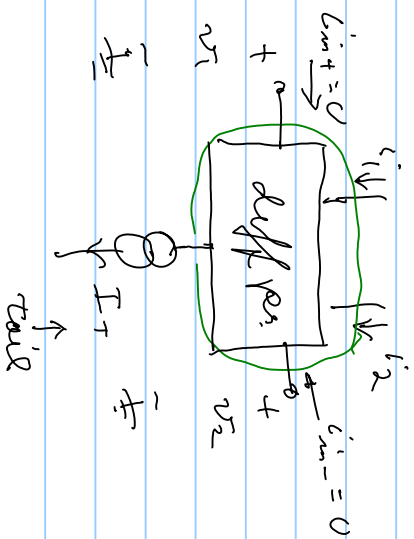


EE 307

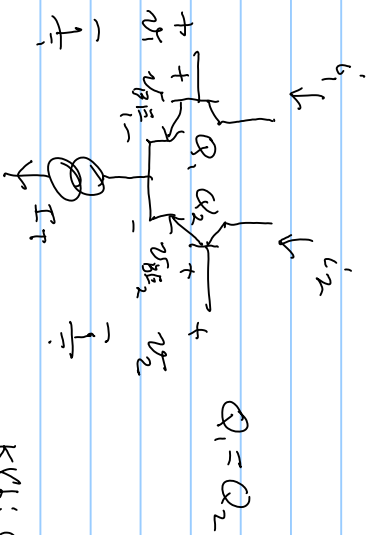
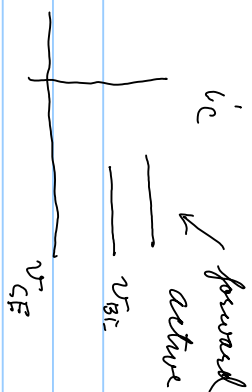
03/27/17



by KCL: $0 = i_1 + i_2 - I_T$

$$I_T = i_1 + i_2$$

for diff pair made by BJTs



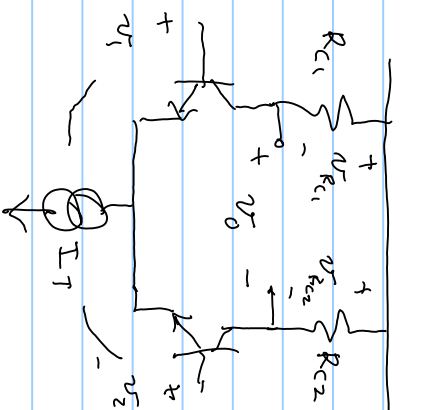
$$i_c = \alpha I_S e^{v_{BE}/V_T}$$

$$\text{KVL: } 0 = v_{BE1} - v_{BE2} + v_{C2} - v_{C1}$$

$$\frac{i_{C1}}{i_{C2}} = \frac{\alpha I_S e^{v_{BE1}/V_T}}{\alpha I_S e^{v_{BE2}/V_T}} = e^{(v_{BE1} - v_{BE2})/V_T} = e^{(v_{C1} - v_{C2})/V_T} = e^{v_{CE}/V_T}$$

$$I_T = i_{C1} + i_{C2} = i_{C2} (e^{v_{CE}/V_T} + 1) = i_{C2} (1 + e^{v_{CE}/V_T})$$

$$i_{C2} = \frac{I_T}{1 + e^{v_{CE}/V_T}} ; \quad i_{C1} = I_T - i_{C2} = I_T \left(1 - \frac{1}{1 + e^{v_{CE}/V_T}} \right) = \frac{I_T e^{v_{CE}/V_T}}{1 + e^{v_{CE}/V_T}}$$



