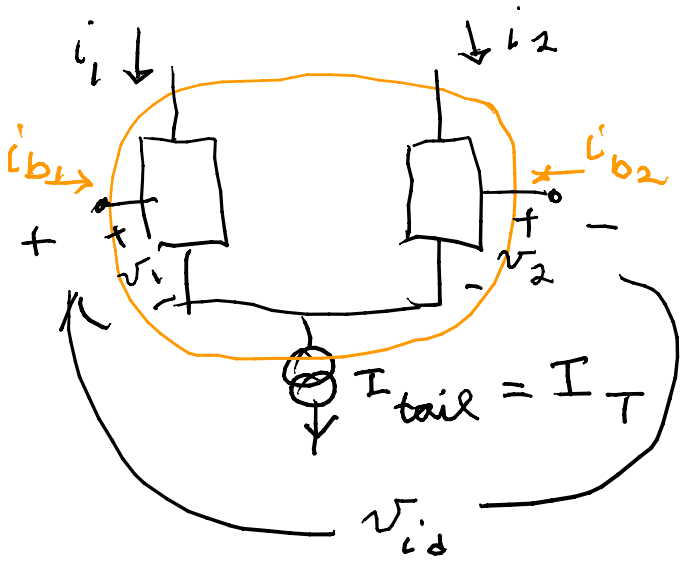
EE303
02/27/06

Differential pairs (amplifies)

BJT ⇒ p. 709

MOS ⇒ p. 728

steers a current



$v_{id} = v_1 - v_2$

I_T goes between i_1 & i_2; as $v_1 \uparrow \Rightarrow i_1 \uparrow$

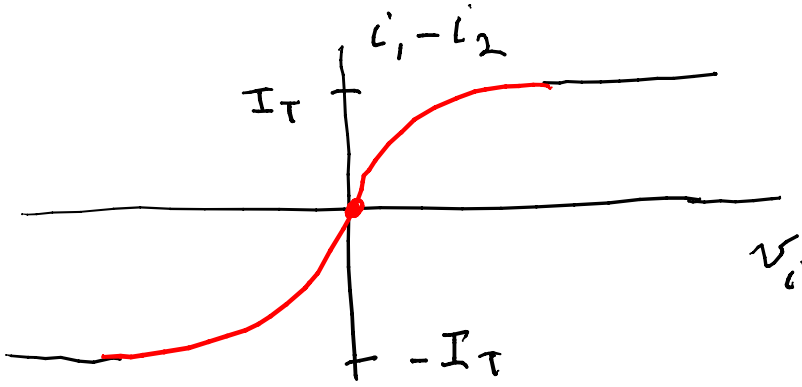
as $v_1 \downarrow \Rightarrow i_1 \downarrow$

as $v_{id} \uparrow \Rightarrow i_1 \uparrow$, $i_2 \downarrow$

by KCL: $-I_T + i_1 + i_2 + i_{b_1} + i_{b_2} = 0$

we force i_{b_1} & $i_{b_2} = 0$ (for example as i_{gate} of an MOS or as i_{base} of a BJT)

$\therefore \; I_T = i_1 + i_2$ if $i_1 \uparrow$ then $i_2 \downarrow$

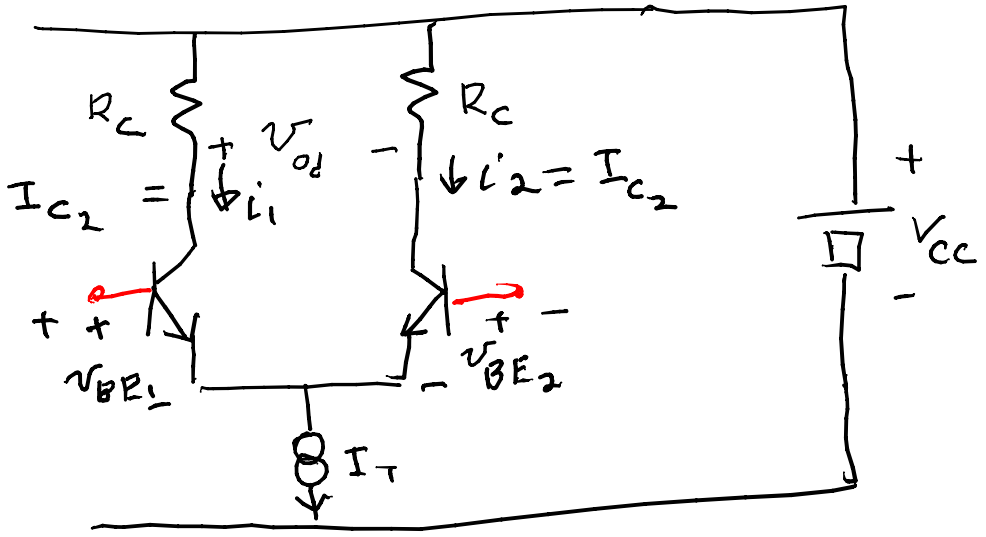


by physical reasoning

$\approx I_T \tanh\left(\frac{v_{id}}{2V_T}\right)$

$= i_1 - i_2$

for the BJT form get almost exactly $i_1 - i_2 = I_T \tanh\left(\frac{v_{id}}{2V_T}\right)$



