EE 101: Basic Electronics

Bipolar Junction Transistor

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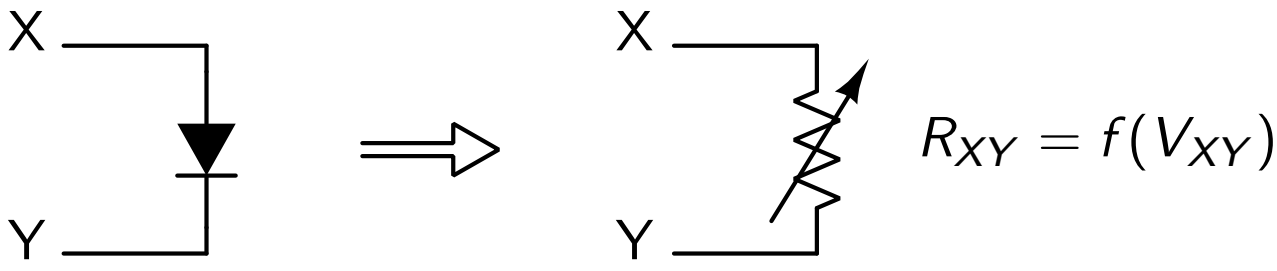
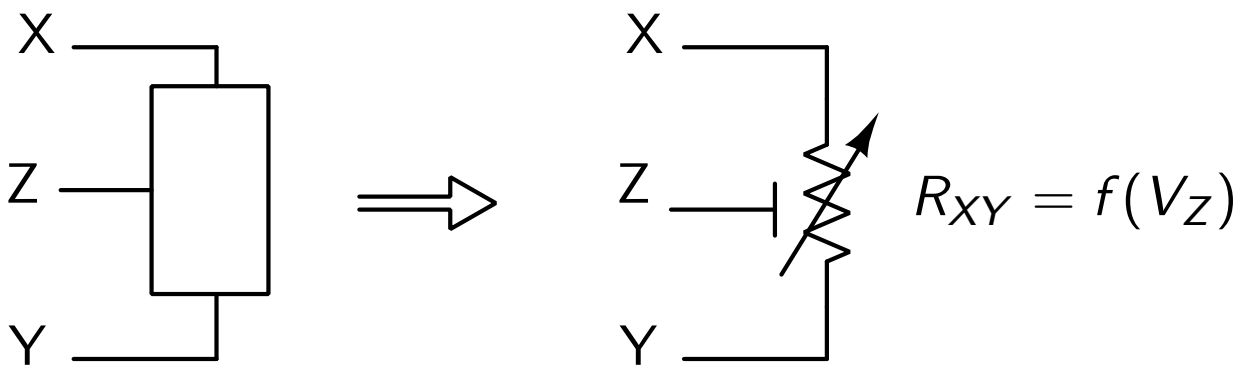
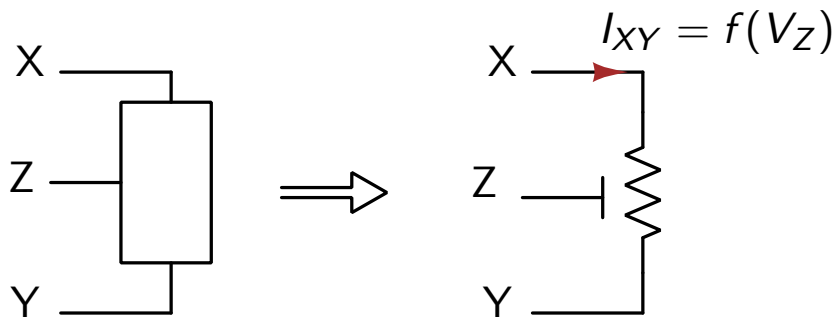
Diode $\rightarrow$ Transistor





