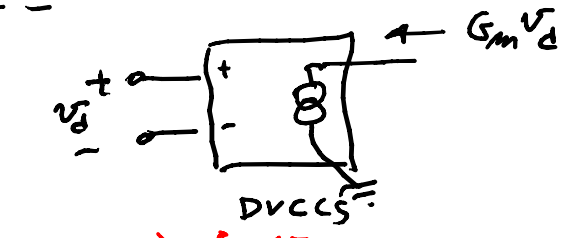
@ $v_{id} = 0$

$$\tanh x = \frac{\sinh x}{\cosh x} = \frac{e^x - e^{-x}}{2} \times \frac{2}{e^x + e^{-x}}$$

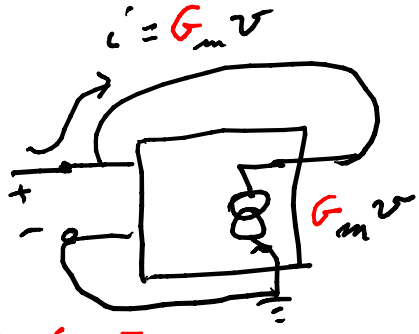
(sinh) (1/cosh)

$$\frac{d \tanh x}{dx} = (e^x + e^{-x}) \times \frac{1}{e^x + e^{-x}} - \frac{(e^x - e^{-x})(e^x - e^{-x})}{(e^x + e^{-x})^2}$$

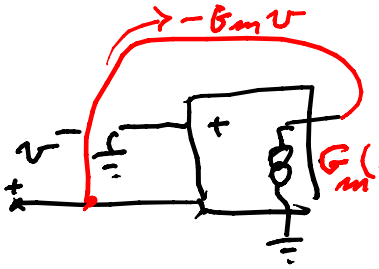
$$= 1 - \tanh^2 x$$



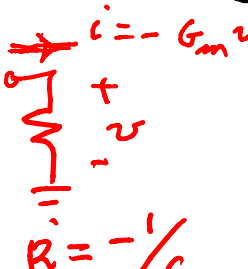
$\Rightarrow$



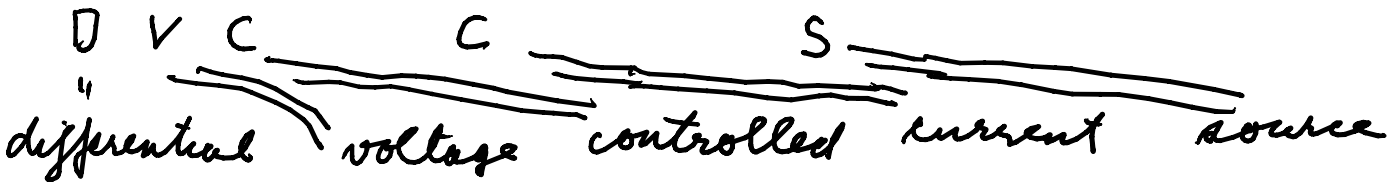
$$R = \frac{1}{G_m}$$



$=$



$$R = -1/G_m$$


D V C C S
differential voltage controlled current source