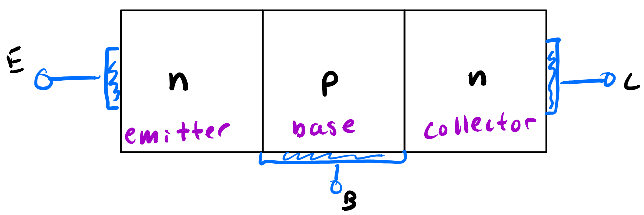
Bipolar Junction Transistors (BJTS)

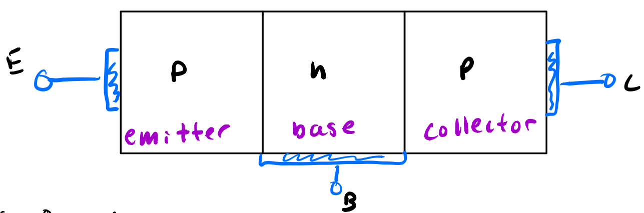
BJT's were the transistor of choice but they were supplanted by mosfets in 1980s

↳ large, asymmetrical, higher power

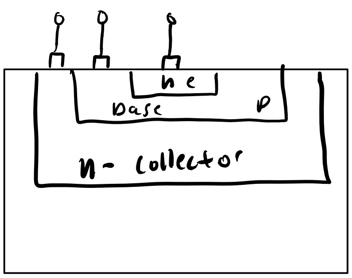
↳ good for discrete circuits, for high power or high frequency application.



npn



pnp



npn cross section.

BJTs look like 2 pn junctions

emitter base junction EBJ
Collecter base junction CBJ } FB or RB

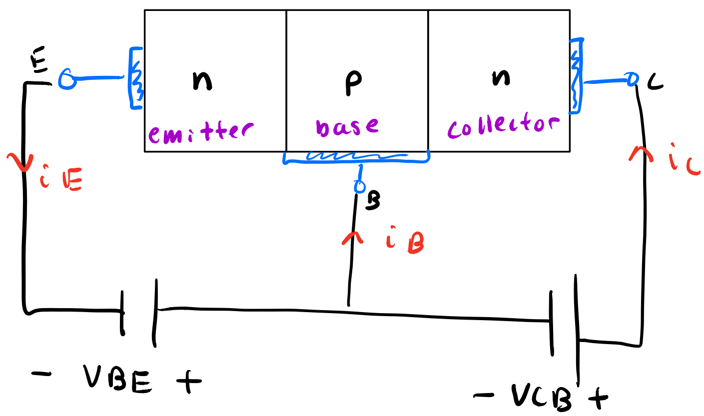
modes of operation:

active : amplifiers

cutoff :
Saturation : } digital logic ckts

↑ junctions ✳ Both types of charge carrier participate in current conduction → Bipolar operation

Active Mode operation



$V_{BE} > 0$ (p) base is greater than the (n) emitter => Forward biased

$V_{CB} > 0$ (n) collector is greater than the (p) base => Reverse Biased.

$$i_c = I_S \exp\left(V_{BE}/V_T\right)$$

Saturation current

Thermal Voltage

i_c is independent of V_{CB} iff V_{CB} is at least greater than 0. (Reverse Biased)

$$i_B = \frac{i_c}{\beta}$$

$\beta \equiv$ common emitter current gain
↳ 50 -> 200

β unitless

related to width of base region and ratio of the doping levels to the to the emitter

high β -> thin base lightly doped base heavily doped emitter.

$$i_B = \frac{I_S}{\beta} \exp\left(V_{BE}/V_T\right) \qquad i_E = i_B = i_c$$

$$= \frac{I_S}{\beta} \exp\left(V_{BE}/V_T\right) + I_S \exp\left(V_{BE}/V_T\right)$$

