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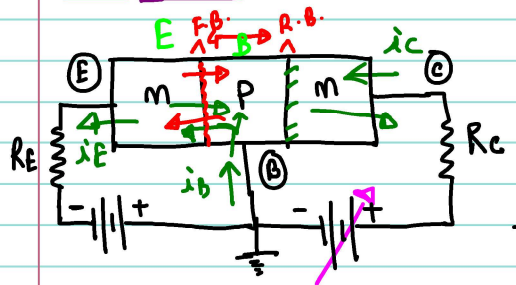
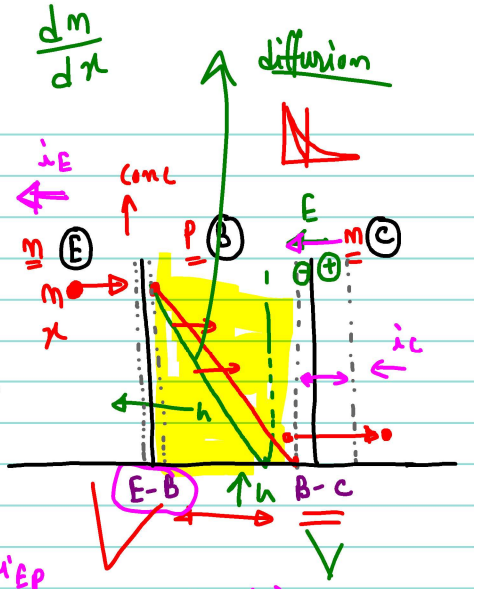
BJT – Operation:

In forward-Active Mode





$i_E = i_{En} + i_{Ep}$; $i_{En} >> i_{Ep}$

$i_E \propto \exp\left(\frac{V_{BE}}{V_T}\right)$

$\rightarrow i_E = I_{EO} \exp\left(\frac{V_{BE}}{V_T}\right)$

$i_C \propto i_E$

$\rightarrow i_E > i_C$

$\rightarrow i_C \propto \exp\left(\frac{V_{BE}}{V_T}\right)$

$i_C = I_{CO} \exp\left(\frac{V_{BE}}{V_T}\right)$

$i_C = \alpha I_E$; $\alpha < 1$, $\alpha \approx 1$

$i_B = i_{Ep} + i_{BR}$

$i_{Ep} \rightarrow \exp\left(\frac{V_{BE}}{V_T}\right)$

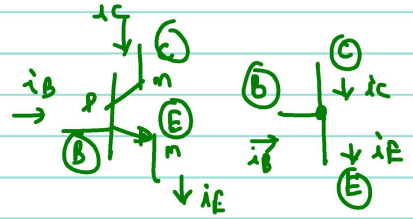
$i_{BR} \rightarrow \exp\left(\frac{V_{BE}}{V_T}\right)$

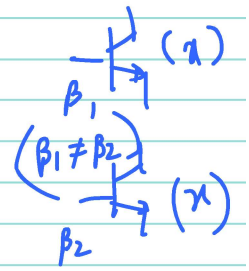
$i_B \propto \exp\left(\frac{V_{BE}}{V_T}\right)$

i_C, i_B are linearly related.

$\frac{i_C}{i_B} = \beta$; β = Common-Emitter current gain

$50 < \beta < 300$ (typical value)





