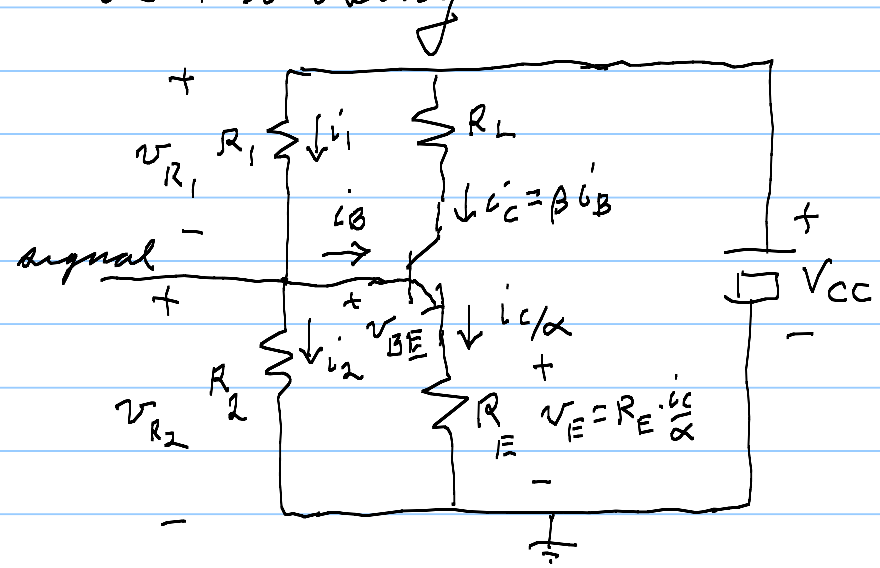
Note Title 9/29/2015

EE303H
09/29/15

BJT biasing



$$v_{R_2} = v_{BE} + v_E$$
$$v_{BE} = 0.65$$

$$i_1 = i_B + i_2 = \frac{i_C}{\beta} + i_2$$

$$i_2 = \frac{0.65 + v_E}{R_2}$$

assume $V_E = 1v$

$$i_2 = \frac{1.65}{R_2}$$

choose R_2 say $10\,Meg\,\Omega$

$I_2 = 0.165\,\mu A$

$I_B \Rightarrow$ need I_C choose $= 1\,mA \Rightarrow g_m = \frac{1 \times 10^{-3}}{26 \times 10^{-3}} = \frac{I_C}{V_T}\ \mho$

need β, assume $\beta = 200$

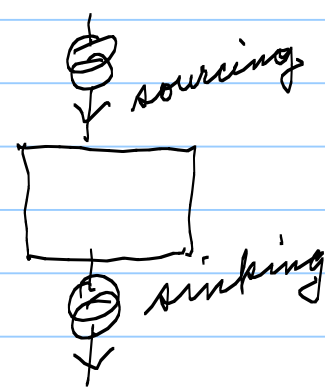
$$I_B = \frac{I_C}{\beta} = \frac{10^{-3}}{2\times 10^2} = 0.5\times 10^{-5} = 5\,\mu A$$

$$I_1 = I_B + I_2 = (5 + 0.165)\times 10^{-6} = 5.165\,\mu A$$

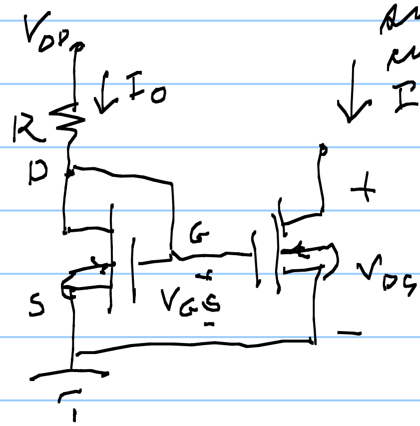
assume $V_{CC} = 6V$ then $V_{R_1} = V_{CC} - V_{R_2} = 6 - 1.65 = 4.35\,V$

$$R_1 = \frac{V_{R_1}}{I_1} = \frac{4.35}{5.165\times 10^{-6}} \approx 0.8\times 10^6 = 800\,K\Omega$$