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

$$i_C = \alpha \, i_E$$

$\alpha \equiv$ common base current gain

α unitless

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

$\alpha < 1$ (.98-.99

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

$$I_S = \frac{A_E \, q \, D_n \, n_i^2}{N_A \cdot W}$$

A_E cross sectional area of emitter base junction

D_n diffusivity of electrons in the base

n_i intrinsic carrier concentration

N_a concentration of acceptor atoms in the base

W base width

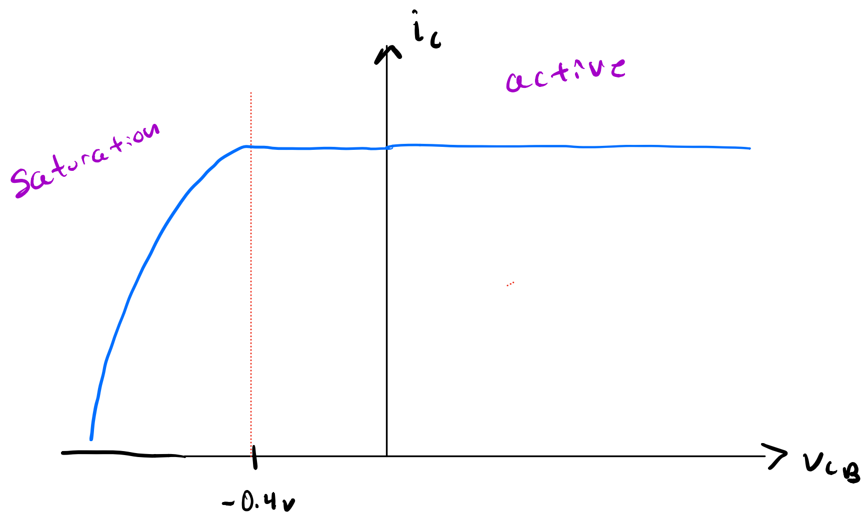
$I_S \sim 10^{-12}$ to 10^{-18} A

very dependent on temp.

Scale current

Saturation mode

To be active $V_{CB} > -0.4v$



$V_{CE_{sat}} = V_{BE} - V_{BC}$

V_{BC} is always smaller than V_{BE} by $.1v \rightarrow .3v$

↳ C_{BJ} area < EBJ

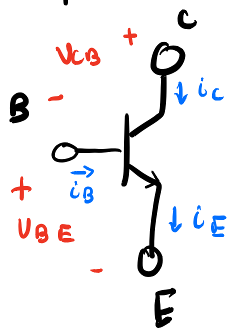
$V_{CE\,sat} = 0.1$ to $0.3v$

$V_{CE\,sat}$ (edge) $= 0.3v$

$V_{CE\,sat}$ (deep) $= 0.2v$

BJT Operation / DC Biasing

npn



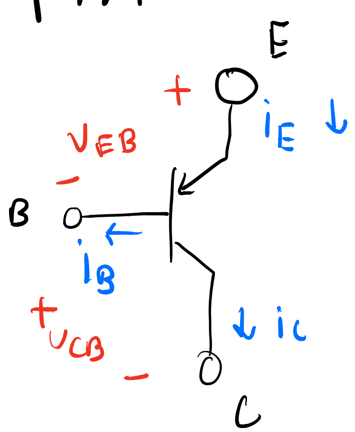
$$I_C = I_S \exp\left({V_{BE}}/{V_T} \right)$$

$$i_B = \frac{i_C}{\beta} \qquad \beta = \frac{\alpha}{\alpha - 1} \qquad \alpha = \frac{\beta}{\beta + 1}$$

$$i_E = i_B + i_C$$

active: $V_{BE} > 0$ $\quad$ $v_{CB} > -0.4v$

pnp



$$I_C = I_S \exp\left({V_{EB}}/{V_T} \right)$$

$$i_B = \frac{i_C}{\beta} \qquad \beta = \frac{\alpha}{\alpha - 1} \qquad \alpha = \frac{\beta}{\beta + 1}$$

$$i_E = i_C + i_B \qquad i_C = \alpha i_E$$

active mode $VEB > 0$ $\quad$ $V_{BC} > -0.4v$