$i_E = i_C + i_B$

$i_E = (\beta+1) i_B$

$i_E = i_C + \frac{i_C}{\beta}$

$i_E = \left(\frac{\beta+1}{\beta}\right) i_C$

$\rightarrow i_C = \left(\frac{\beta}{1+\beta}\right) i_E$

$\rightarrow i_C = \alpha i_E$

$i_C = \beta i_B$; $i_B = \frac{i_C}{\beta}$

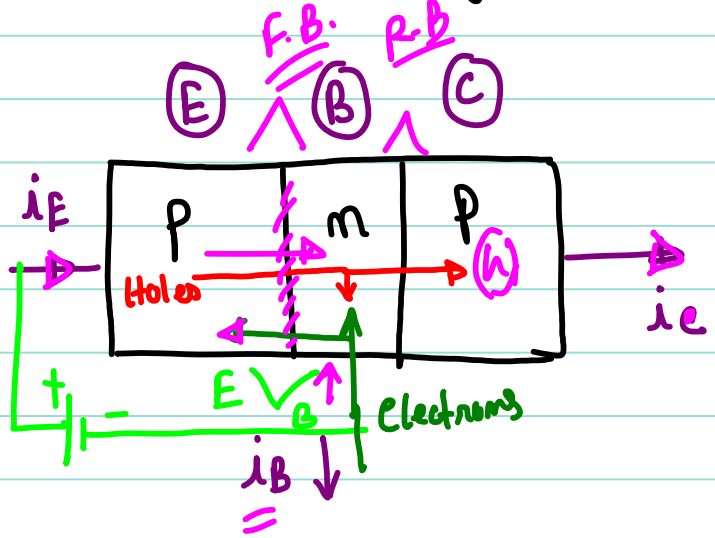
$\alpha = \frac{\beta}{1+\beta}$

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

$\beta = 100$

$= \frac{100}{101} \approx 1$

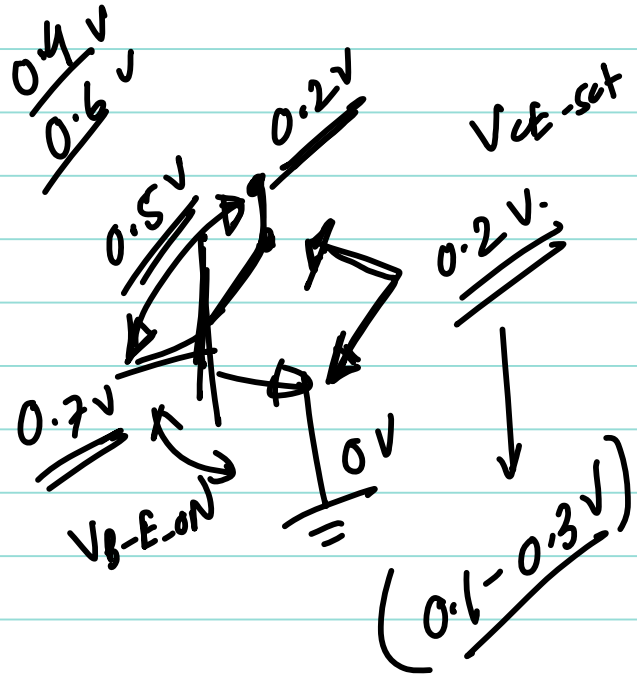
BJT: P-n-P type



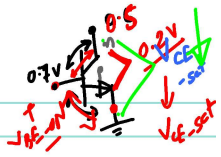
$$i_E = i_B + i_C$$

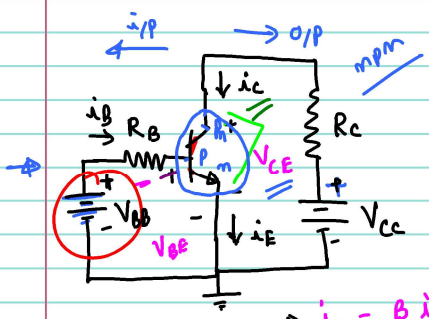
$$i_E = I_{E0} \exp\left(\frac{V_{EB}}{V_T}\right)$$

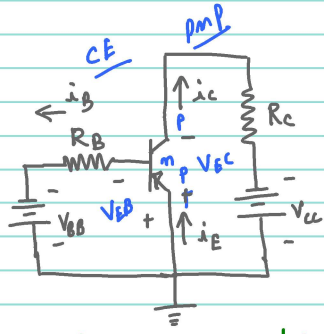
$$i_C = I_{S0} \exp\left(\frac{V_{EB}}{V_T}\right)$$



