$$i_{D_1} = \frac{I_T}{2} \pm \frac{1}{2}\sqrt{I_T^2 - 4\frac{k^2}{4}\left(v_D^2 - \frac{I_T}{k}\right)^2} = \frac{I_T}{2} \pm \frac{1}{2}\sqrt{\cancel{I_T^2} - \left(k^2 v_D^4 - \frac{2k^2 I_T v_D^2}{k} + \cancel{I_T^2}\right)}$$

$$= \frac{I_T}{2} \pm \frac{\sqrt{2}}{2}\cdot\sqrt{I_T}\sqrt{k}\, v_D\sqrt{1 - \frac{k^2 v_D^2}{2 I_T k}}$$

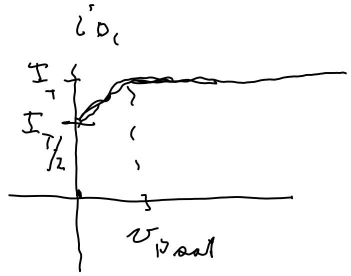
to find max

$$I_T = \frac{I_T}{2} + \sqrt{\frac{I_T k}{2}}\, v_D \sqrt{1 - \left(\frac{v_D}{\sqrt{2I_T/k}}\right)^2} \implies \text{achieve at } \left(\frac{v_D}{\sqrt{2I_T/k}}\right)^2 = 1/2 \Leftrightarrow v_{D_{sat}} = \sqrt{\frac{2I_T}{2k}} \simeq \sqrt{\frac{I_T}{k}}$$

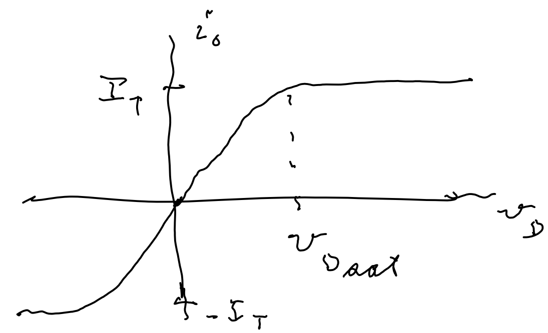
$$\simeq \frac{I_T}{2} + I_T\left(\frac{v_D}{\sqrt{2I_T/k}}\right)\sqrt{1-\left(\frac{v_D}{\sqrt{2I_T/k}}\right)^2}$$

(@ $v_D = v_{D_{sat}}$, $I_T = \frac{I_T}{2} + \frac{I_T}{\sqrt{2}}\cdot\left(\sqrt{1-\frac{1}{2}}\right) = I_T$

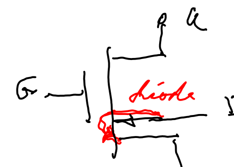
$$i_{D_2} - i_{D_1} \simeq I_T \cdot 2\left(\frac{v_D}{\sqrt{2I_T/k}}\right)\cdot\sqrt{1-\left(\frac{v_D}{\sqrt{2I_T/k}}\right)^2}$$



