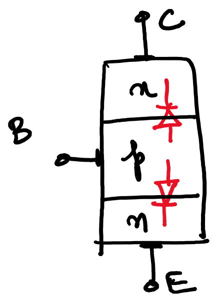
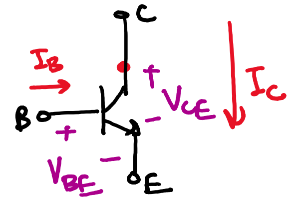
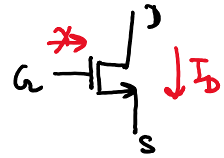
ECE 310 - Lecture 27.

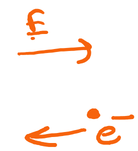
Friday, March 30, 2018 10:26 AM

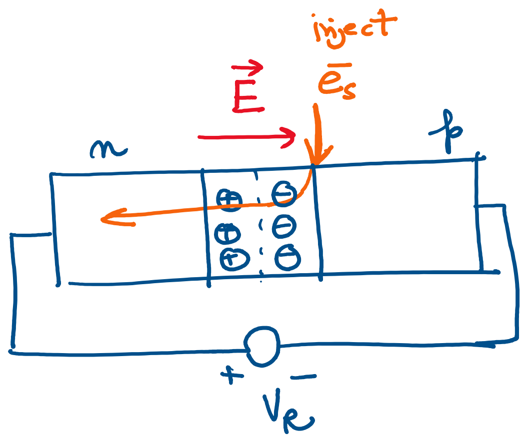
BJTs









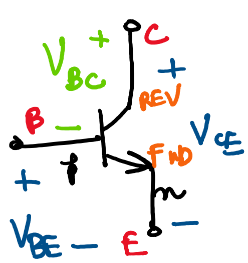


an $\bar{e}$ injected from the right edge of the D.R.

↳ minority carrier in the p-side

↳ experiences the E-field and is swept to the n-side

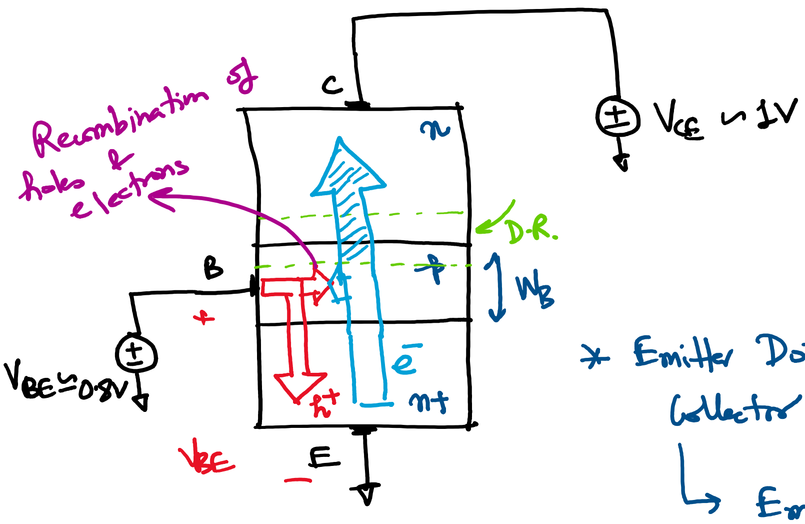
↳ Reversed biased pn junction efficiently "collects" externally injected electrons.



* We begin with an assumption that

$V_{BE} > 0$ forward biased

$V_{BC} < 0$ is reversed-biased



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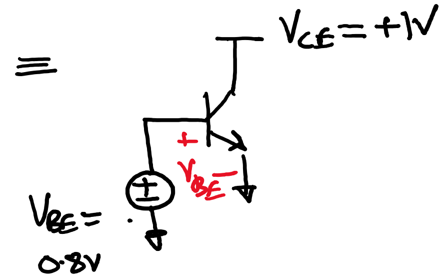
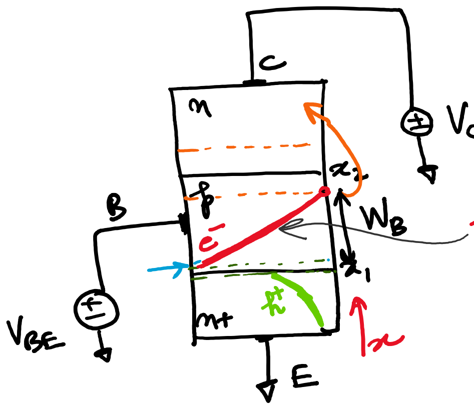