$$I_C = \alpha(-I_E) = \alpha(I_S)\, e^{v_{BE}/V_T}$$

$$I_{C_1} = \alpha I_S e^{v_{BE_1}/V_T}, \quad I_{C_2} = \alpha I_S e^{v_{BE_2}/V_T}$$

$$i_1 - i_2 \simeq I_{C_1} - I_{C_2} = i_{od}$$

$$I_T \simeq I_{C_1} + I_{C_2} \quad ; \quad v_{id} = v_{BE_1} - v_{BE_2}$$

$$\text{or } I_T = \alpha I_S \left(e^{v_{BE1}/V_T} + e^{v_{BE2}/V_T} \right)$$

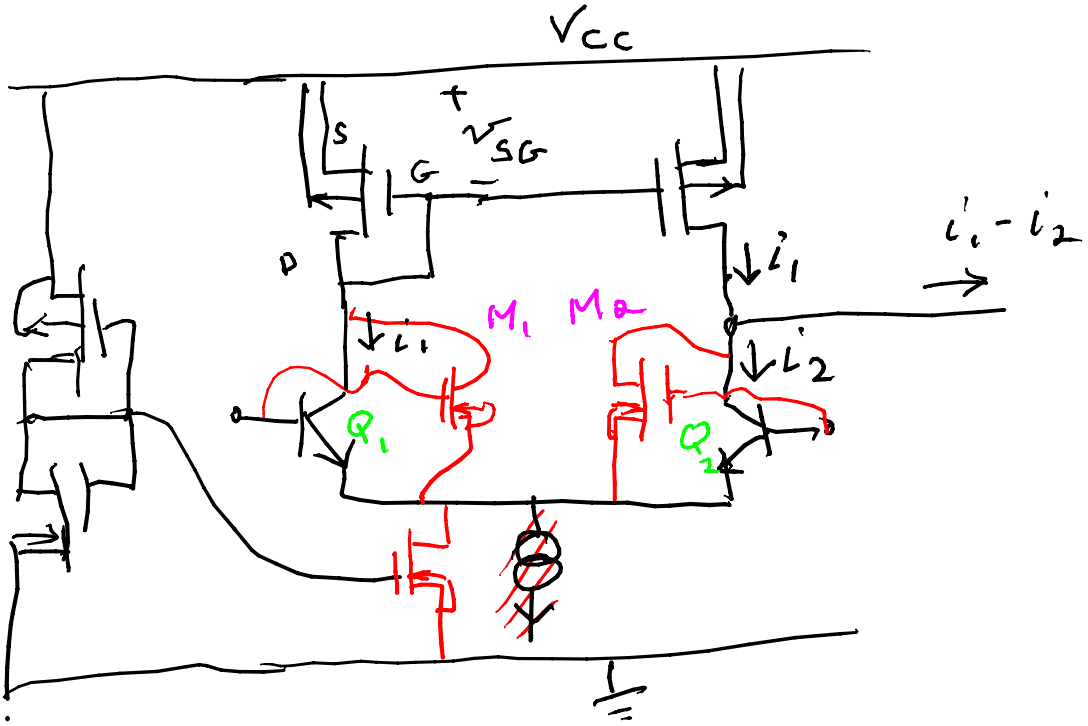
$$= \alpha I_S e^{v_{BE2}/V_T} \left(e^{v_{id}/V_T} + 1 \right)$$

$$i_{od} = \alpha I_S e^{v_{BE2}/V_T} \left(e^{v_{id}/V_T} - 1 \right)$$

$$\Rightarrow \frac{i_{od}}{I_T} = \frac{e^{v_{id}/V_T} - 1}{e^{v_{id}/V_T} + 1} = \frac{e^{x} - e^{-x}}{e^{x} + e^{-x}} = \frac{e^{v_{id}/(2V_T)} \left[e^{v_{id}/2V_T} - e^{-v_{id}/2V_T} \right]}{e^{v_{id}/(2V_T)} \left[e^{v_{id}/2V_T} + e^{-v_{id}/2V_T} \right]}$$

$$i_{od} = I_T \cdot \tanh\left(\frac{v_{id}}{2V_T} \right)$$

to use the output place i_1 in a current mirror



MOS in red M_1 & M_2

BJT in black Q_1 & Q_2