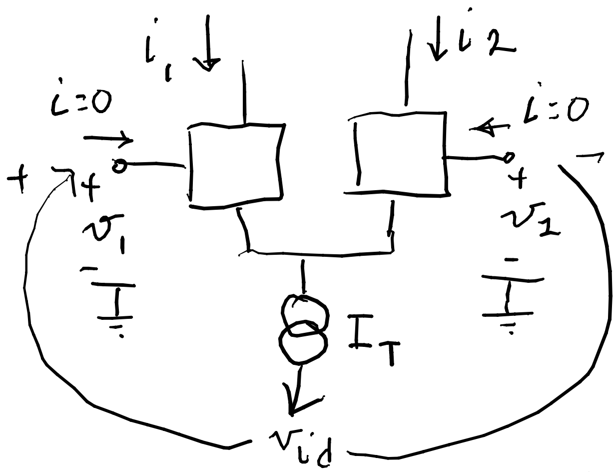
Differential pairs

EE302
02/17/05

pp. 693 = CMOS , 738 = BJT, 1052 = ECL

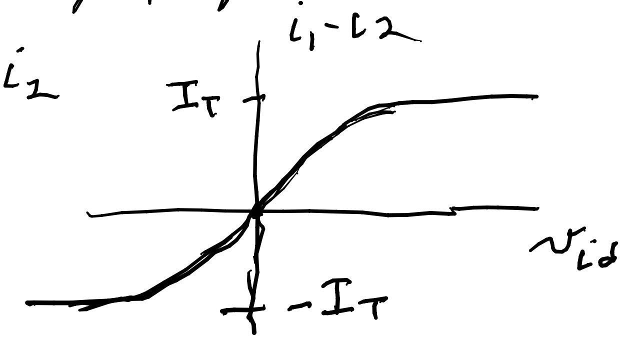


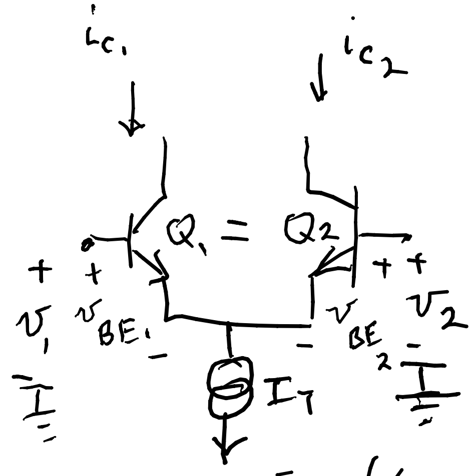
$v_{id} = v_1 - v_2$

$i_1 + i_2 = I_T$ = tail current

normally i_1 increases if v_1 is raised if v_2 is fixed
if v_1 is fixed & v_2 raised i_2 increases

usually look at $i_1 - i_2$





$i_{C_1} + i_{C_2} = I_T$

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

$i_{C_1} \approx \alpha(-i_{E_1})$; $i_{C_2} \approx \alpha(-i_{E_2})$

$i_{E_1} \approx I_S e^{v_{BE_1}/V_T}$; $i_{E_2} = I_S e^{v_{BE_2}/V_T}$ if Q_1 & Q_2 in the forward active region

V_T = thermal voltage = $\frac{kT}{|q|} \approx 26\,mv$ @ room T

$$i_{C_1} - i_{C_2} = \alpha(-i_{E_1} - (-i_{E_2})) = \alpha(i_{E_2} - i_{E_1})$$

$$= \alpha I_S \left(e^{+v_{BE_2}/V_T} - e^{v_{BE_1}/V_T}\right)$$

$$= \alpha I_S\, e^{v_{BE_2}/V_T}\left(1 - e^{[v_{BE_1} - v_{BE_2}]/V_T}\right)$$

$$= \alpha I_S\, e^{v_{BE_2}/V_T}\left(1 - e^{v_{id}/V_T}\right)$$

$$i_{C_1} + i_{C_2} = I_T$$

Sum: $2i_{C_1} = I_T + \alpha I_S e^{v_{BE_2}/V_T}\left(1 - e^{v_{id}/V_T}\right)$

difference: $2i_{C_2} = I_T - \alpha I_S e^{v_{BE_2}/V_T}\left(1 - e^{v_{id}/V_T}\right)$

$= I_T + i_{C_2}\left(1 - e^{v_{id}/V_T}\right)$ as $\alpha i_E = -i_C$

$$i_{C_2}\left[2 - \left(1 - e^{v_{id}/V_T}\right)\right] = I_T$$

$$i_{C_2} = \frac{I_T}{1 + e^{v_{id}/V_T}}\ ; \quad i_{C_1} = \frac{I_T}{1 + e^{-v_{id}/V_T}}$$ by symmetry of the circuit

$$i_{C_1} - i_{C_2} = I_T\left[\frac{1}{1 + e^{-v_{id}/V_T}} - \frac{1}{1 + e^{+v_{id}/V_T}}\right]$$

