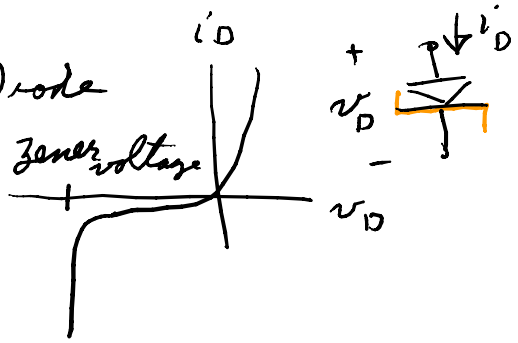
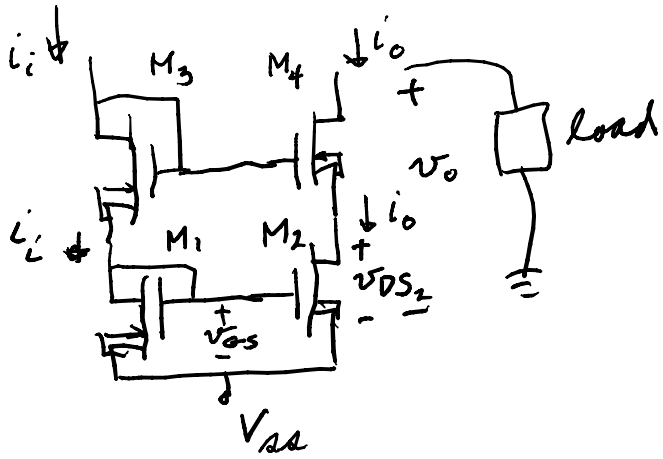
BJT small signal parameters

