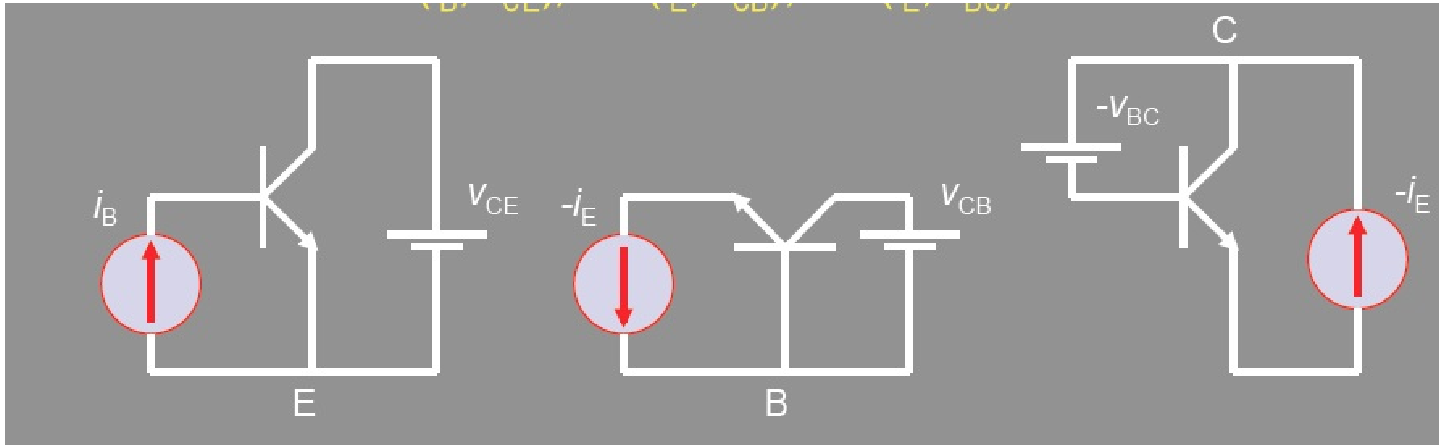
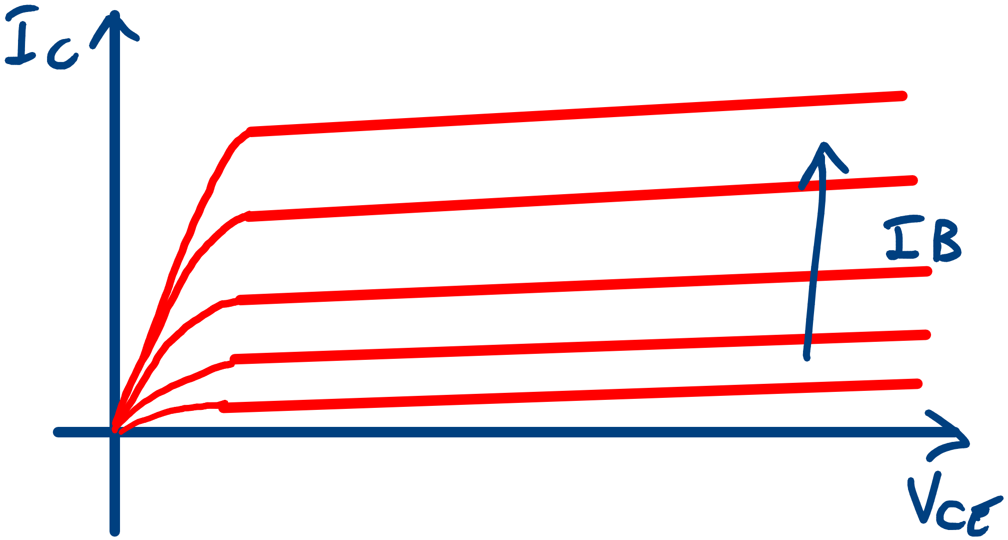
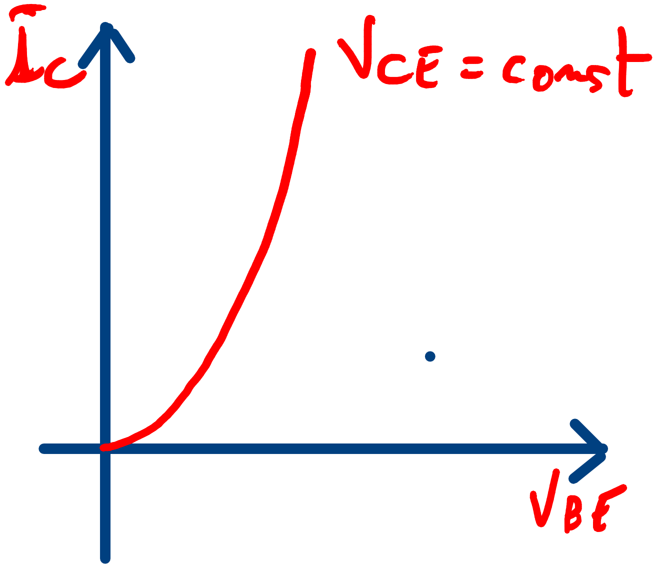
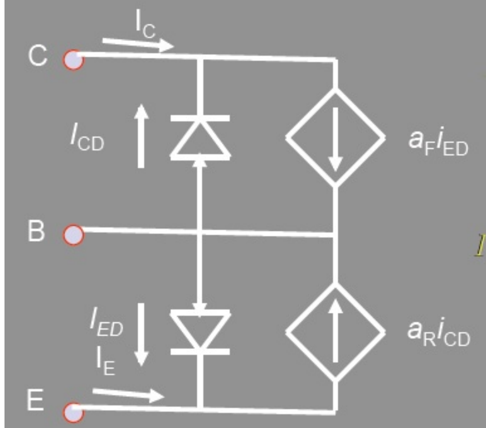