Transistor another description

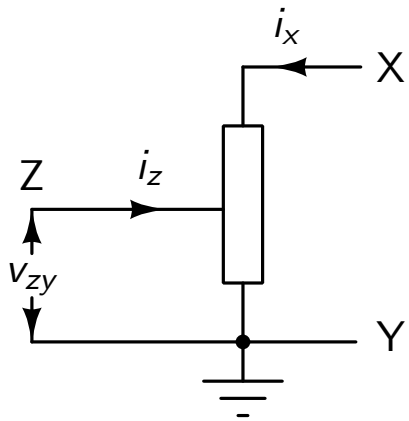


$I_{XY} = f(V_Z) \Longrightarrow$ Transconductance device

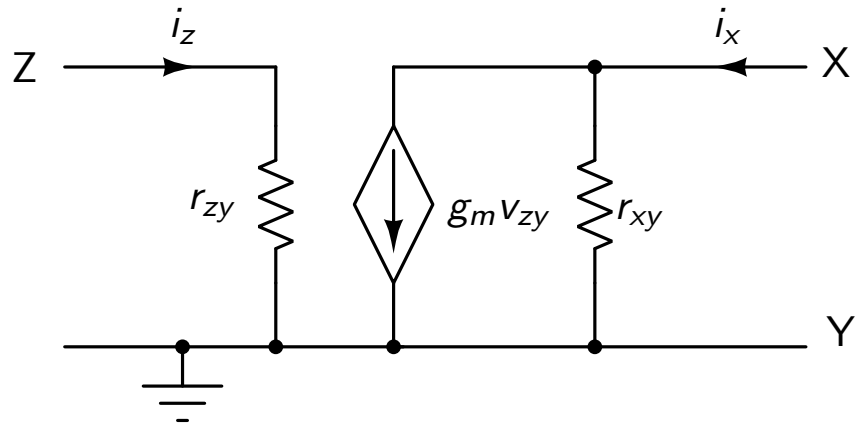
Small-signal transconductance $= \frac{\partial I_{XY}}{\partial V_Z} = f'(V_Z)$

Recap: Small-signal gain = slope of the DC transfer curve at the given bias

Typical configuration and small-signal model



Typical configuration



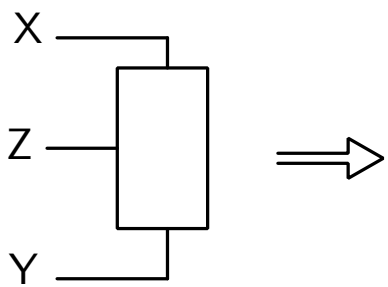
Small-signal model of a transconductor

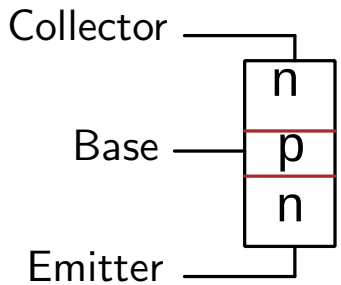
$$g_m = \frac{\partial I_X}{\partial V_{ZY}}$$

$$r_{zy} = \frac{\partial V_{ZY}}{\partial I_Z}$$

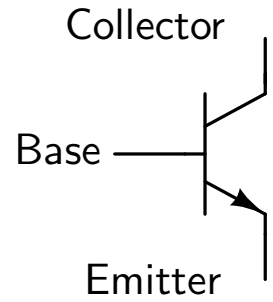
$$r_{xy} = \frac{\partial V_{XY}}{\partial I_X}$$