* Emitter Doping level is much higher than the Collector
  - ↳ Emitter injects a large

* Emitter injects a large number of electrons into the base while it receives a small number of holes from it

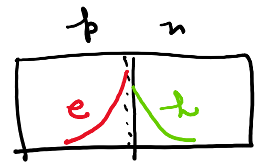
* Base region is "thin"
  - ↳ most of the $\bar{e}$s reach the edge of the C-B depletion region
    - ↳ swept to the collector by the Electric field

electron concentration in the base region



gradient of e^-s concentration in the base

$$-\frac{dn(x)}{dx}$$



$$e^{V_{bi}/V_T} = \frac{N_E N_B}{n_i^2} \rightarrow (1)$$

$N_E \Rightarrow$ Doping concentration in the emitter

$N_B \Rightarrow$ Base doping concentration

$V_{bi} \Rightarrow$ Built-in potential of BE junction

$W_B \Rightarrow$ Base width

Excess minority carriers at $x = x_1$

$$\Delta n(x_1) = \frac{N_E}{e^{V_{bi}/V_T}}\left(e^{V_{BE}/V_T} - 1\right)$$

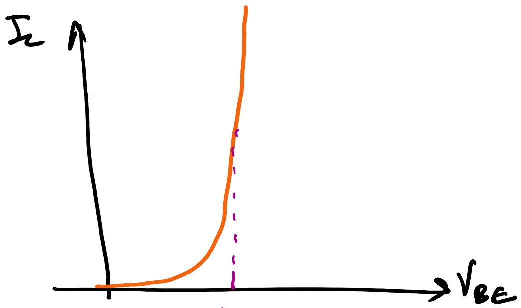
$$= \frac{N_B}{n_i^2}\left(e^{V_{BE}/V_T} - 1\right)$$

$$\Rightarrow J_n = q D_n \frac{dn}{dx} = q D_n \frac{[0 - \Delta n(x_1)]}{W_B}$$

$$\Rightarrow J_n = \frac{q D_n n_i^2}{W_B N_B}\left(e^{V_{BE}/V_T} - 1\right)$$

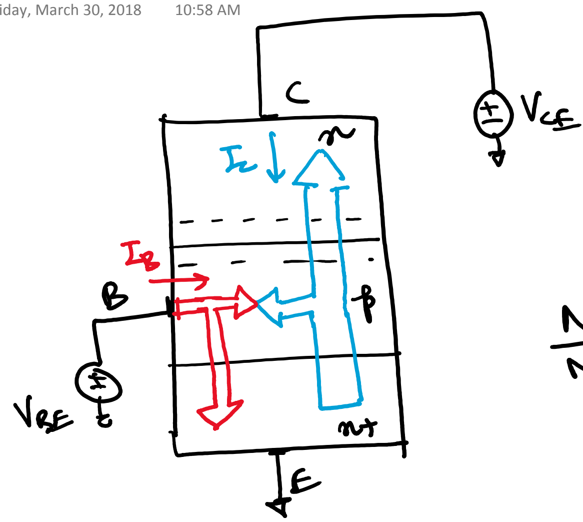
$$I_c = A J_n = \underbrace{\frac{q A D_n n_i^2}{W_B N_B}}_{I_s}\left(e^{V_{BE}/V_T} - 1\right)$$

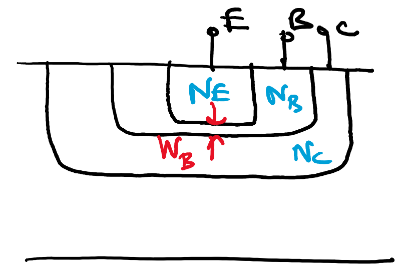
$$\boxed{I_c = I_s\left(e^{V_{BE}/V_T} - 1\right) \simeq I_s e^{V_{BE}/V_T}} \rightarrow (1)$$