C
$-V_{BC}$
i_B
V_{CE}
$-i_E$
V_{CB}
$-i_E$
E
B


I_C
I_B
V_{CE}


I_C
$V_{CE} = const$
V_{BE}

Modello di Ebers e Moll

- Occorre introdurre in parallelo ai diodi dei generatori di corrente
  - Proporzionali alla corrente nella giunzione opposta
    - I diodi seguono la legge di Schokley
    - Nel caso ideale si ha $a_R I_{SCB} = a_F I_{SEB}$

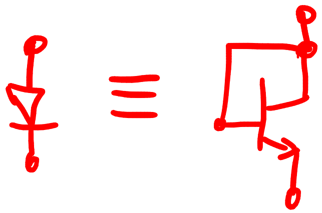


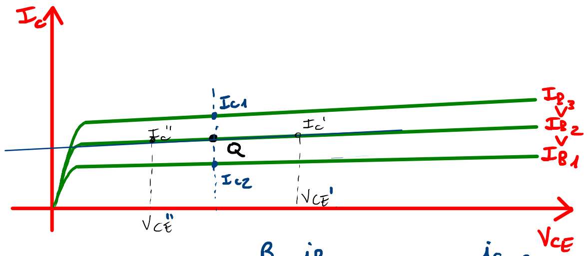
$$I_E = -I_{SEB}\left(e^{\frac{V_{BE}}{V_T}} - 1\right) + a_R I_{SCB}\left(e^{\frac{V_{BC}}{V_T}} - 1\right)$$

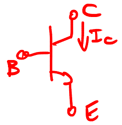
$$I_C = -I_{SCB}\left(e^{\frac{V_{BC}}{V_T}} - 1\right) + a_F I_{SEB}\left(e^{\frac{V_{BE}}{V_T}} - 1\right)$$

