Spring 2019 Purdue University

ECE 255: L11.1

BJT IV Characteristics

(Sedra and Smith, 7th Ed., Sec. 6.1, 6.2)

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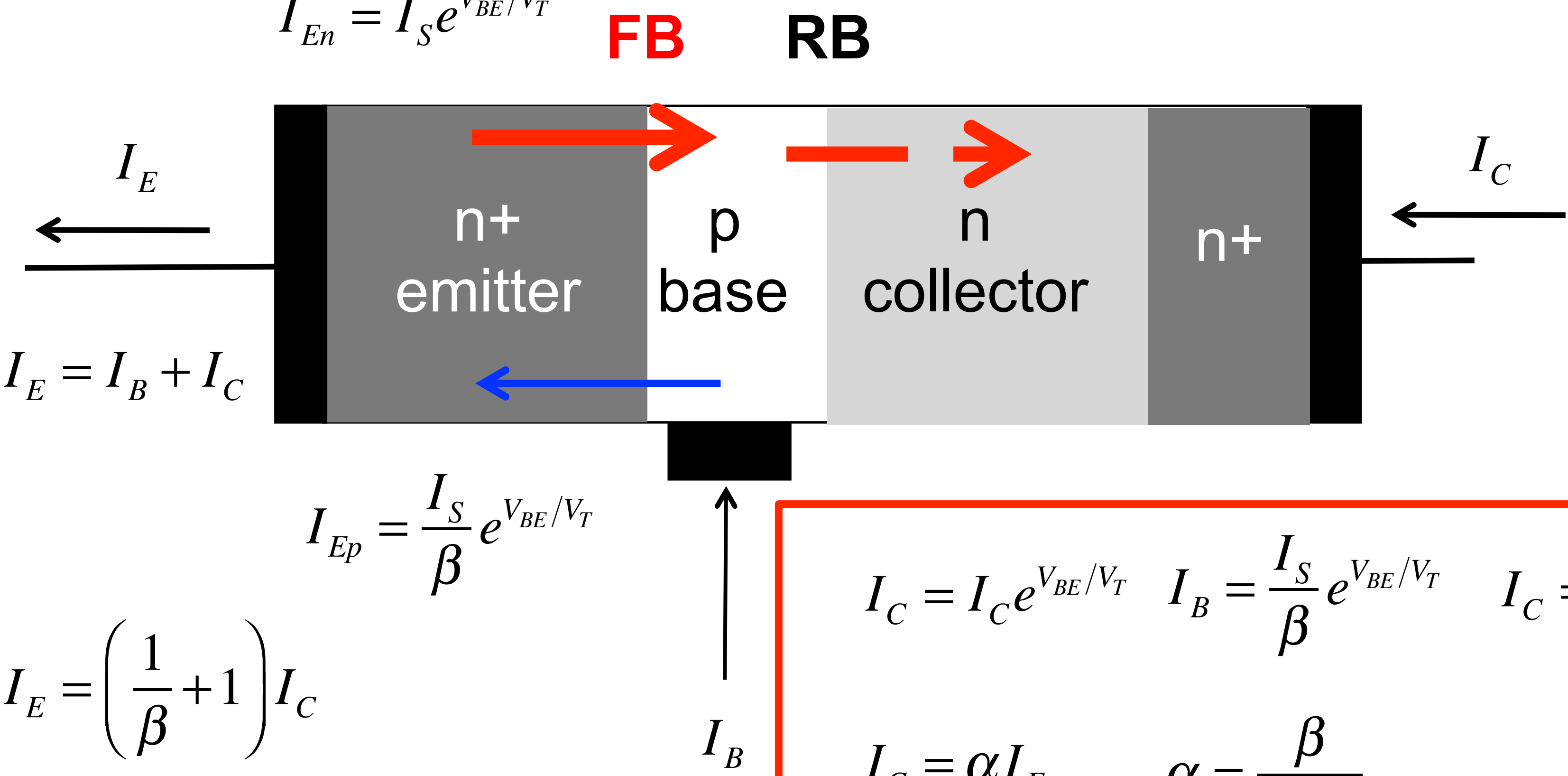
BJT IV characteristics