Rd. 443 – 449

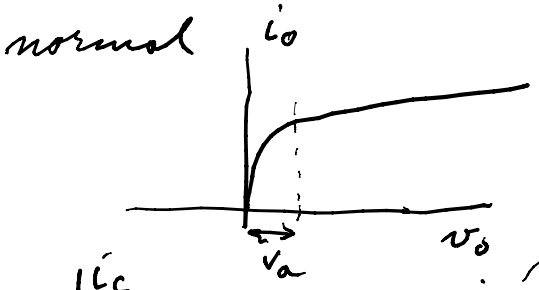
P-N Diode

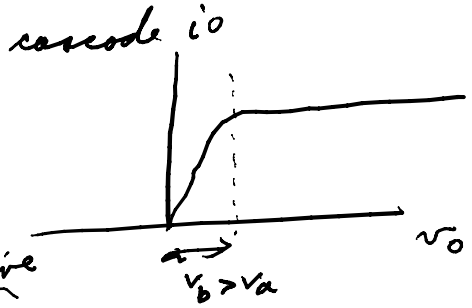


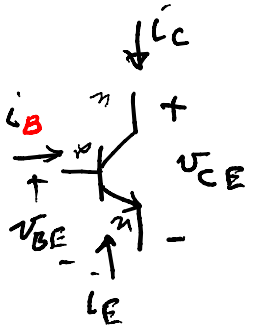
cascode current mirror

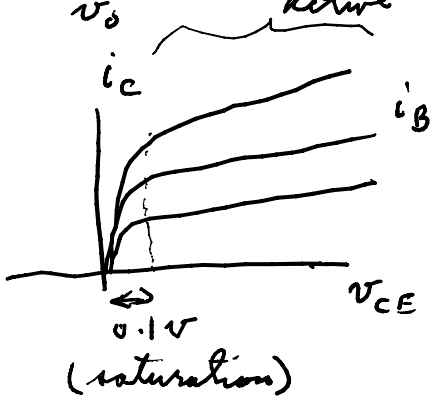


allows changes in v_o to not affect v_{DS_2} so i_o is determined by M_1 & M_2





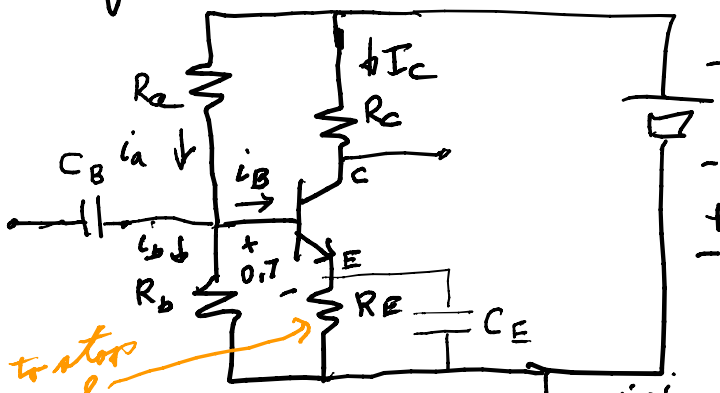


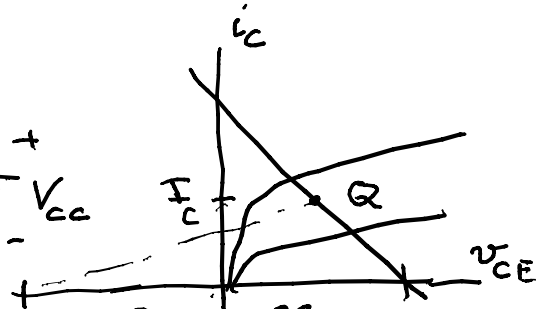


In forward active region C-B junction is back biased

E-B " " forward biased

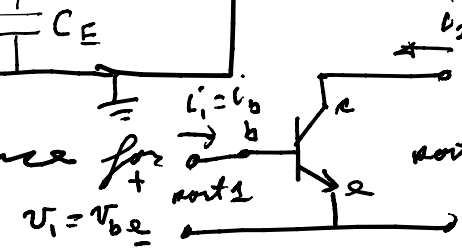
Biasing

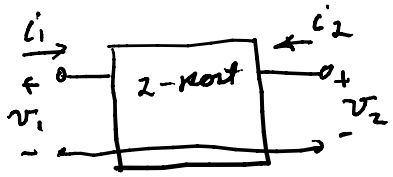




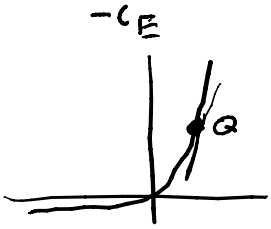
to stop thermal runaway

The 2-port admittance for





$$\begin{bmatrix} i_1 \\ i_2 \end{bmatrix} = \begin{bmatrix} y_{11} & y_{12} \\ y_{21} & y_{22} \end{bmatrix} \begin{bmatrix} v_1 \\ v_2 \end{bmatrix}$$



$$-i_E = I_{ES} e^{v_{BE}/V_T} \quad ; \quad i_C = \alpha(-i_E)$$

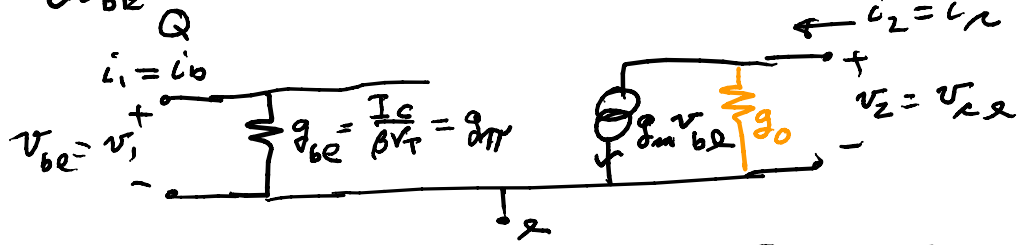
$$g_E = \frac{\partial(-i_E)}{\partial v_{BE}} = \frac{1}{V_T} I_{ES} e^{v_{BE}/V_T} = \frac{-i_E}{V_T} = \frac{1}{\alpha}\frac{i_C}{V_T}\bigg|_Q = \frac{I_C}{\alpha V_T}$$