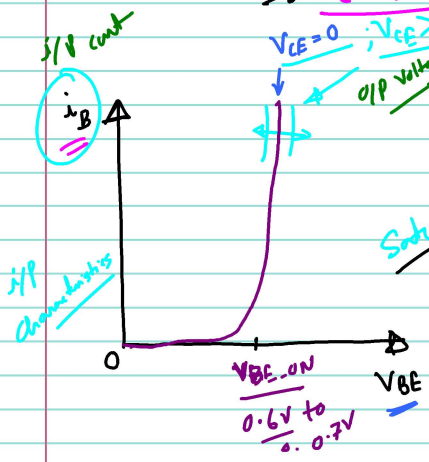
Common Emitter circuit (CE):

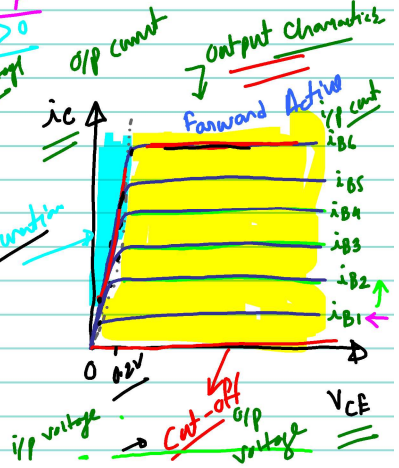






$i_C = \beta i_B$





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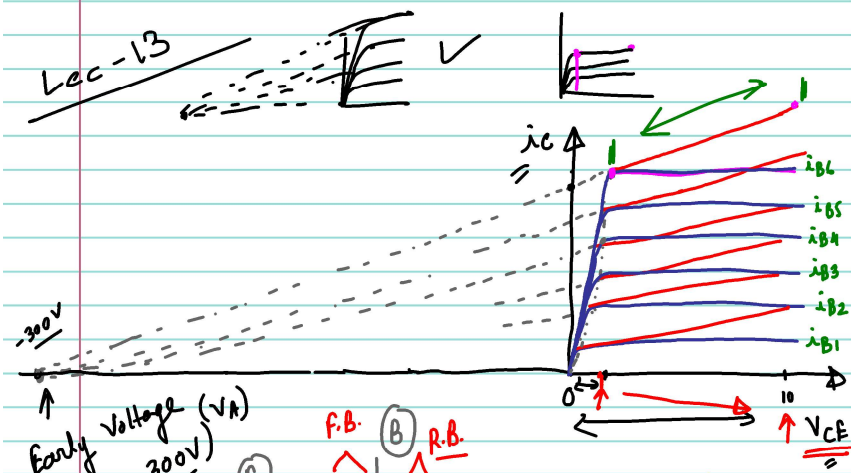
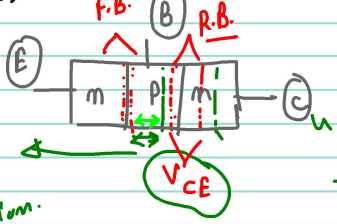


Early Voltage (V_A) (50 - 300V)



Base width modulation.

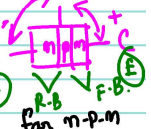
J.M. Early

Early Effect

Active region $\rightarrow$ $i_C = \left[I_S \exp\left(\frac{V_{BE}}{V_T}\right)\right]\left(1 + \frac{V_{CE}}{V_A}\right)$

$\frac{1}{r_o} = \left.\frac{\partial i_C}{\partial V_{CE}}\right|_{V_{BE}=\text{const.}} = \frac{\left[I_S \exp\left(\frac{V_{BE}}{V_T}\right)\right]}{V_A} = \frac{I_C}{V_A}$

$r_o = \frac{V_A}{I_C}$



for n-p-n BJT