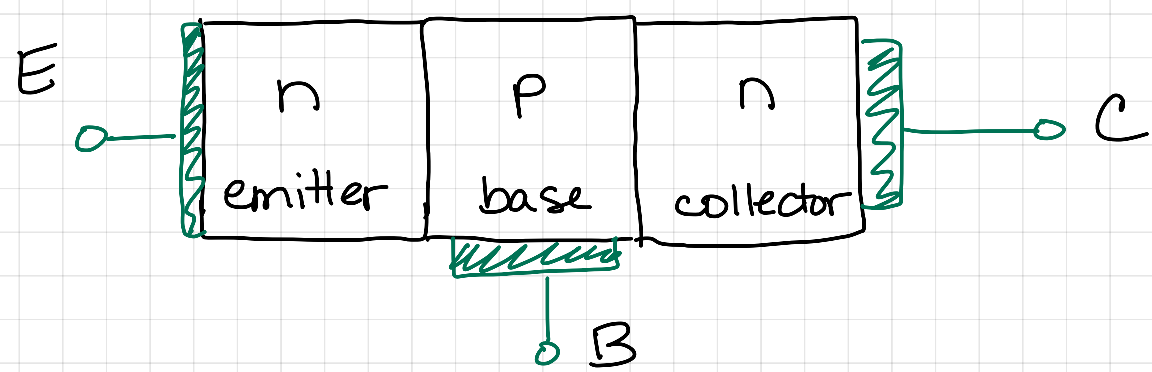
Bipolar Junction Transistors (BJTs)

BJTs were the transistor but they were supplanted by MOSFETs 1980s.

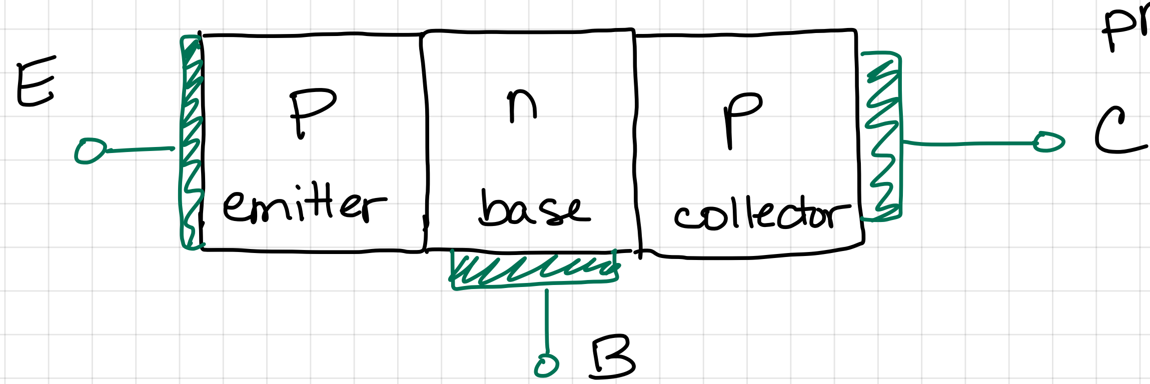
↳ large, asymmetrical, higher power

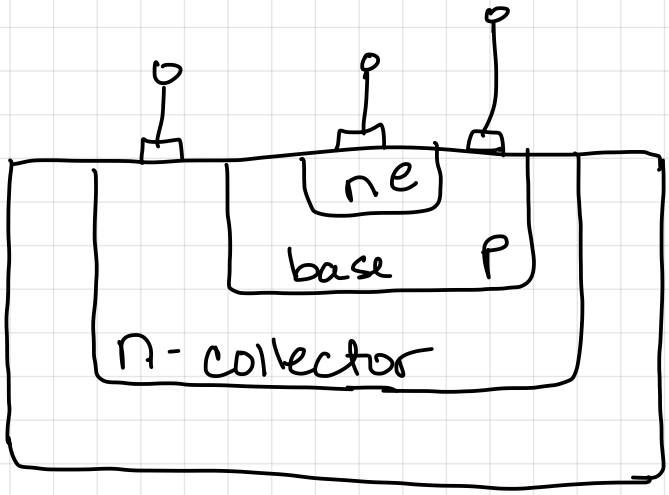
↳ good discrete circuits, for high power or high frequency application

