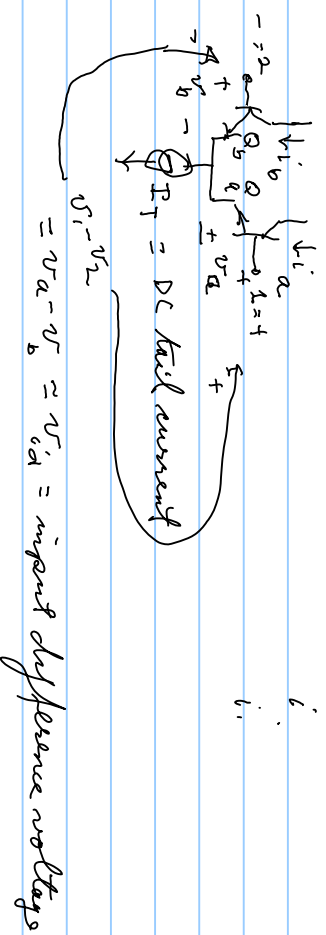
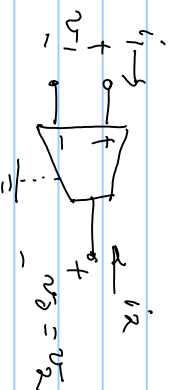


Extend Homework 4 $\Rightarrow$ due 10/10/17 = Tu

With pairs = Chapter 9

OTA $\Rightarrow$ ideal = G in μ sec

$$Y = \begin{bmatrix} 0 & 0 \\ g_m & 0 \end{bmatrix} \Rightarrow \begin{bmatrix} i_1 \\ i_2 \end{bmatrix} = Y \begin{bmatrix} v_1 \\ v_2 \end{bmatrix}$$



assume $R_a = R_b$ & in forward active region (above large signal operation)

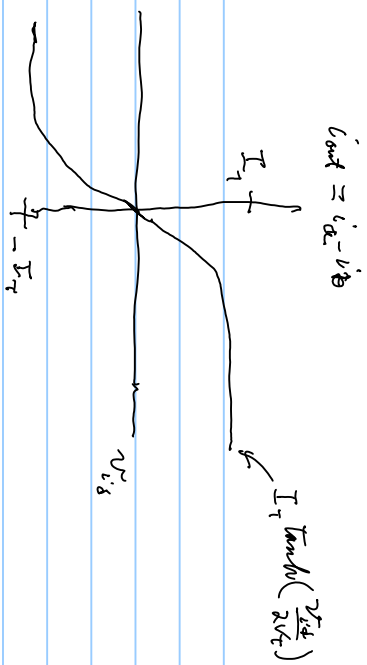
$$i_c = \alpha (-i_E) \quad , \quad -i_E = I_S e^{v_{BE}/V_T} \Rightarrow i_c = \alpha I_S e^{v_{BE}/V_T}$$

$$i_a = i_c \quad \text{in } Q_a \quad , \quad i_b = \alpha e^{v_B/V_T} \Rightarrow i_a - i_b = \alpha I_S \left(e^{v_a/V_T} - e^{v_b/V_T} \right) \\ = \alpha I_S e^{v_a/V_T} \left[e^{(v_a - v_b)/V_T} - 1 \right]$$

$$-(i_E + i_{E_b}) = I_T = i_c / \alpha + i_c / \alpha = \frac{1}{\alpha} (i_a + i_b) = \frac{1}{\alpha} [\alpha I_S e^{v_a/V_T} + \alpha I_S e^{v_b/V_T}] \\ \Rightarrow I_T = I_S e^{v_a/V_T} [e^{(v_a - v_b)/V_T} + 1]$$

$$\frac{i_a - i_b}{I_T} = \frac{\alpha I_S [e^{v_a/V_T} - 1] e^{v_b/V_T}}{I_S [e^{v_a/V_T} + 1]} = \alpha \frac{e^{v_a/V_T} - 1}{e^{v_a/V_T} + 1} \frac{e^{v_b/V_T}}{[e^{v_a/V_T} + e^{v_b/V_T}]} \cdot \frac{2}{2}$$