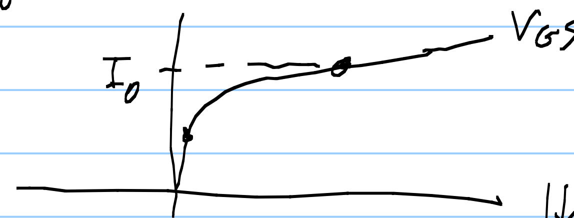
Current mirrors



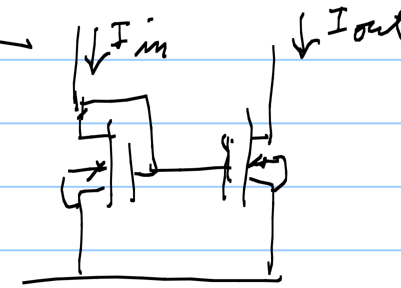
sinking



sinking current

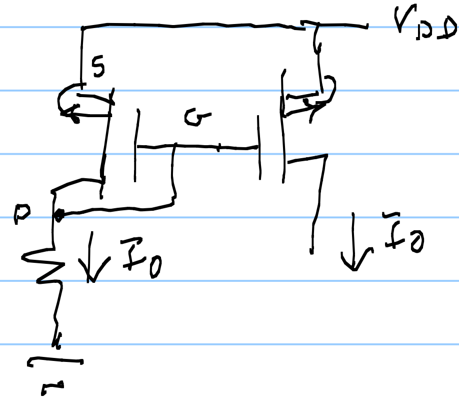


⇒

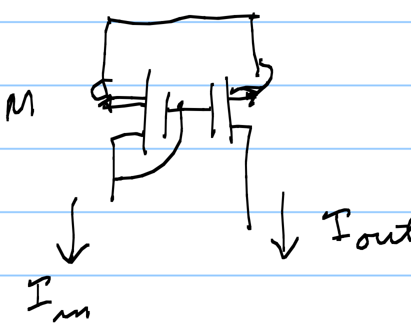


CM
=
current mirror

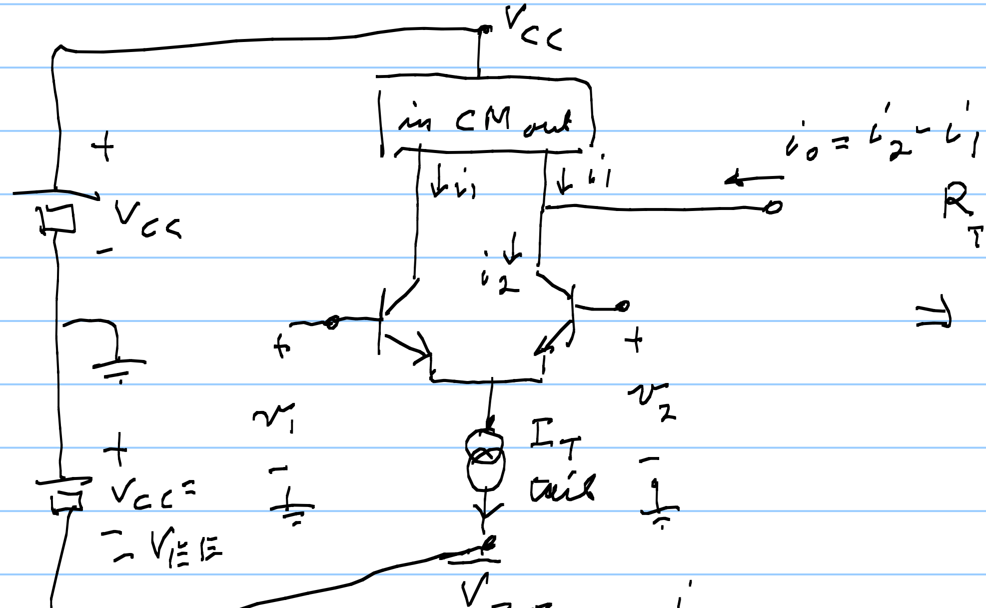
sourcing



CM



differential pair ⇒ i_{out} vs $v_{\text{differential input}}$



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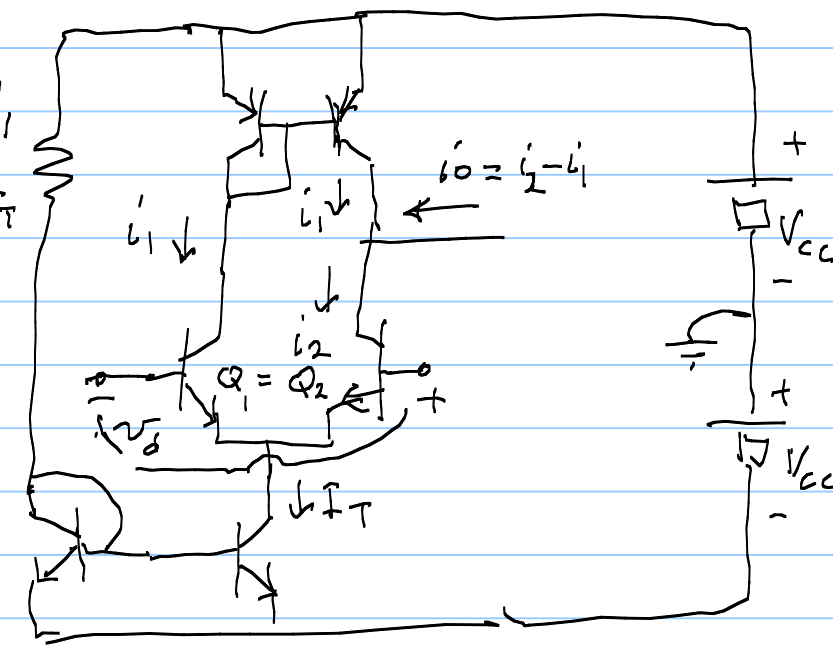
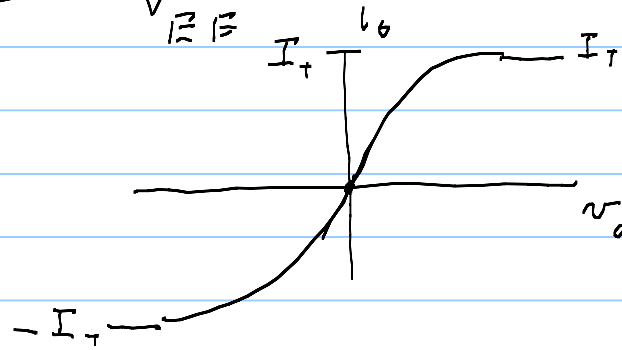




$i_o = \alpha I_T \tanh(v_d/2V_T)$

need i_1 & i_2 assume in forward active region

I_T fixed $\quad I_T = \frac{i_1}{\alpha} + \frac{i_2}{\alpha}$; $\quad v_d = v_{BE_2} - v_{BE_1}$

$$\frac{i_1}{\alpha} = I_S e^{v_{BE_1}/V_T}, \quad \frac{i_2}{\alpha} = I_S e^{v_{BE_2}/V_T}$$