1) Essential BJT physics
2) Terminal characteristics
3) NPN vs. PNP

NPN BJT operation (active)

$$I_{En} = I_S e^{V_{BE}/V_T}$$



$$I_E = I_B + I_C$$

$$I_{Ep} = \frac{I_S}{\beta} e^{V_{BE}/V_T}$$

$$I_E = \left(\frac{1}{\beta} + 1\right) I_C$$

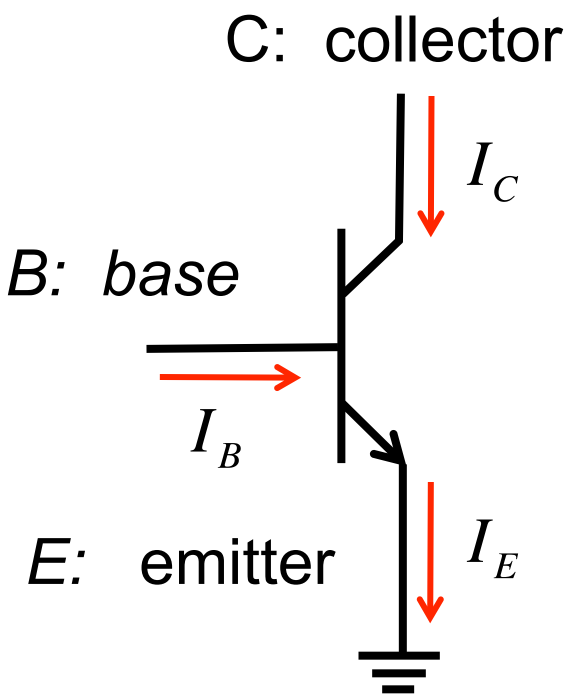
$$I_E = \left(\frac{\beta + 1}{\beta}\right) I_C$$

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

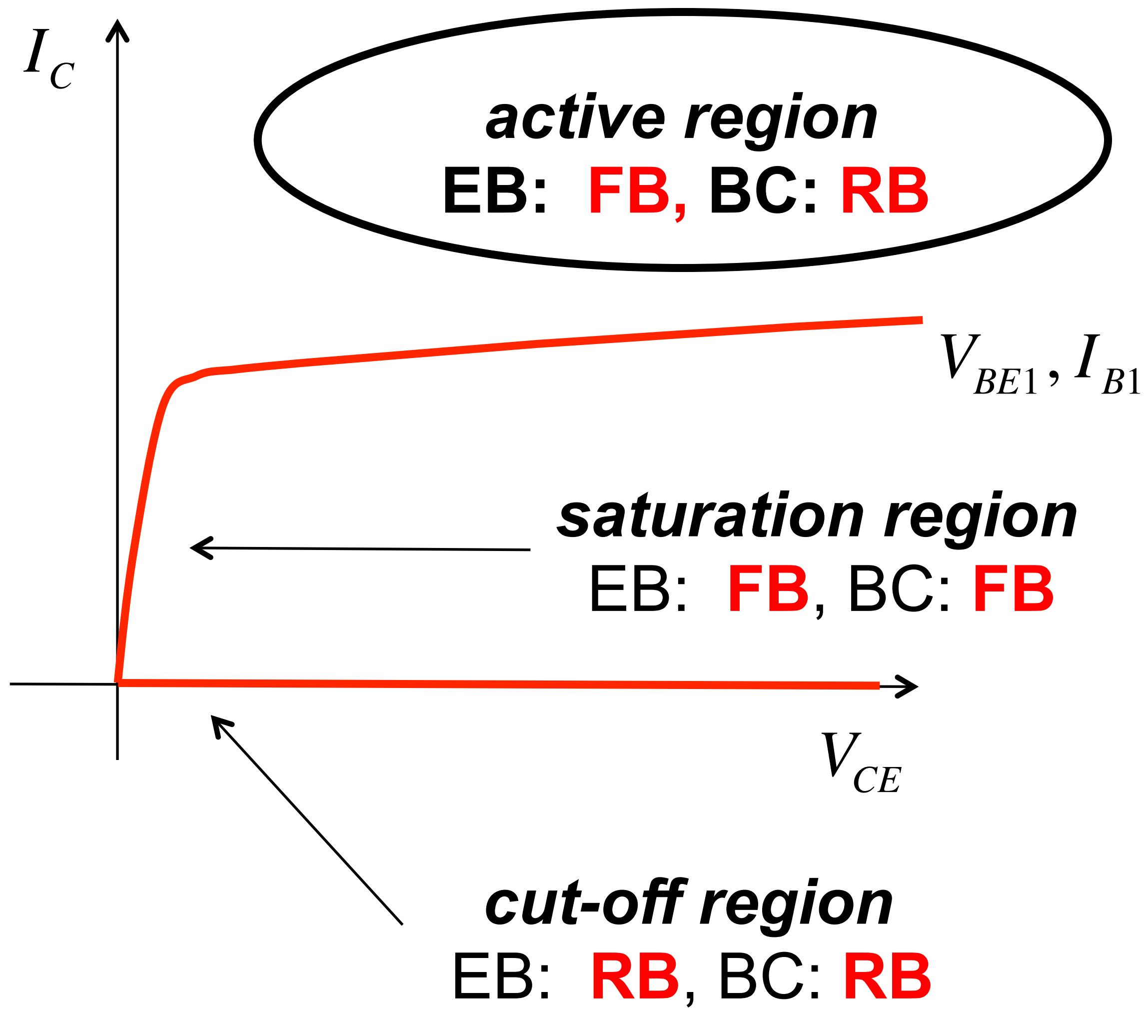
$$I_C = \alpha I_E \qquad \alpha = \frac{\beta}{\beta + 1}$$

