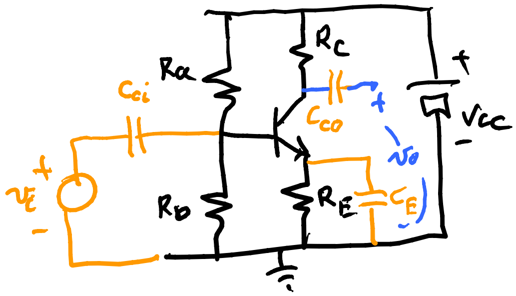
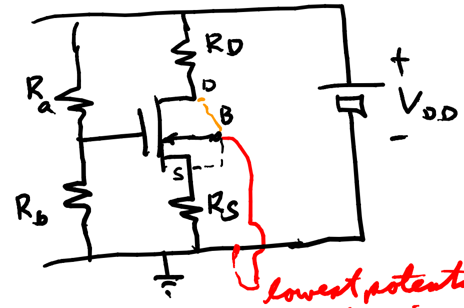
EE 303H
10/01/09

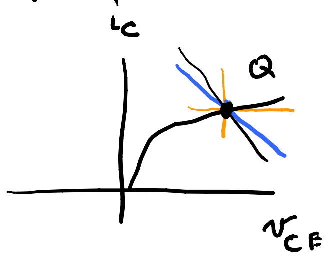
Biasing

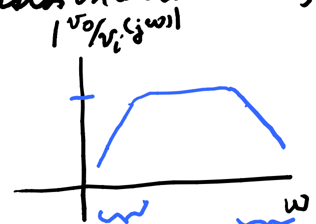




lowest potential in the circuit

use for small signals, class A (transistor on all the time)





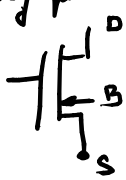
due to C_{co}, C_{ci}, C_E

due to transistor capacitance

mid band
$A_v = -g_m R_L$

Interesting problem: biasing as an optimization problem with equality and inequality constraints

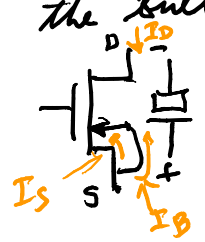
Biasing problem with MOS



then D = drain if $V_{D\,gnd} \geq V_{S\,gnd}$

S = drain if $V_{D\,gnd} < V_{S\,gnd}$

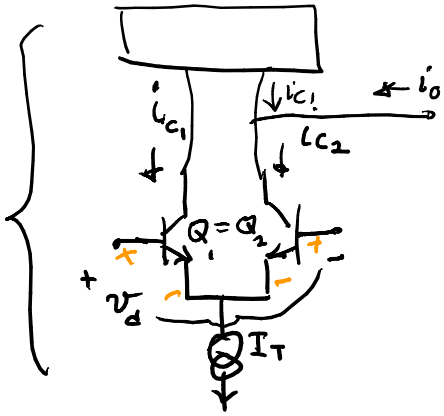
if S becomes the drain and if B is tied to S then the bulk to source (B to D) is forward biased
⇒ bulk current is (very) large



if monitor I_S & I_D & I_B

$I_S + I_B = -I_D$ (also large)

an OTA



out = $i_o = i_{c_2} - i_{c_1}$

$i_{c_1} + i_{c_2} = -\alpha i_{E_1} - \alpha i_{E_2}$

$-i_{E_1} - i_{E_2} = I_T$

$\alpha I_T = i_{c_1} + i_{c_2}$

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

$i_{c_1} = \alpha I_s e^{v_{BE_1}/V_T}$, $i_{c_2} = \alpha I_s e^{v_{BE_2}/V_T}$
$= \alpha I_s e^{(v_{BE_1} - v_d)/V_T}$

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

$$i_o = \alpha I_s \left[e^{(v_{BE_1} - v_d)/V_T} - e^{v_{BE_1}/V_T} \right] = \alpha I_s e^{v_{BE_1}/V_T} \left[e^{-v_d/V_T} - 1 \right]$$

$$I_T = \frac{1}{\alpha} \{ i_{c_1} + i_{c_2} \} = \frac{\alpha I_s}{\alpha} \{ e^{v_{BE_1}/V_T} + e^{(v_{BE_1} - v_d)/V_T} \}$$

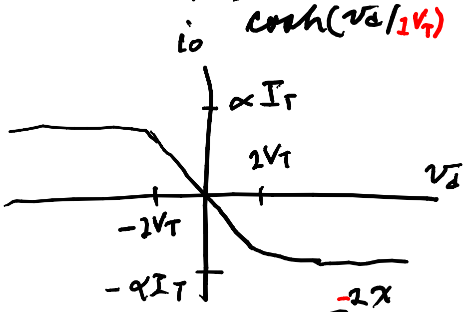
$$= I_s e^{v_{BE_1}/V_T} \{ 1 + e^{-v_d/V_T} \}$$