$$\ln\left(\frac{i_1/\alpha}{I_S}\right) = v_{BE_1}/V_T \qquad \ln\left(\frac{i_2/\alpha}{I_S}\right) = v_{BE_2}/V_T$$

$$\frac{v_d}{V_T} = \ln\left(\frac{i_2/\alpha}{I_S}\right) - \ln\left(\frac{i_1/\alpha}{I_S}\right) = \ln\left(i_2/i_1\right) \Rightarrow \frac{i_2}{i_1} = e^{v_d/V_T}$$

$$i_1 + i_2 = \alpha I_T, \quad i_o = i_2 - i_1 \Rightarrow i_o = i_1 \times \left(\frac{i_2}{i_1} - 1\right) \Rightarrow \frac{i_o}{\alpha I_T} = \frac{\left(\frac{i_2}{i_1} - 1\right)}{i_2/i_1 + 1}$$

$$\alpha I_T = i_1 \times \left(\frac{i_2}{i_1} + 1\right)$$

$$i_o = \alpha I_T \left[\frac{e^{v_d/V_T} - 1}{e^{v_d/V_T} + 1}\right] = \alpha I_T \frac{e^{v_d/2V_T}\left[e^{v_d/2V_T} - e^{-v_d/2V_T}\right]}{e^{v_d/2V_T}\left[e^{v_d/2V_T} + e^{-v_d/2V_T}\right]}$$

