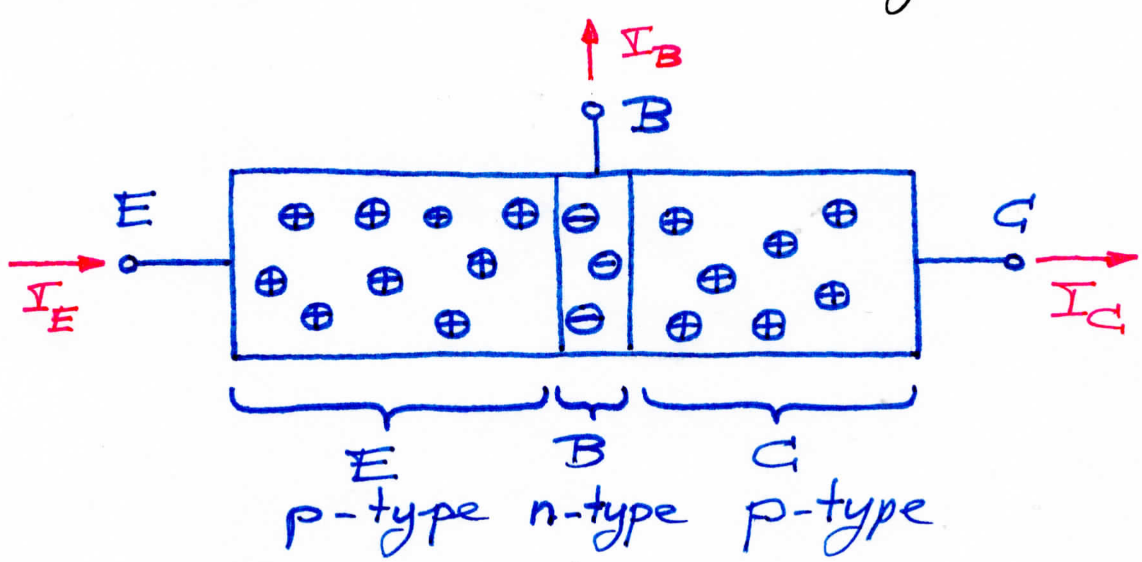
Bipolar junction transistor (BJT)

* Two pn-junctions, e.g. pnp, with the middle n-type layer being very thin
* Base thickness ≪ Diffusin length of carriers
* Three electrodes : Emitter (E), Base (B) and Collector (C)

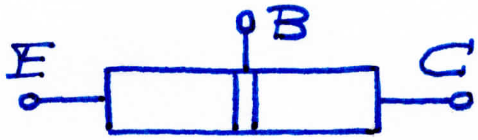
Emitter ⇒ Emits charge carriers

Base ⇒ Middle electrode ; Control electrode

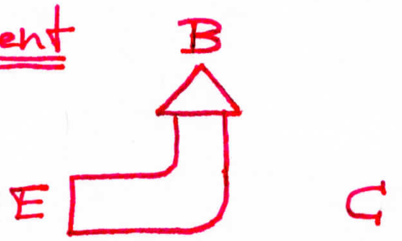
Collector ⇒ Collects charge carriers



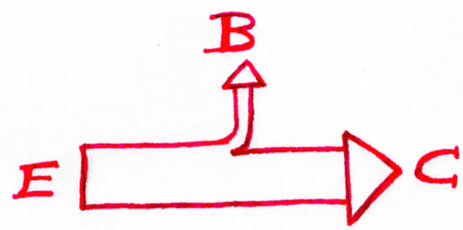
* BE diode ⇒ Forward bias ⇒ $V_{BE} \approx 0.7V$
⇒ I_E is controlled by V_{BE} ⇒ Base (B) is very thin ⇒ Most carriers injected from Emitter (E) into Base (B) reach the Collector (C).



<u>Current</u>



<u>No!</u> <u>False!</u>



$I_C = \alpha\, I_E$

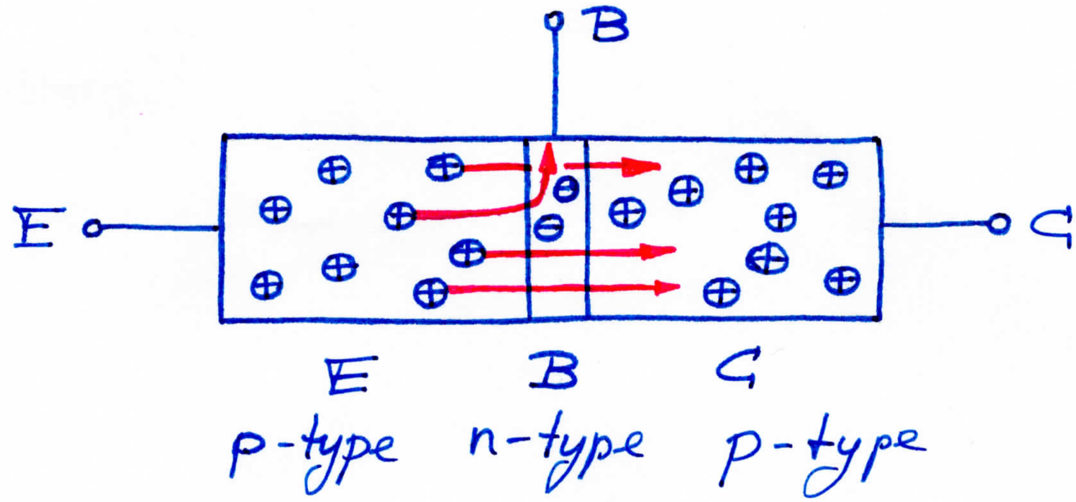
$\alpha \rightarrow \lesssim 1.0$

$\alpha \rightarrow 0.99$

KCL

$$\boxed{I_E = I_B + I_C}$$

Flow of charge carriers

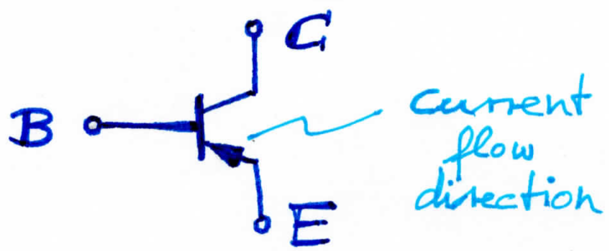


⇒ Most holes (⊕) injected from E into B reach the C.