$\implies$

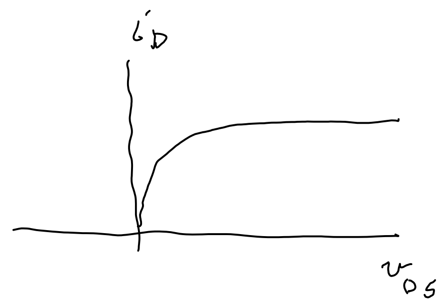


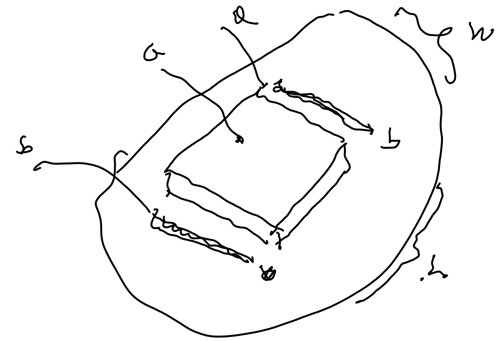
Bulk



a = D if $v_{ab} > 0$
= S

b = S if $v_{ab} > 0$
= S if $v_{ab} < 0$





$i_B = I_{B_{sat}}\left(e^{v_{Bb}/V_T} - 1\right)$

if $v_{Bb} >> 1/2$ then draw bulk current, desire normally $i_B = 0$
true if v_B is smaller than any other voltage in the circuit or $v_{Bb} = 0$

often see

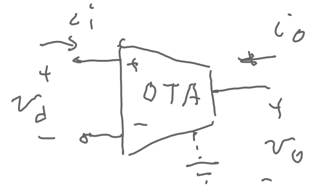
here B = b
so if $v_a < v_b$ then trouble as Bulk to lower potential terminal becomes forward biased $\Rightarrow i_B$ extremely large

p. 288 Body effect

$$V_{th} = V_{TO} + \gamma\left[\sqrt{(2\phi_f + v_{SB})} - \sqrt{2\phi_f}\right]$$

λ = LAMBDA, ϕ = PHI
γ = GAMMA

Use of OTA



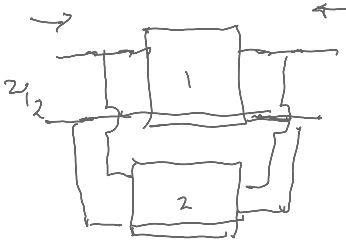
$\Rightarrow \quad Y \Rightarrow \begin{bmatrix} 0 & 0 \\ g_m & 0 \end{bmatrix} \begin{bmatrix} v_d \\ v_o \end{bmatrix} = \begin{bmatrix} i_i \\ i_o \end{bmatrix}$

$i_1 = 0$

$i_o = g_m v_d$

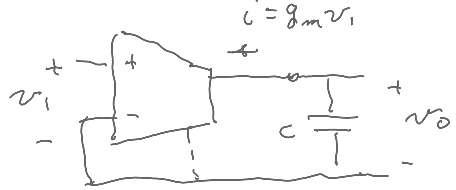
$i_1 = i_{1_1} + i_{1_2}$ $\quad$ $i_{2_1} + i_{2_2} = i_2$

$v_1 = v_{1_1} = v_{1_2}$ $\quad$ $v_2 = v_{2_1} = v_{2_2}$

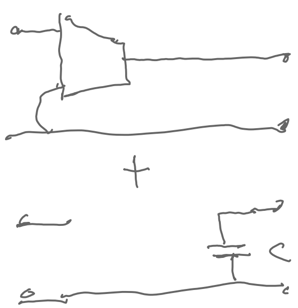


$$\begin{bmatrix} i_1 \\ i_2 \end{bmatrix} = Y_1 \begin{bmatrix} v_{1_1} \\ v_{2_1} \end{bmatrix} + Y_2 \begin{bmatrix} v_{1_2} \\ v_{2_2} \end{bmatrix} = (Y_1 + Y_2) \begin{bmatrix} v_1 \\ v_2 \end{bmatrix}$$

$i = g_m v_1$



open load



$Y_1 = \begin{bmatrix} 0 & 0 \\ g_m & 0 \end{bmatrix}$

$Y_2 = \begin{bmatrix} 0 & 0 \\ 0 & sC \end{bmatrix}$

$\Rightarrow \quad Y = \begin{bmatrix} 0 & 0 \\ g_m & sC \end{bmatrix}$ but $i_1 = 0$, v_1 = input