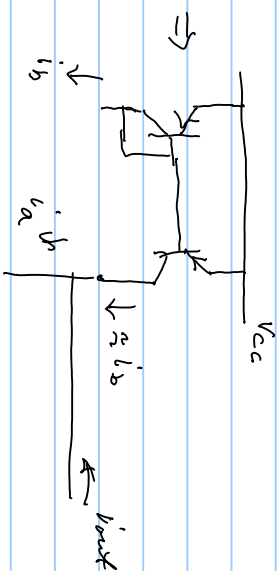
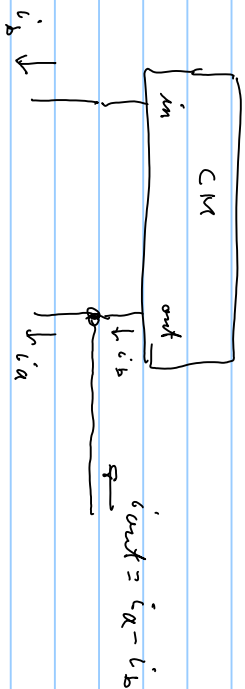
$$= \alpha \tanh\left(\frac{v_{id}}{2V_T}\right) = \alpha \frac{\sinh(v_{id}/2V_T)}{\cosh(v_{id}/2V_T)} \Rightarrow i_{out} \approx I_T \tanh\left(\frac{v_{id}}{2V_T}\right)$$



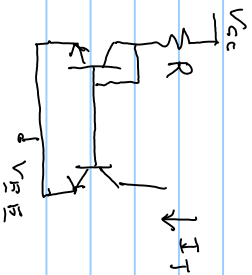
$$g_m \bigg|_{\substack{v_{is}=0 \\ v_{ia}=0}} = \frac{d I_T \tanh\left(\frac{v_{is}}{2V_T}\right)}{d v_{is}} \bigg|_{\substack{v_{is}=0 \\ v_{ia}=0}} = I_T \left(1 - \tanh^2\left(\frac{v_{is}}{2V_T}\right)\right) \cdot \frac{1}{2V_T} \bigg|_{\substack{v_{is}=0 \\ v_{ia}=0}} = \frac{I_T}{2V_T}$$

(= slope at origin)

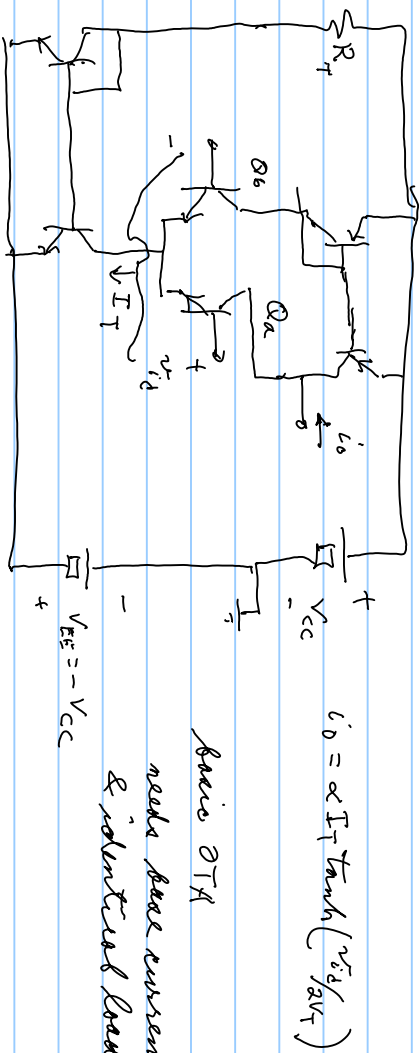
Next $\Rightarrow$ generate $i_{out} = i_a - i_b$



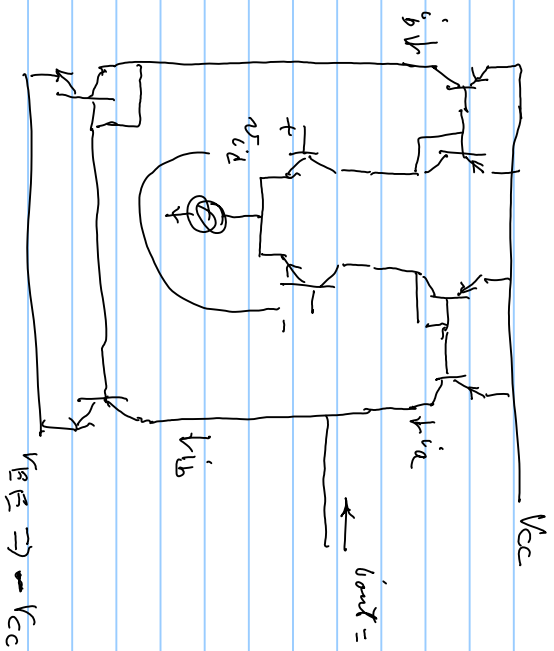
finally generate I_T



⇒ OTA



to fix the loading differences on Q_a & Q_b ⇒ insert new CM



$$i_{out} = i_b - i_a = \alpha I_T \tanh(v_{id}/V_T)$$

$$g_m = \frac{\alpha I_T}{2V_T} \quad \Big| \quad \text{at } v_{id} = 0$$