Bipolar Junction Transistor

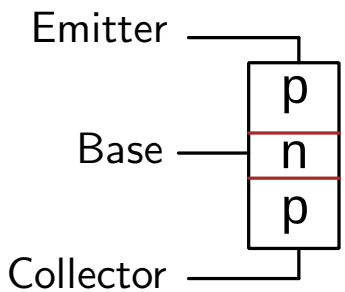




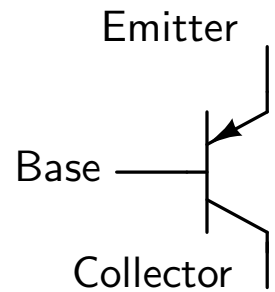
npn transistor



Circuit symbol of npn BJT

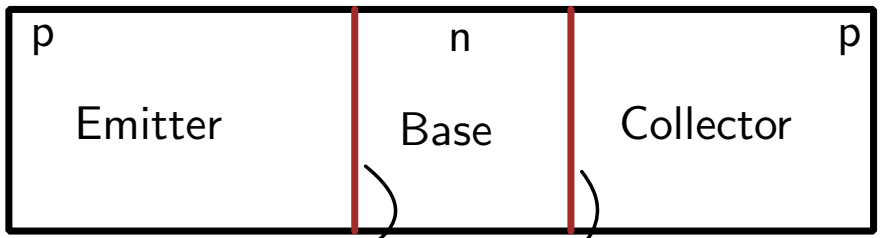


pnp transistor



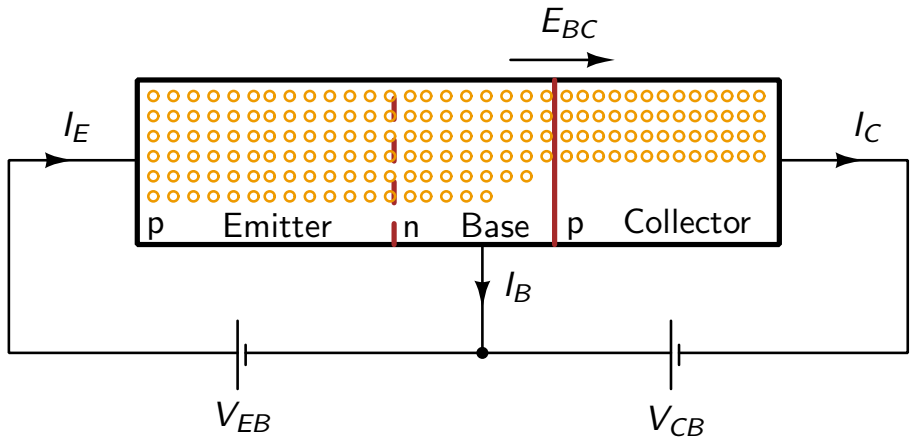
Circuit symbol of pnp BJT

Two Junctions - Four Possibilities



EB junction	CB junction	Region of operation	
Forward	Forward	Saturation	→ Closed Switch
Reverse	Reverse	Cut-off	→ Open Switch
Forward	Reverse	Active	→ Transconductor
Reverse	Forward	Reverse active	→ ??

Active Region of Operation



$$I_E = I_C + I_B$$

$$I_C = \alpha I_E \qquad 0 < \alpha < 1$$

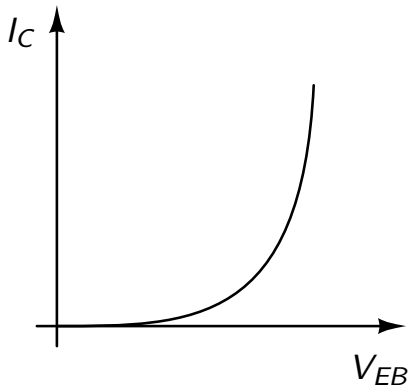
$$I_C = \beta I_B \qquad \beta \gg 1$$

$$I_C \approx I_0 e^{V_{EB}/V_T}$$

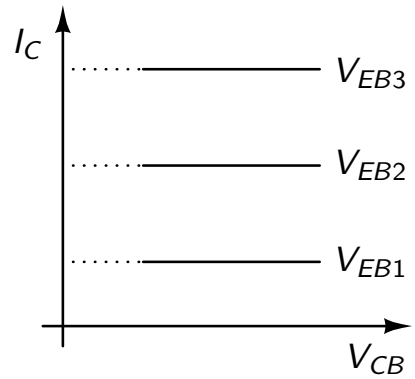
α is known as the common-base current gain