npn



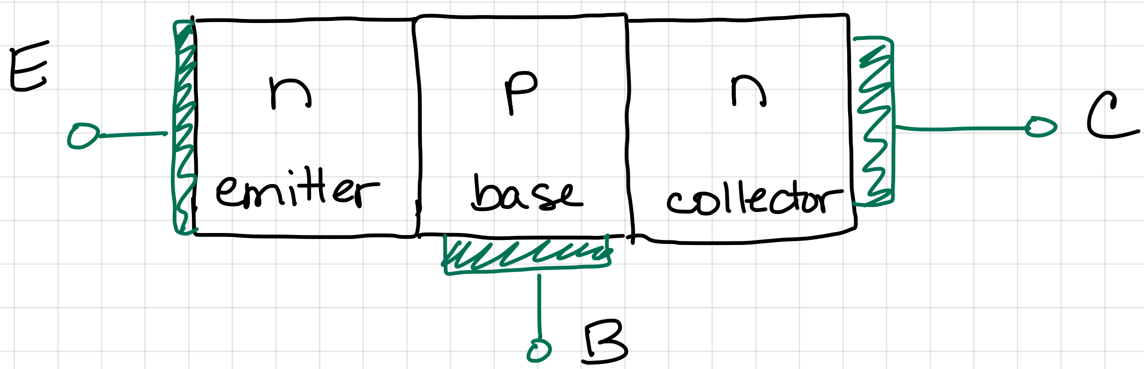
pnp





npn crossection

BJTs look like 2 pn junctions.



emitter - base junction EBJ } FB or
collector base junction CBJ } RB

<u>modes of operation</u>

Active : → amplifiers

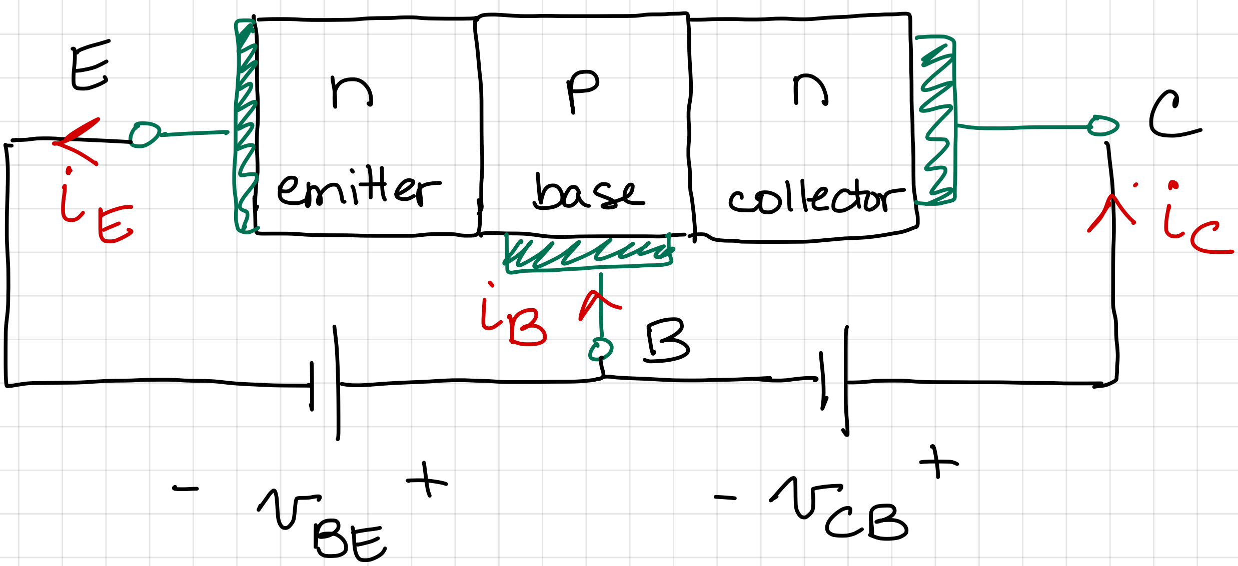
Cutoff : } digital logic ckts
Saturation :

↑ Junctions are important

* 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

$$i_C = I_S \exp\left(v_{BE}/V_T \right)$$

I_S ↑ saturation current

V_T thermal voltage

i_c is independent of v_{CB} as long as v_{CB} is at least greater zero. (Reverse Biased)

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

$\beta \equiv$ common emitter current gain $= 50$ to 200

related to width of the base region

and ratio of the doping levels of the base to the emitter.

high $\beta \rightarrow$ thin base (geom.)
lightly doped base
heavily doped emitter

β is unitless

$$i_B = \frac{I_s}{\beta} \exp(v_{BE}/V_T)$$

$$i_E = i_B + i_c$$

$$= \frac{I_s}{\beta} \exp(v_{BE}/V_T) + I_s \exp(v_{BE}/V_T)$$

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

$$i_C = \alpha \, i_E$$

$\alpha \equiv$ common base current gain.