$V_{BE,on} \simeq 0.8V$

$0.65 - 0.8V$





$\frac{N_E}{N_B} \Leftarrow$ doping ratios

+ Base current results from flow of holes

↳ The $\bar{e}$ and hole currents in BE fwd-bias pn junction bear a constant ratio with each other

↳ designed by $\frac{N_E}{N_B}$ (doping ratio)

$$\boxed{I_C = \beta I_B} \rightarrow (2)$$

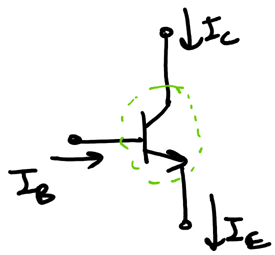
$\beta \simeq 50$ to 500

* for every $\beta \simeq 200$ electrons injected by the emitter, one hole must be supplied by the base.

$\beta \Rightarrow$ Current gain

↳ shows how much the base current is amplified

$I_C = \beta I_B$



KCL $\Rightarrow$ $I_E = I_C + I_B$

$= \beta I_B + I_B$

$= \boxed{(\beta+1) I_B}$

$= I_C + \frac{I_C}{\beta} = I_C(1 + 1/\beta)$

$$I_E = I_C(1 + 1/\beta)$$

$$\Rightarrow \quad I_C = \underbrace{\left(\frac{\beta}{\beta+1}\right)}_{\alpha} I_E$$

$$\boxed{I_C = \alpha I_E} \rightarrow ③ \qquad \alpha = \frac{\beta}{\beta+1} < 1$$

for $\beta = 100 \Rightarrow \alpha = 0.99$

if $\beta \to \infty$ very large $\Rightarrow \alpha \to 1$

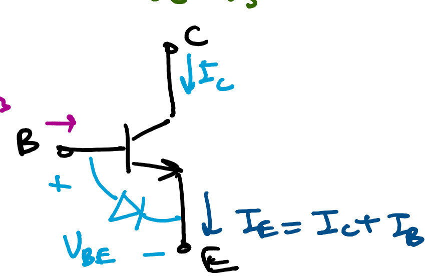
$\Rightarrow \boxed{I_C \simeq I_E}$ for large β

Large-Signal Model

$I_C = I_S e^{V_{BE}/V_T}$ in "forward-active region"

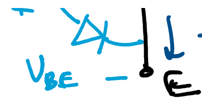
BE is fwd biased

$$\frac{I_C}{\beta} = \frac{I_S}{\beta} e^{V_{BE}/V_T} = I_B$$



Useful equations so far

✓ $I_C = I_S e^{V_{BE}/V_T}$



$I_E = I_C + I_B$

$\tilde{V}_{BE} \rightarrow \tilde{I}_C \rightarrow \tilde{I}_B \rightarrow \tilde{I}_E$

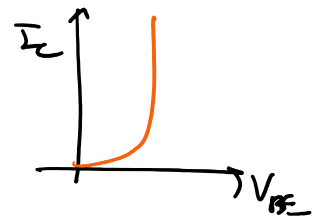
Cause-effect chain of BJT

$I_C = I_S e^{V_{BE}/V_T}$

$I_C = \beta I_B$

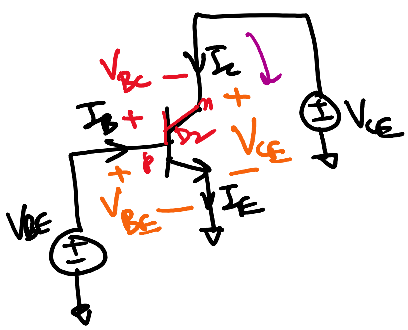
$I_C = \alpha I_E$

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



$\equiv I_D - V_{GS}$

Friday, March 30, 2018 11:16 AM



$V_{BE} \simeq V_{CE}$ $V_{BC} = 0$

$V_{BE} < V_{CE}$ $V_{BC} < 0$ D_2 is rev biased

$V_{BE} > V_{CE}$ $V_{BC} > 0$ D_2 is fwd biased

"Saturation Regime"