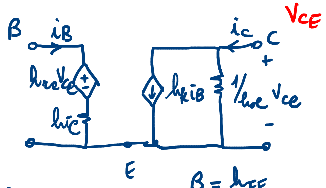
$$I_E = -I_{ED} + \alpha_R i_{CD} = -I_{SEB}\left(e^{\frac{V_{BE}}{V_T}} - 1\right) + \alpha_R I_{SCB}\left(e^{\frac{V_{BC}}{V_T}} - 1\right)$$

$$I_C = -I_{CD} + \alpha_F i_{ED} = -I_{SCB}\left(e^{\frac{V_{BC}}{V_T}} - 1\right) + \alpha_F I_{SEB}\left(e^{\frac{V_{BE}}{V_T}} - 1\right)$$









$$\begin{cases} V_{BE} = h_{re} V_{ce} + h_{ie} i_B \\ i_c = h_{fe} i_B + V_{ce} h_{oe} \end{cases}$$

$\beta = h_{FE}$

$I_C = h_{FE} I_B = \beta I_B$

$h_{FE} \neq h_{fe}$

$$\Delta i_c = h_{fe} \Delta i_B + 0 \Rightarrow h_{fe} = \frac{\Delta i_c}{\Delta i_B}\Big|_{V_{CE}=cost}$$

$$h_{fe} = \frac{I_{c1} - I_{c2}}{I_{B3} - I_{B1}} \qquad h_{oe} = \frac{\Delta i_c}{\Delta V_{CE}}\Big|_{i_B = cost}$$

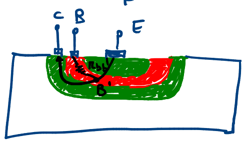
$$h_{oe} = \frac{I_c' - I_c''}{V_{CE}' - V_{CE}''} \qquad h_{re} = \frac{\Delta V_{BE}}{\Delta V_{CE}}\Big|_{i_B = cost}$$

$$h_{ie} = \frac{\Delta V_{BE}}{\Delta i_B}\Big|_{V_{CE} = cost}$$

$$i_c \simeq I_S e^{\frac{V_{BE}}{V_T}} \qquad i_B = \frac{i_c}{\beta} \simeq \frac{I_S}{\beta} e^{\frac{V_{BE}}{V_T}}$$

$$\frac{\Delta i_B}{\Delta V_{BE}} = \frac{1}{h_{ie}} = \frac{1}{\beta V_T} I_S e^{\frac{V_{BE}}{V_T}} = \frac{i_c}{\beta V_T}$$

$$h_{ie} = \underbrace{\frac{\beta V_T}{i_c}}_{r_{b'e}}$$



$$h_{ie} = r_{bb'} + r_{b'e}$$

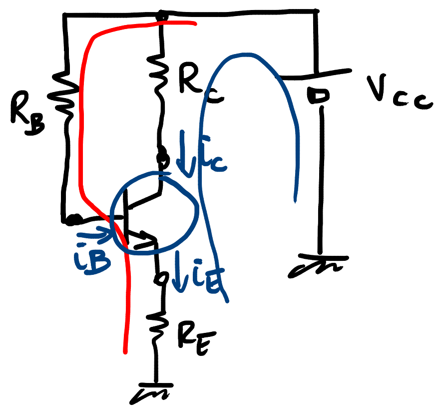
Es.: BC109B $\quad h_{ie}^* (@\, I_C = 2mA, V_{CE} = 5V) = 4{,}8k\Omega$

$h_{fe}^* (@\, I_C = 2mA, V_{CE} = 5V) = 300$

$$h_{ie}^* = r_{bb'} + r_{b'e}^* = r_{bb'} + \frac{h_{fe}^* V_T}{I_C^*} =$$

$$r_{bb'} = h_{ie}^* - \frac{h_{fe}^* V_T}{I_C^*} = 900\Omega$$

$$r_{b'e} = \frac{h_{fe} V_T}{I_C}$$



$$V_{CC} = R_B i_B + V_{BE} + R_E i_E$$

$$i_C = \beta i_B = h_{FE} i_B$$

$$i_E = i_C + i_B = (h_{FE}+1) i_B$$

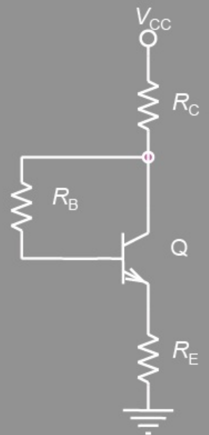
$$i_B = \frac{V_{CC} - V_{BE}}{R_B + (\beta+1) R_E}$$