β is known as the common-emitter current gain

Characteristics of pnp Transistor

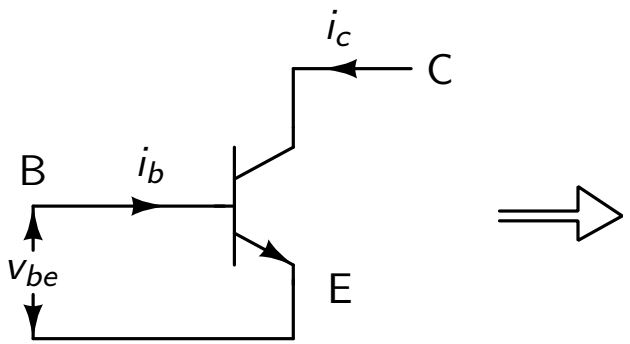


$I_C = I_0 e^{V_{EB}/V_T}$

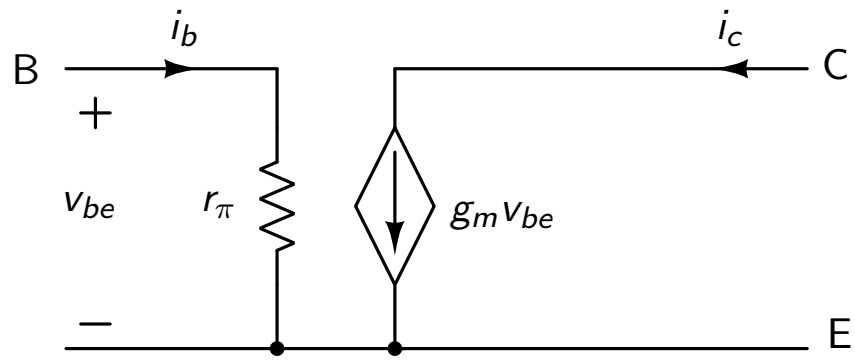


I_C is independent of V_{CB}

Small-signal model of a BJT



Typical configuration

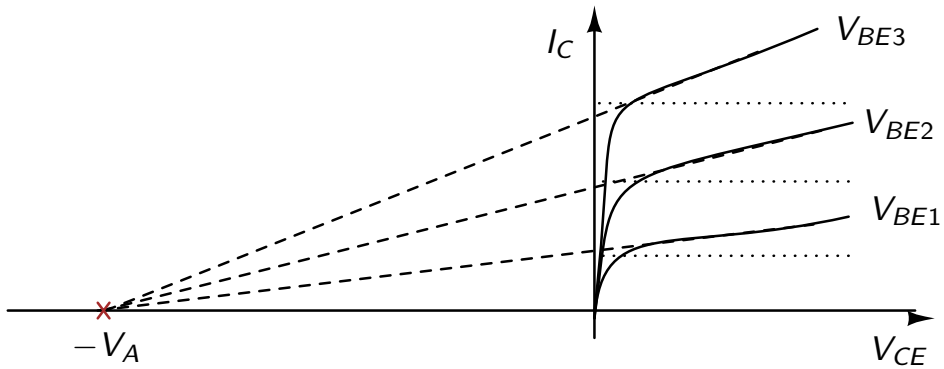


Small-signal model of a transconductor

$$g_m = \frac{\partial I_C}{\partial V_{BE}} = \frac{I_C}{V_T}$$

$$r_\pi = \frac{\partial V_{BE}}{\partial I_B} = \frac{V_T}{I_B}$$

Early effect and output impedance



I_C depends on V_{CB}

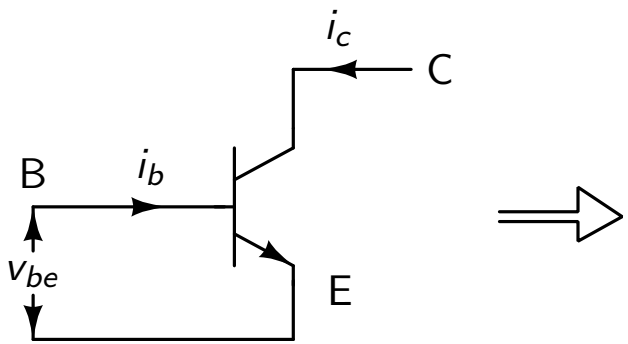
Modified current equation: $I_C \approx I_0 e^{V_{BE}/V_T}(1 + \frac{V_A}{V_{CE}})$

Output resistance $r_0 = \frac{\partial V_{CE}}{\partial I_C} \approx \frac{V_A + V_{CE}}{I_C}$

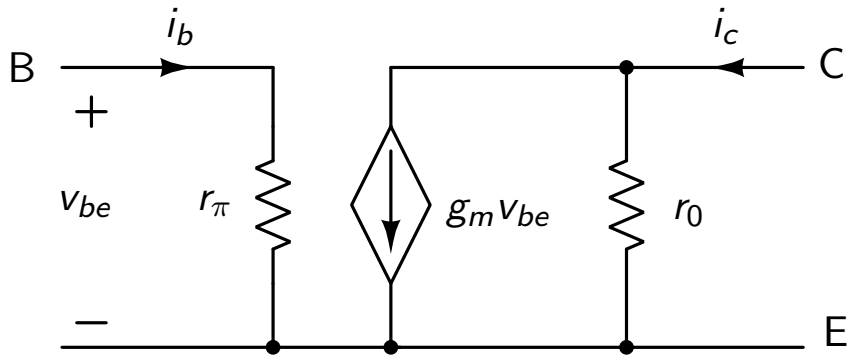
V_A is called the Early voltage.

Alternatively, $r_0 \approx \frac{V_A}{I'_C}$; I'_C is the collector current without Early effect.

Small-signal model of a BJT



Typical configuration



Small-signal model of a transconductor

$$g_m = \frac{\partial I_C}{\partial V_{BE}} = \frac{I_C}{V_T}$$

$$r_\pi = \frac{\partial V_{BE}}{\partial I_B} = \frac{V_T}{I_B}$$

$$r_0 = \frac{\partial V_{CE}}{\partial I_C} \approx \frac{V_A}{I_C'}$$

Summary

- Transistor
- Generic small-signal model of a transconductor
- BJT
- Operation of a BJT in active mode/region
- I-V relations
- Small-signal model of a BJT

Reference Book

[1] A. Sedra and K. C. Smith, "Microelectronic Circuits," 6th Ed., Oxford university press, 2011.