$$\beta >> 1 \qquad \alpha < 1$$

Three regions



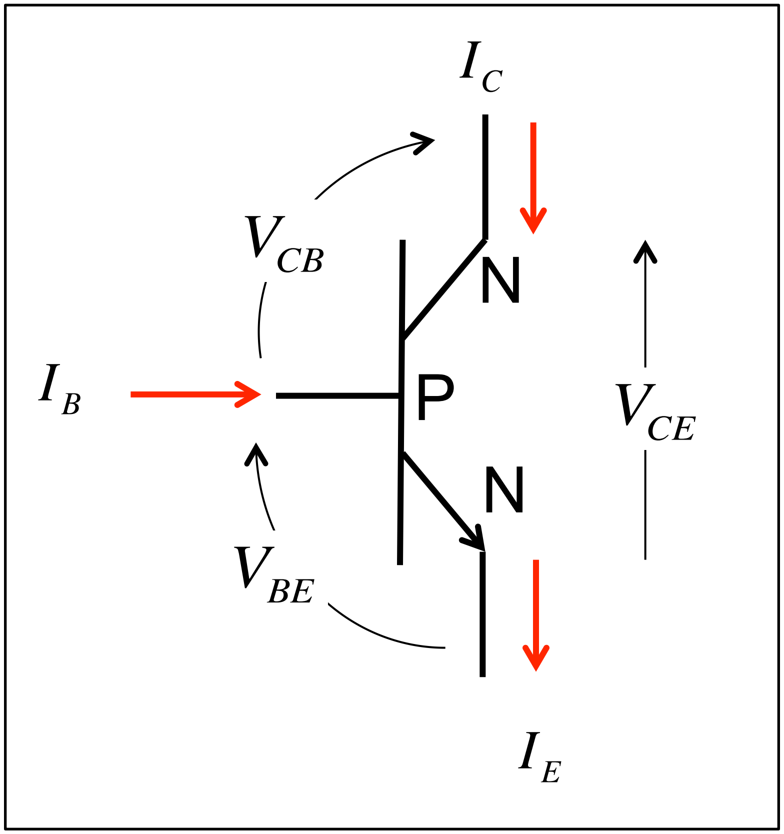
NPN BJT

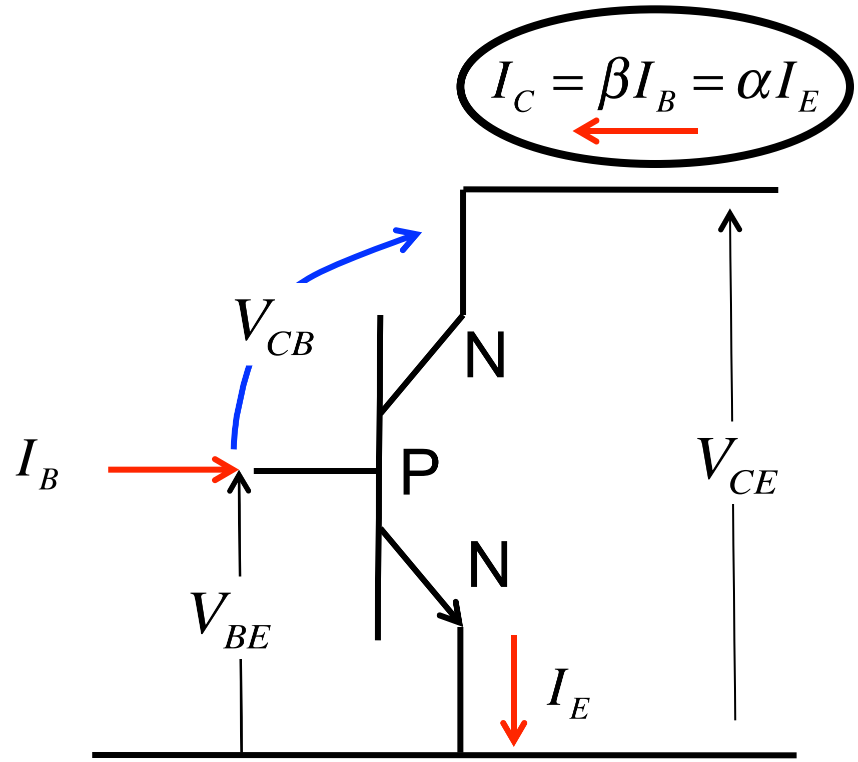


BJT IV characteristics

1) Essential BJT physics
2) **Terminal characteristics**
3) NPN vs. PNP
4) Circuits

Common emitter (active region)