⇒ C is negatively biased with respect to B, thereby attracting holes and make them go from **E** to **C**.

BJT circuit symbols

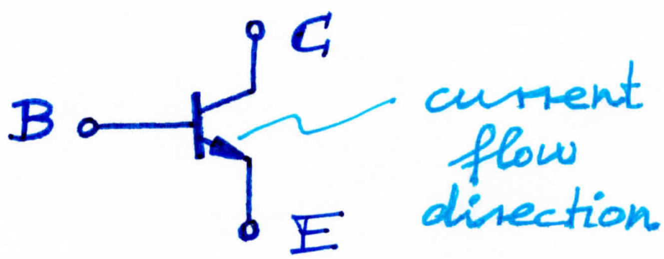
pnp transistor



C ⇒ p-type
B ⇒ n-type
E ⇒ p-type

$V_{BE} < 0$ (negative) in active regime

npn transistor

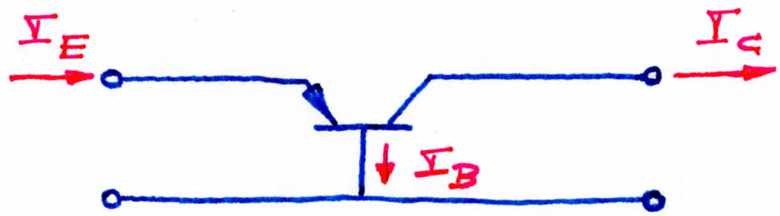


C ⇒ n-type
B ⇒ p-type
E ⇒ n-type

$V_{BE} > 0$ (positive) in active regime

Current amplification

Common-base (B) circuit



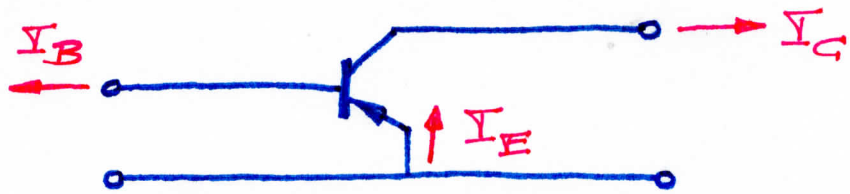
Recall: $\quad I_C = \underbrace{\alpha}_{\lesssim 1.0 \text{ e.g. } 0.99} I_E$

KCL: $\quad I_B = I_E - I_C$

Current amplification $= \dfrac{I_{out}}{I_{In}} = \dfrac{I_C}{I_E} = \alpha$

$$\Rightarrow \quad \boxed{I_C = \alpha I_E}$$

Common-emitter (E) circuit



Recall: $\quad I_C = \alpha I_E$

KCL: $\quad I_B = I_E - I_C$

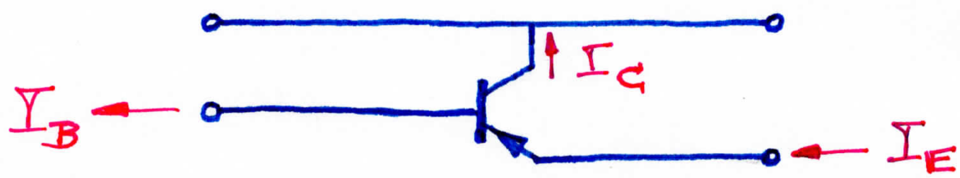
Current amplification $= \dfrac{I_{out}}{I_{In}} = \dfrac{I_C}{I_B} = \dfrac{I_C}{I_E - I_C} =$

$$= \left(\frac{I_E - I_C}{I_C}\right)^{-1} = \left(\frac{I_E}{\alpha I_E} - 1\right)^{-1} = \left(\frac{1}{\alpha} - 1\right)^{-1} = \frac{1}{\frac{1}{\alpha} - 1}$$

$$= \frac{\alpha}{1-\alpha} = \beta \qquad \text{with } \beta \gg 1 \quad \text{e.g. } \beta = 100$$

$$\Rightarrow \quad \boxed{I_C = \beta I_B} \qquad \boxed{\beta = \alpha/1-\alpha}$$

Common-collector (CC) circuit



Recall: $\quad I_C = \alpha I_E$

KCL: $\quad I_B = I_E - I_C$

$$\text{Current amplification} = \frac{I_{out}}{I_{In}} = \frac{I_E}{I_B} = \frac{I_E}{I_E - I_C} =$$

$$= \left(\frac{I_E - I_C}{I_E} \right)^{-1} = \left(1 - \frac{I_C}{I_E} \right)^{-1} = (1-\alpha)^{-1} = \frac{1}{1-\alpha} =$$

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

Note: $\quad \frac{\alpha}{1-\alpha} = \beta$

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

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

$$\boxed{\frac{1}{1-\alpha} = \beta + 1}$$ ... what was to be shown