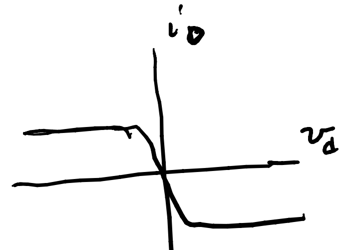
gives

$$\frac{i_o}{I_T} = \frac{\alpha I_s e^{v_{BE_1}/V_T} \left[e^{-v_d/V_T} - 1 \right]}{I_s e^{v_{BE_1}/V_T} \left[e^{-v_d/V_T} + 1 \right]} \Rightarrow i_o = -\alpha I_T \left[\frac{1 - e^{-v_d/V_T}}{1 + e^{-v_d/V_T}} \right]$$

$$i_o = -\alpha I_T \frac{e^{-v_d/2V_T}}{e^{-v_d/2V_T}} \cdot \left[\frac{\frac{e^{v_d/2V_T} - e^{-v_d/2V_T}}{2}}{\frac{e^{v_d/2V_T} + e^{-v_d/2V_T}}{2}} \right] =$$

$$= -\alpha I_T \frac{\sinh(v_d/2V_T)}{\cosh(v_d/2V_T)} = -\alpha I_T \tanh(v_d/2V_T)$$





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

$$= 2e^{-2x} \left(\frac{+(1 + e^{-2x}) + (1 - e^{-2x})}{(1 + e^{-2x})^2} \right) = \frac{+2(2e^{-2x})}{(1 + e^{-2x})^2} = +(1 - \tanh^2 x)$$

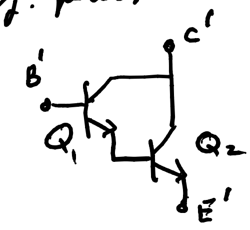
$$\stackrel{?}{=} 1 - \tanh^2 x$$

$$= 1 - \left(\frac{(1 - e^{-2x})}{(1 + e^{-2x})} \right)^2 = \frac{(1 + e^{-2x})^2 - (1 - e^{-2x})^2}{(1 + e^{-2x})^2}$$

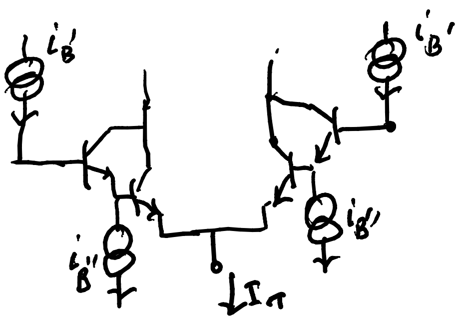
$$= (\cancel{1} + 2e^{-2x} + \cancel{e^{-4x}} - \cancel{1} + 2e^{-2x} - \cancel{e^{-4x}})/(1 + e^{-2x})^2 = \frac{4e^{-2x}}{(1 + e^{-2x})^2}$$

This diff. pair needs i_B for transistors

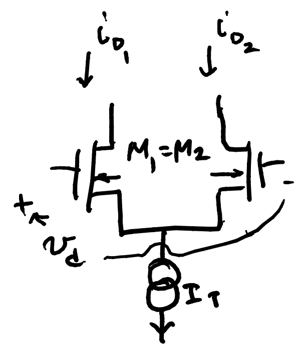
here $i_{C'} \approx \beta^2 i_{B'}$ if β is the β of Q_1, Q_2



Darlington pair



MOS



$$i_{D_2} - i_{D_1} = i_o$$

$$I_T = i_{D_1} + i_{D_2}$$

$$i_{D_1} = \frac{KP}{2}\frac{W}{L}\left(v_{GS_1} - V_{TO_m}\right)^2$$

$$i_{D_2} = \frac{KP}{2}\frac{W}{L}\left(v_{GS_1} - v_d - V_{TO_m}\right)^2$$

$$\sqrt{i_{D_1}} = +\sqrt{\frac{KP}{2}\frac{W}{L}}\left(v_{GS_1} - V_{TOm}\right)$$

$$v_d = v_{GS_1} - v_{S_2}$$

$$\sqrt{i_{D_2}} = +\sqrt{\frac{KP}{2}\frac{W}{L}}\left(v_{GS_1} - v_d - V_{TOm}\right)$$

$$\sqrt{i_{D_2}} - \sqrt{i_{D_1}} = \sqrt{\frac{KP}{2}\frac{W}{L}}\, v_d$$