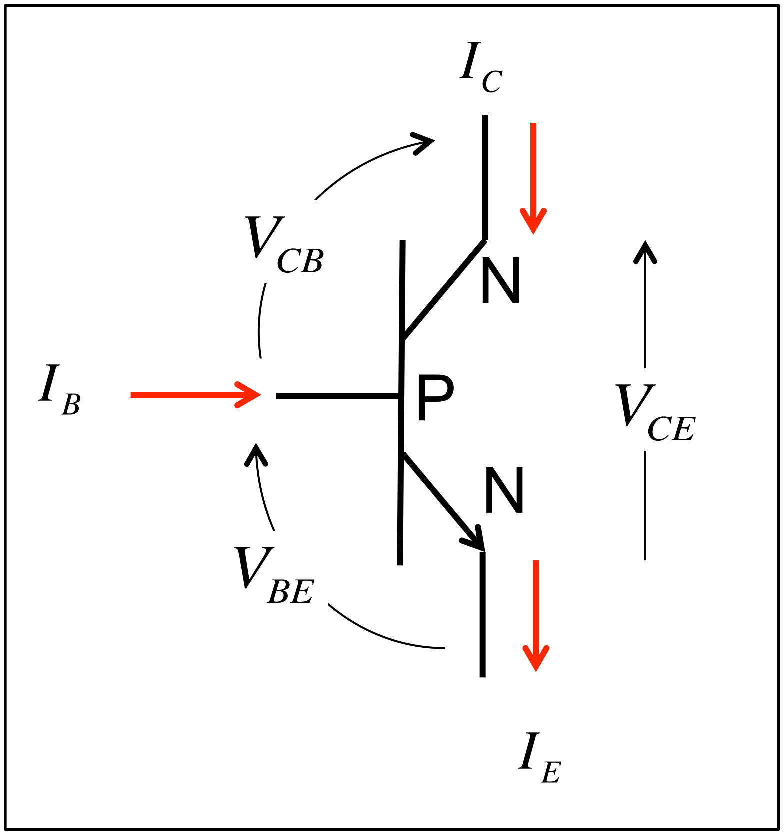
KCL: $I_B + I_C = I_E$

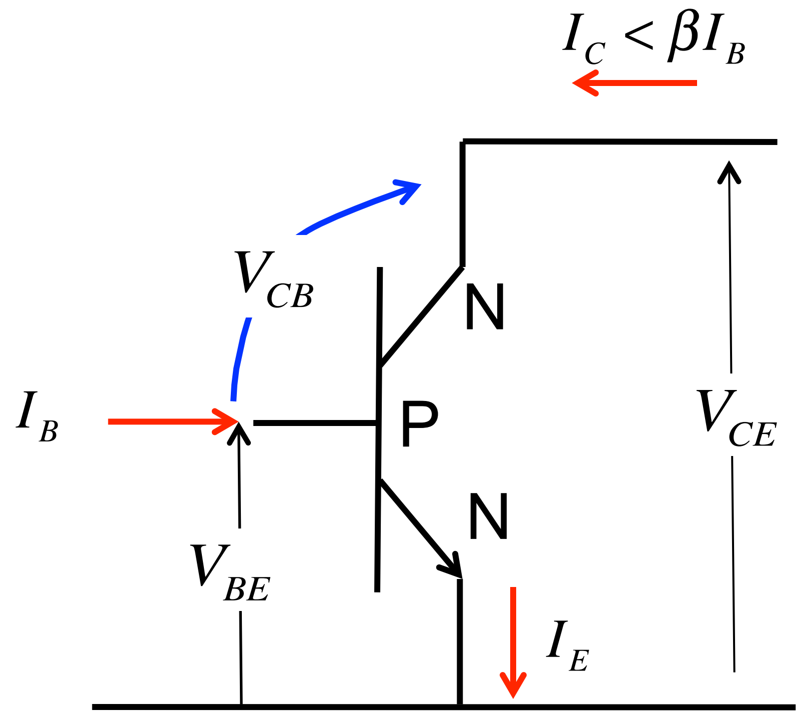
KVL: $V_{BE} + V_{CB} = V_{CE}$

BE: **FB** $V_{BE} > 0$

BC: **RB** $V_{CB} = V_{CE} - V_{BE} > 0$