$$R_{C1} = R_{C2} = R_C$$

$$K_V i_{D1} = 0 = -v_{DS} - v_{RC1} + v_{RC2}$$

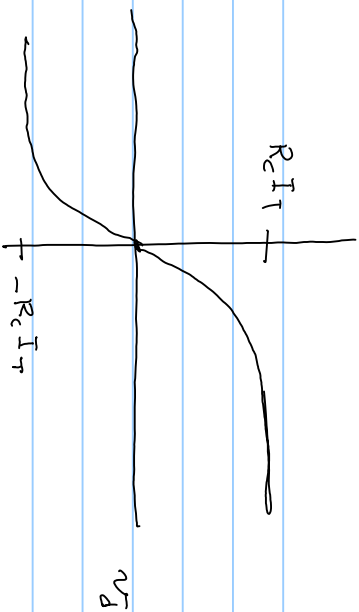
$$v_{DS} = v_{RC2} - v_{RC1}$$

$$= R_C i_{D2} - R_C i_{D1}$$

$$= R_C (i_{D2} - i_{D1}) = v_{DS}$$

$$\begin{aligned} v_{DS} &= R_C (i_{D2}' - i_{D1}') = R_C I_T \left(\frac{e^{v_{DS}/V_T} - 1}{1 + e^{v_{DS}/V_T}} \right) = -R_C I_T \left(\frac{1 - e^{v_{DS}/V_T}}{1 + e^{v_{DS}/V_T}} \right) \\ &= -R_C I_T \left[\frac{e^{v_{DS}/2V_T}}{e^{v_{DS}/2V_T} + e^{-v_{DS}/2V_T}} - \frac{e^{-v_{DS}/2V_T}}{e^{-v_{DS}/2V_T} + e^{v_{DS}/2V_T}} \right] = R_C I_T \left(\frac{e^{\frac{v_{DS}}{2V_T}} - e^{-\frac{v_{DS}}{2V_T}}}{e^{\frac{v_{DS}}{2V_T}} + e^{-\frac{v_{DS}}{2V_T}}} \right) \\ &= R_C I_T \frac{\sinh\left(\frac{v_{DS}}{2V_T}\right)}{\cosh\left(\frac{v_{DS}}{2V_T}\right)} = R_C I_T \tanh\left(\frac{v_{DS}}{2V_T}\right) \end{aligned}$$

$$v_O = R_C I_T \tanh(v_D / R_V) = R_C (i_2 - i_1)$$



$$\frac{dv_O}{dv_D} = R_C I_T \frac{1}{R_V} \left[1 - \tanh^2 \left(\frac{v_D}{R_V} \right) \right]$$

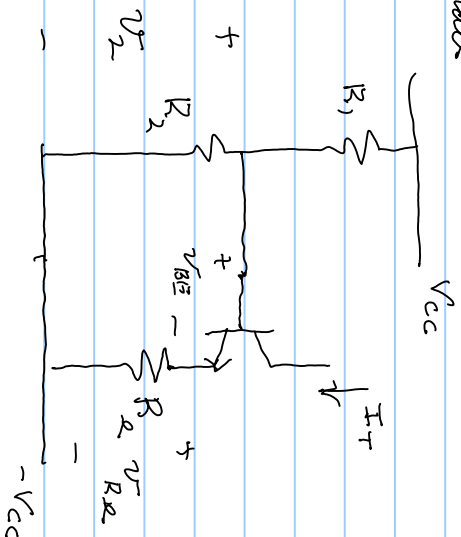
$$\text{at } v_D = 0$$

$$\frac{dv_O}{dv_D} = R_C \cdot \frac{I_T}{R_V} = R_C \frac{I_C}{V_T}$$

$$= R_C \cdot g_m$$

small signal
gain = $\frac{dv_O}{dv_D}$
@ bias

OTM Tail



assume no base current

$$V_2 = \frac{2V_{cc} \cdot R_2}{R_1 + R_2}$$

$$V_{RE} = V_2 - V_{BE}$$

$$\approx V_2 - 0.7$$

$$V_{RE} = \left(\frac{I_T}{\alpha} \right) R_E$$

$$= V_2 - 0.7$$

$$= \frac{2V_{cc} \cdot R_2}{R_1 + R_2} - 0.7$$

given I_T find R_1, R_2, R_E

need to correct due to base current