α = unitless

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

$\alpha < 1$ typically 0.98-0.99

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

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

A_E = cross-sectional area of the emitter base junction

D_n = diffusivity of electrons in the base

$n_i \equiv$ intrinsic carrier concentration

$N_A \equiv$ concentration of acceptor atoms in the base

W = base width

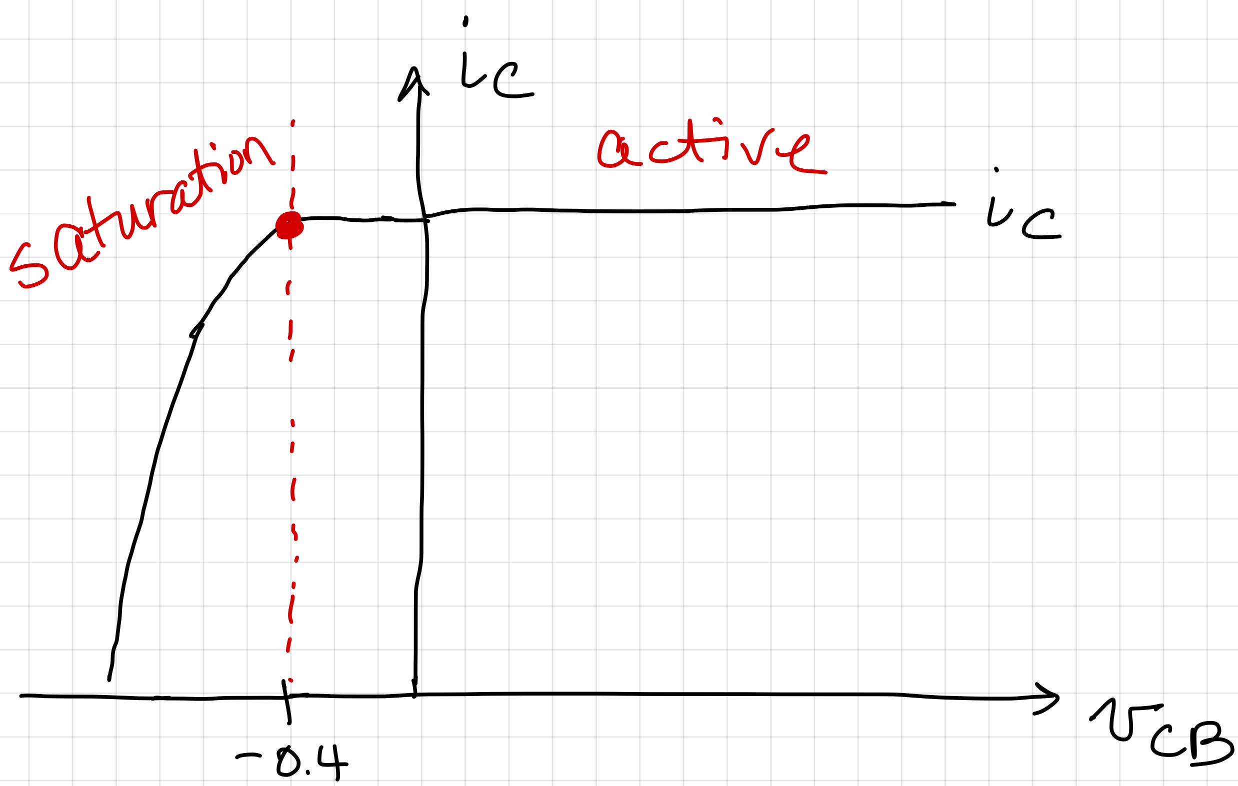
$I_S \sim 10^{-12}$ to 10^{-18} A

↑ very dependent on temperature

scale current

<u>saturation mode</u>

to be active $v_{CB} > -0.4V$



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

v_{BC} is always smaller than v_{BE} by 0.1V to 0.3V

CBJ area < EBJ

$v_{CE\,sat} = 0.1$ to $0.3V$

$v_{CE\,sat}$ (edge) $= 0.3V$

$v_{CE\,sat}$ (deep) $= 0.2V$