Common emitter (saturation region)

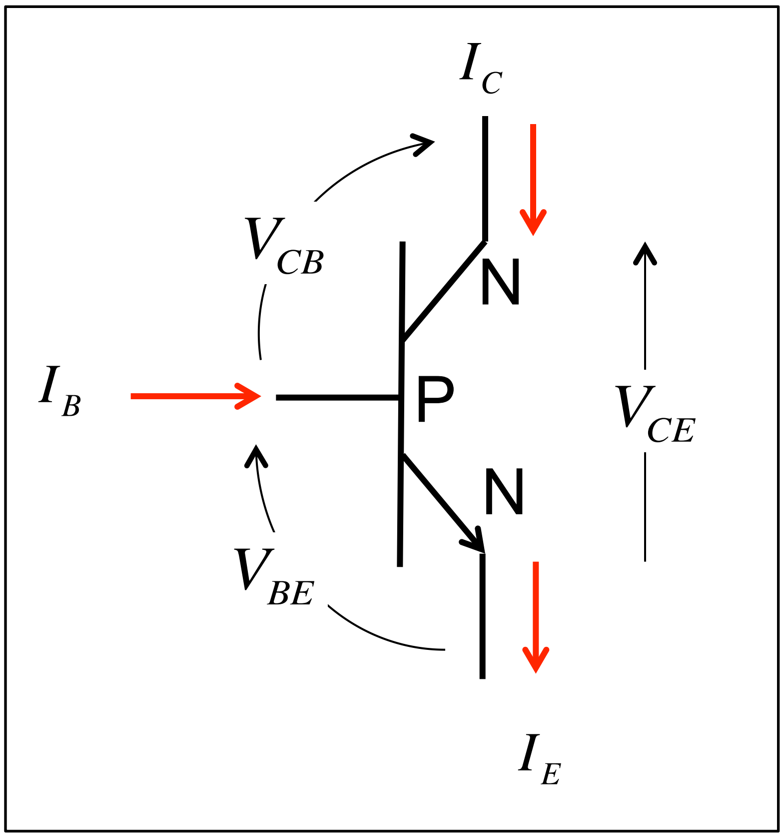


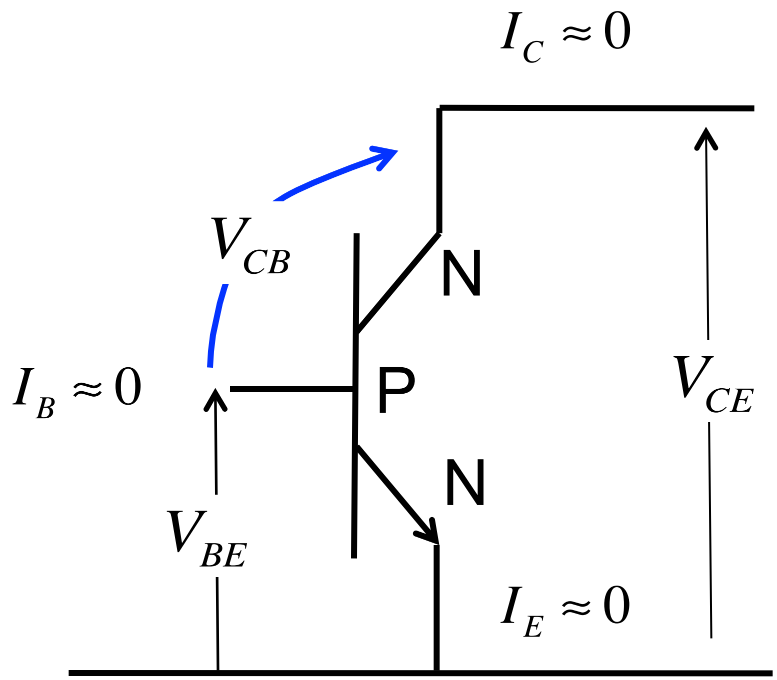


BE: **FB** $V_{BE} > 0$

BC: **FB** $V_{CB} = V_{CE} - V_{BE} < 0$

Common emitter (cutoff region)