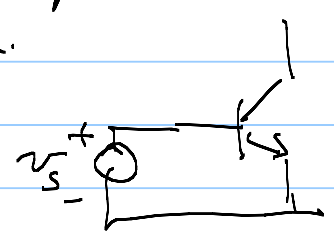
$$= \alpha I_T \tanh\left(v_d/2V_T\right)$$

$$g_m = \left.\frac{\partial i_o}{\partial v_d}\right|_{v_d=0} = \alpha I_T \cdot \frac{1}{2V_T} \left.\frac{d \tanh(v_d/2V_T)}{d(v_d/2V_T)}\right|_{v_d=0} = \left.\frac{\alpha I_T}{2V_T} \cdot (1 - \tanh^2(v_d/2V_T))\right|_{v_d=0}$$

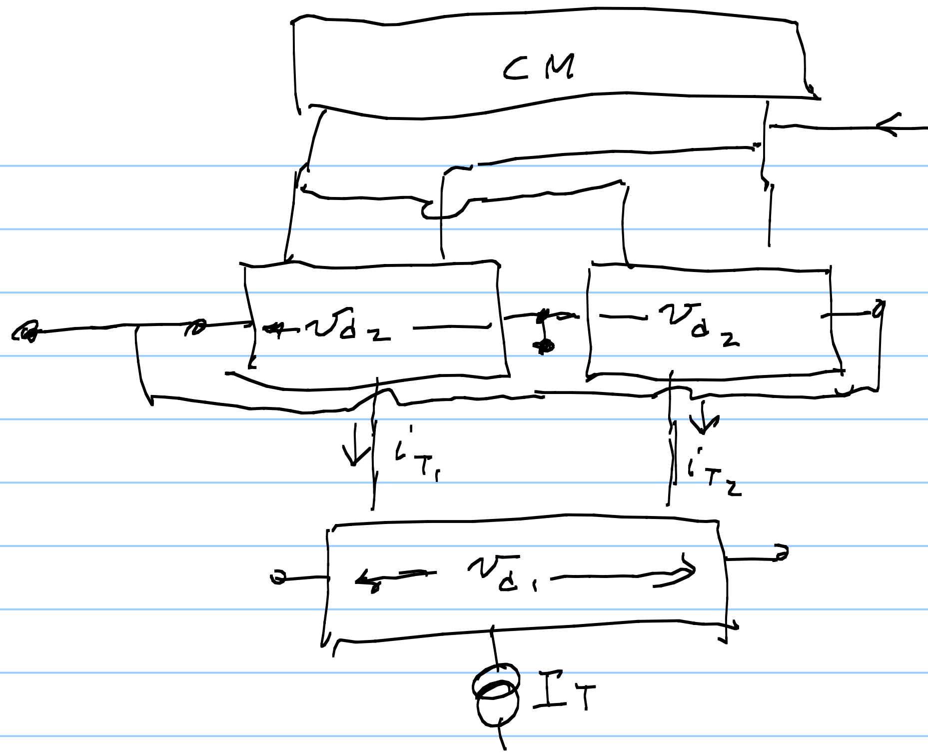
$$= \frac{\alpha}{2} \frac{I_T}{V_T}$$

a multiplier: make I_T vary with another signal, but I_T needs to be ≥ 0 } gives a 2 quadrant multiplier

i.e.



for a 4-quadrant multiplier



$$i_o = I_T \tanh(v_{d_1}/2V_T) \cdot \tanh(v_{d_2}/2V_T)$$