$i_B + i_E + i_C = 0$ by KCL

$$i_B = -(i_E + i_C) = -(i_E - \alpha i_E) = -(1-\alpha) i_E = -(1-\alpha)\left(\frac{-i_C}{\alpha}\right) = \frac{i_C}{\frac{\alpha}{1-\alpha}} \qquad \beta = \frac{\alpha}{1-\alpha}$$

$$= \frac{i_C}{\beta} \Rightarrow @Q \quad I_B = \frac{I_C}{\beta} = \frac{\alpha V_T \cdot g_E}{\beta}$$

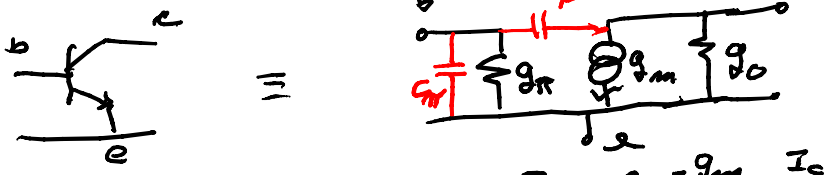
$$i_b = i_1 = \frac{\partial i_B}{\partial v_{BE}}\bigg|_Q \cdot v_{be} = \frac{\partial i_B}{\partial i_E} \cdot \frac{\partial i_E}{\partial v_{BE}} \cdot v_{be} = -(1+\alpha)\frac{I_C}{\alpha V_T} \cdot v_{be} = \frac{I_C}{\beta V_T} \cdot v_1$$



$$\left.\frac{\partial i_C}{\partial v_{BE}}\right|_Q = g_m = \left.\frac{\partial(-\alpha i_E)}{\partial v_{BE}}\right|_Q = \alpha\left(\left.\frac{\partial -i_E}{\partial v_{BE}}\right|_Q\right) = \alpha \cdot \frac{I_C}{\alpha V_T} = \frac{I_C}{\alpha} = g_m$$

= mutual conductance
= transconductance

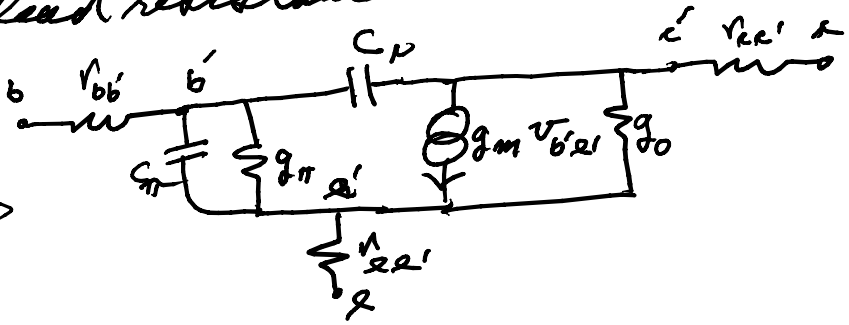
$$\left.\frac{\partial i_c}{\partial v_{CE}}\right|_Q = g_o = \text{output conductance} = \frac{I_C}{V_A}$$



$$g_m = \frac{I_C}{V_T}, \quad g_\pi = \frac{g_m}{\beta} = \frac{I_C}{\beta V_T}, \quad g_o = \frac{I_C}{V_A}$$

C_μ & C_π are junction capacitors

putting in lead resistance



hybrid-π $\Rightarrow$ equivalent circuit

Example: $I_C = 1\,mA$, $\beta = 100$, $V_A = 200$, $V_T = 26\,mV$

$$g_m = \frac{I_C}{V_T} = \frac{10^{-3}}{26\times10^{-3}} = \frac{1}{26}, \quad g_\pi = \frac{g_m}{\beta} = \frac{1}{2600}, \quad g_o = \frac{1\times10^{-3}}{200} = \frac{1}{2}\times10^{-5}$$

$$r_\pi = \frac{1}{g_\pi} = 2.6\,k\Omega \qquad r_o = \frac{1}{g_o} = 2\times10^5 = 200\,k\Omega$$