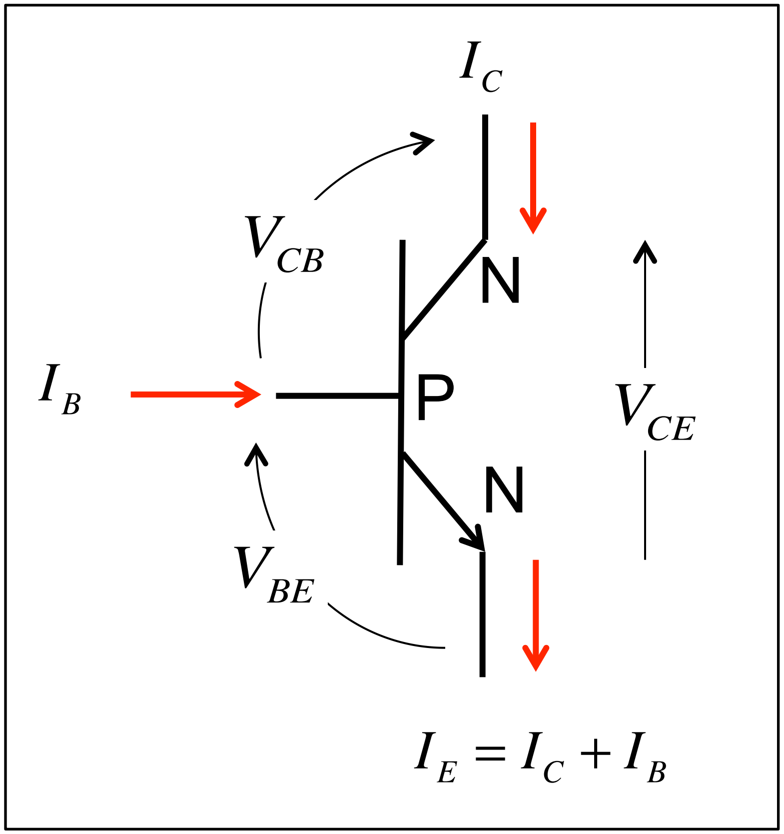




BE: **RB** $V_{BE} < 0$

BC: **RB** $V_{CB} = V_{CE} - V_{BE} > 0$

Alpha and beta (active region)



$$I_C = \alpha I_E \qquad I_C = \beta I_B$$

$$\alpha \equiv \frac{I_C}{I_E} = \frac{I_C}{I_C + I_B} < 1$$

$$\alpha = \frac{I_C}{I_C + I_C/\beta} = \frac{\beta}{\beta + 1} < 1$$

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

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

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Example

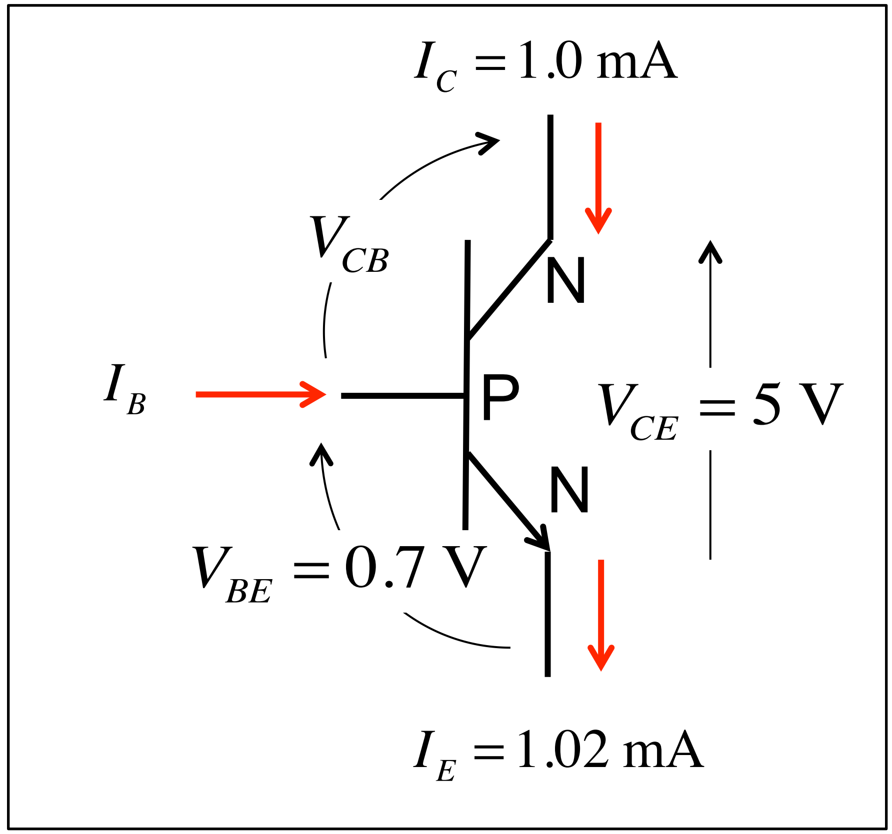
1) Active region?