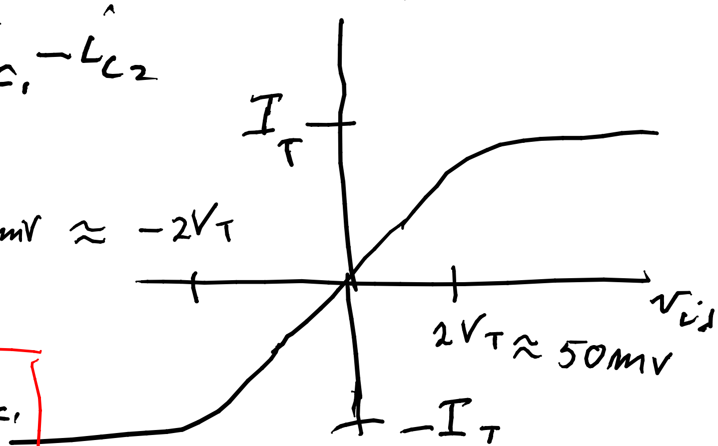
$$= I_T\left[\frac{(1 + e^{+v_{id}/V_T}) - (1 + e^{-v_{id}/V_T})}{\underbrace{(1 + e^{-v_{id}/V_T})(1 + e^{v_{id}/V_T})}_{1 + e^{-v_{id}/V_T} + e^{v_{id}/V_T} + 1}}\right]$$

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

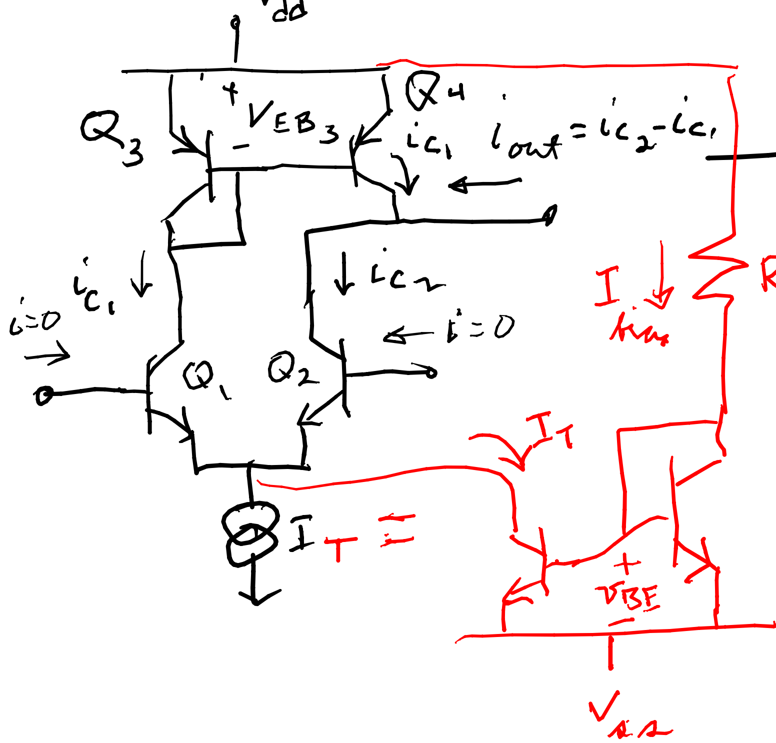
$$= I_T \left[\frac{e^{v_{id}/2V_T} - e^{-v_{id}/2V_T}}{e^{v_{id}/2V_T} + e^{-v_{id}/2V_T}} \right] = I_T \times \frac{2\sinh(v_{id}/2V_T)}{2\cosh(v_{id}/2V_T)}$$

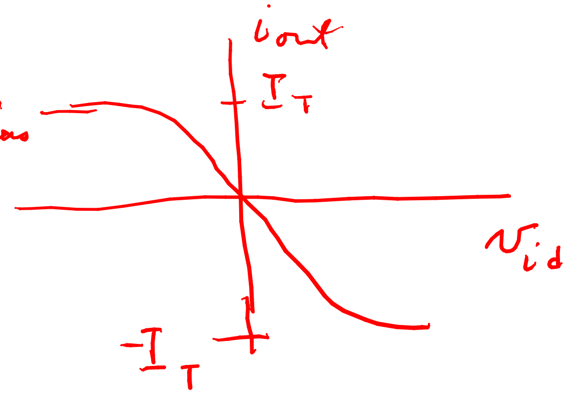
$$i_{C_1} - i_{C_2} = -i_{out}$$

$$= I_T \tanh\left(\frac{v_{id}}{2V_T}\right) = i_{C_1} - i_{C_2}$$



V_{dd} P.738





$v_{BE} \approx 0.6\,v$

$$I_{bias} = (V_{dd} - V_{ss} - 0.6v) / R_{bias}$$

$$\shortparallel$$

$$I_T$$

if $I_T = 3\,ma$ if $V_{dd} = 5\,v$, $V_{ss} = -5\,v$

$$\Rightarrow R_{bias} = \frac{(V_{dd} - V_{ss} - 0.6)}{I_T = 3\times10^{-3}} = \frac{9.4}{3} \times 10^3 = 3.13\,K\Omega$$

More practical