$$V_{BE} = 0{,}7V$$

$$V_{CE} = V_{CC} - R_C i_C - R_E i_E \Rightarrow$$

$$\Rightarrow V_{CE} = V_{CC} - [\beta R_C + (\beta+1) R_E] i_B$$

Polarizzazione con resistenza a C



$$(R_C + R_E) i_E + v_{BE} + R_B i_B = V_{CC}$$

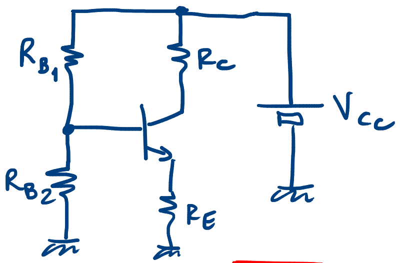
$$i_C = \beta i_B$$

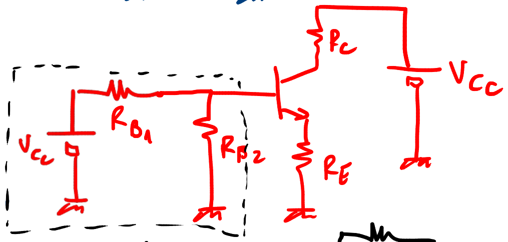
$$i_E = (\beta + 1) i_B$$

$$i_B = \frac{V_{CC} - v_{BE}}{R_B + (\beta+1)(R_C + R_E)}$$

$$v_{CE} = V_{CC} - (R_C + R_E) i_E$$

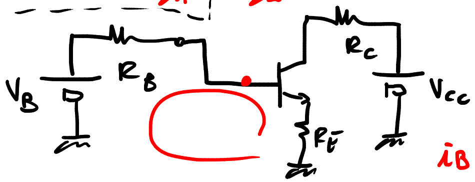
$$v_{CE} = V_{CC} - (\beta+1)(R_C + R_E) i_B$$





$$V_B = \frac{R_{B2}}{R_{B1}+R_{B2}} V_{cc}$$

$$R_B = R_{B1} /\!/ R_{B2}$$



$$V_B = R_B i_B + V_{BE} + R_E i_E$$

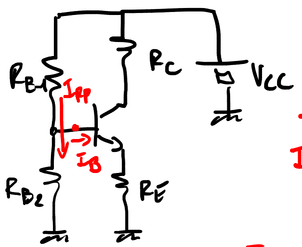
$$i_C = \beta i_B \wedge i_E = (\beta+1) i_B$$

$$i_B = \frac{V_B - V_{BE}}{R_B + (\beta+1) R_E}$$

$$V_{CE} = V_{cc} - R_c i_c - R_E i_E =$$

$$V_{cc} - R_c \beta i_B - R_E(\beta+1) i_B =$$

$$= V_{cc} - \left[R_c \beta + R_E(\beta+1)\right] i_B$$



$$I_{RB} = \frac{V_{cc}}{R_{B1}+R_{B2}} \gg I_B \Rightarrow V_{Base} \simeq \frac{V_{cc} R_{B2}}{R_{B1}+R_{B2}}$$

$$I_E = \frac{V_{Base} - V_{BE}}{R_E} \qquad I_C \gg I_B$$

$$I_C \simeq I_E$$

$$V_{CE} \simeq V_{cc} - (R_C + R_E) I_C$$

Ho ricavato I_c e V_{CE}, allora dalle caratteristiche ricavo $\underline{I_B}$

Devo verificare che $\begin{cases} I_{RB} \gg I_B \\ I_C \gg I_B \end{cases}$