2) Alpha?

$$\alpha \equiv \frac{I_C}{I_E} = \frac{1.0}{1.02} = 0.98$$

3) Beta?

$$\beta = \frac{\alpha}{1-\alpha} = \frac{0.98}{0.02} = 49$$



Device designers and circuit designers

Alpha and beta are used to design and analyze transistor circuits.

Alpha and beta are related to the physical design of the transistor (thicknesses, doping densities, diffusion coefficients, bandgap, etc.

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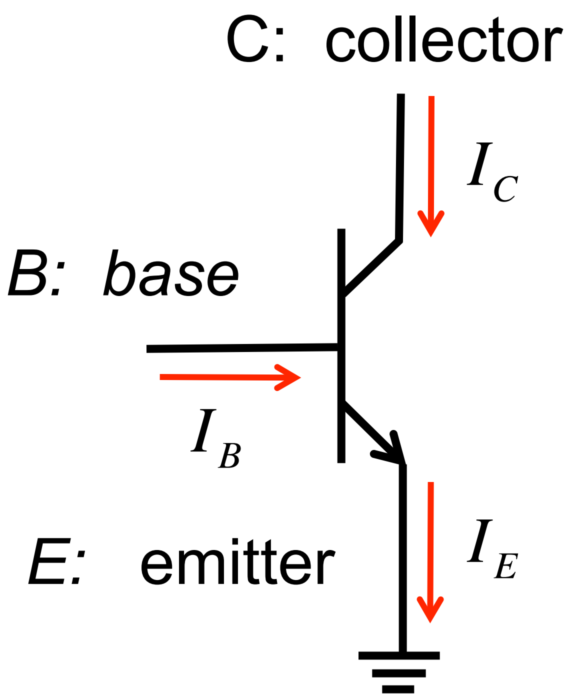
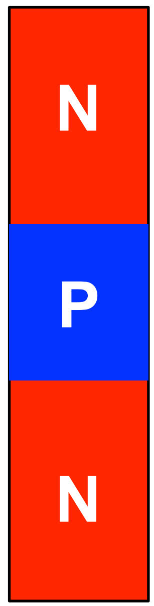
NPN bipolar transistors





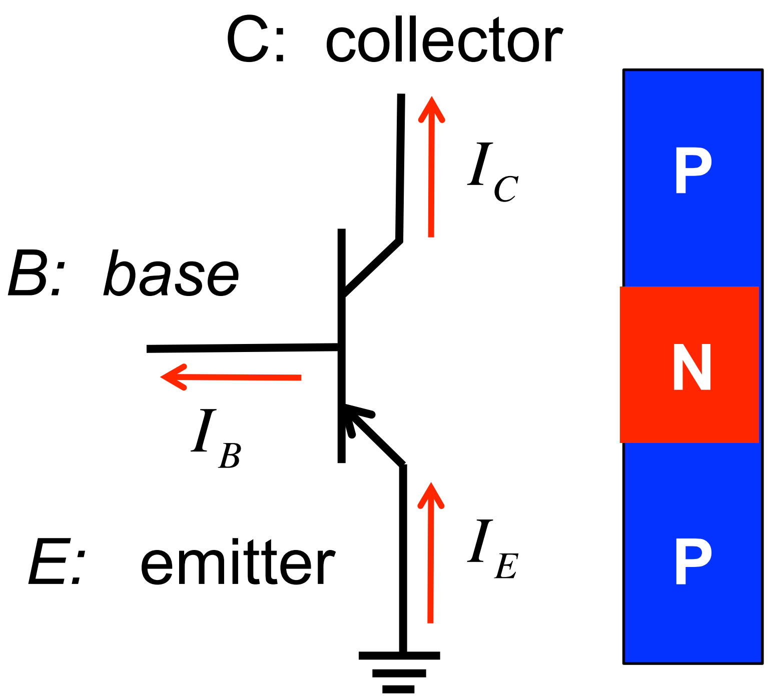
BE	**BC**	**region**
FB	RB	active
FB	FB	saturation
RB	RB	cut-off
RB	FB	inverted reverse active