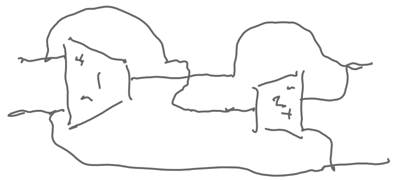
$i_2 = 0$ for open circuit

$v_2 = v_o$ = output

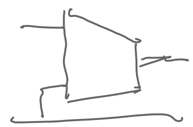
$0 = g_m v_1 + sC v_o \Rightarrow v_o = -\dfrac{g_m}{sC} \cdot v_1$

$\frac{1}{s} \Rightarrow \int_0^t + IC \implies$ this circuit is an integrator

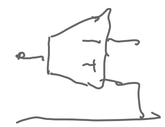
Then also



$$Y = \begin{bmatrix} 0 & -g_{m_2} \\ g_{m_1} & 0 \end{bmatrix}$$



$$Y_1 = \begin{bmatrix} 0 & 0 \\ g_{m_1} & 0 \end{bmatrix}$$

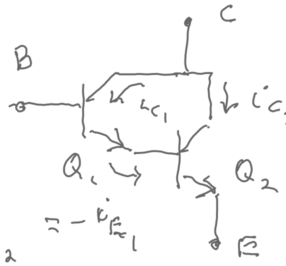


$$Y_2 = \begin{bmatrix} 0 & -g_{m_2} \\ 0 & 0 \end{bmatrix}$$

Power into this signal: $v_1(t)\cdot i_1(t) + v_2(t)\, i_2(t) = v_1 (-g_{m_2}) v_2 + v_2 (g_{m_1}) v_1 = (g_{m_1} - g_{m_2}) v_1 v_2$

if $g_{m_1} = g_{m_2}$ then $P_{in} \equiv 0$

Darlington transistor.



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

$i_{C_2} = \beta_2 i_{B_2} = -\beta_2 i_{E_1}$

$= \frac{\beta_2}{\alpha_1} i_{C_1}$

$= \frac{\beta_2}{\alpha_1} \cdot \beta_2 i_B$

$i_{B_2} = -i_{E_1}$

$-i_{E_1} = \frac{1}{\alpha_1} \cdot i_{C_1}$

$i_{C_1} = \beta_1 i_{B_1}$

$i_C = \beta i_B$

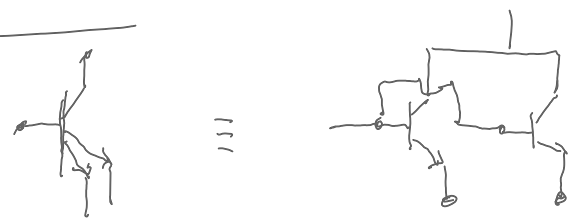
$\beta = \text{BETA}$, $\alpha = \text{ALPHA}$

$i_C = -\alpha i_E$

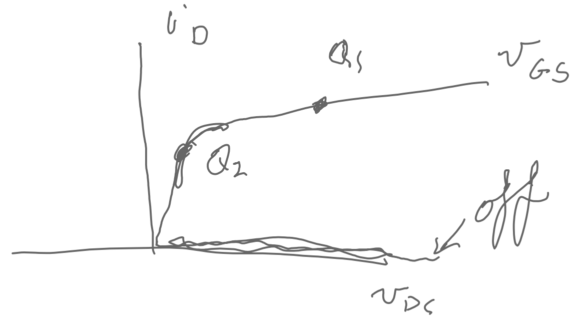
$\beta = \frac{\alpha}{1-\alpha}$

$\Rightarrow i_C = \beta_1 i_B + \frac{\beta_2}{\alpha_1} \beta_1 i_B = \left(\beta_1 + \frac{\beta_1 \beta_2}{\alpha_1} \right) \cdot i_B$

$\beta \approx \beta_1 \beta_2 \approx \beta^2$



Classes



Class A = small signal linear, p. 923

Class B ≈ $\frac{1}{2}$ time on, $\frac{1}{2}$ time off, p. 929

Class AB ≈ on but not linear, p. 935

Class D = p. 965

mentions class C = p. 923

CMRR, p. 630, eq. (9.81)