NPN BJT

$I_C = \alpha I_E \quad I_C = \beta I_B \quad \alpha \approx 1 \quad \beta >> 1$

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

PNP bipolar transistors



PNP BJT

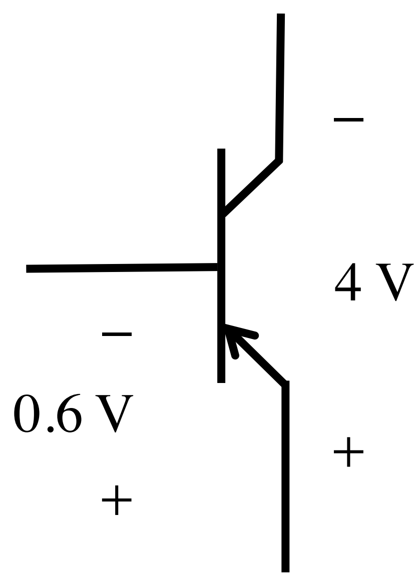
BE	BC	region
FB	RB	active
FB	FB	saturation
RB	RB	cut-off
RB	FB	inverted reverse active

$I_C = \alpha I_E \qquad I_C = \beta I_B \qquad \alpha \approx 1 \qquad \beta >> 1$

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

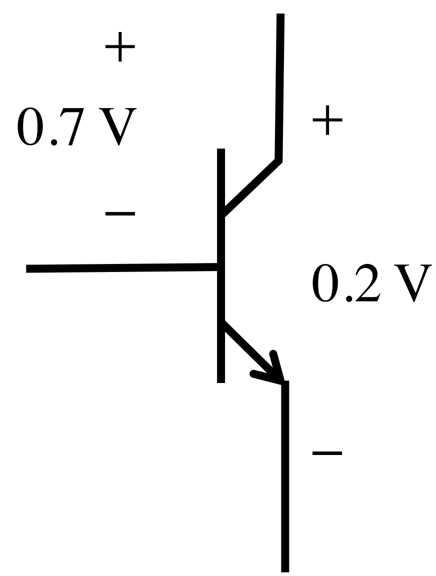
Example 1

What is the region of operation?



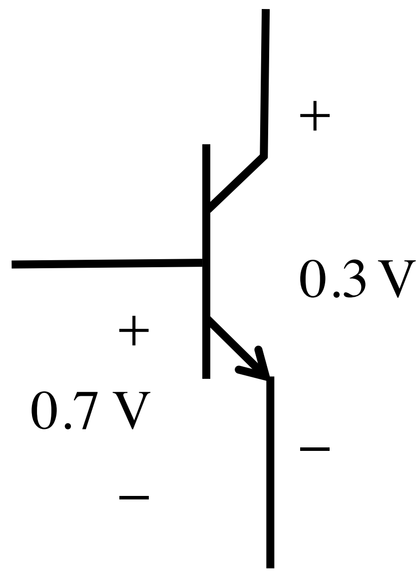
Example 2

What is the region of operation?



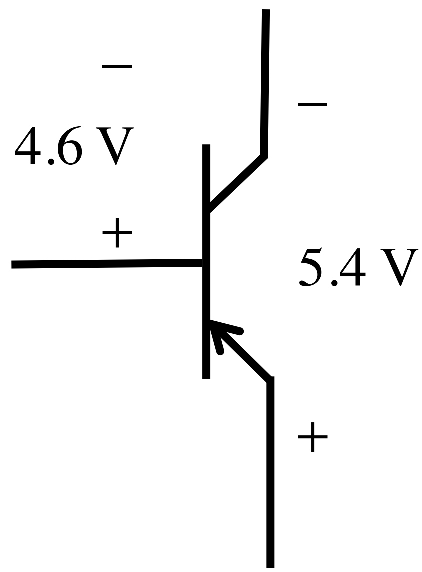
Example 3

What is the region of operation?



Example 4

What is the region of operation?



Summary

BJT's have three operations regions, active, saturation, and cutoff (+ reverse active).

Alpha and beta are two important BJT model parameters (Early voltage too).

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