Lecture 25: Bipolar Junction Transistors (2)

Load Line Analysis, Operating Regions, Examples

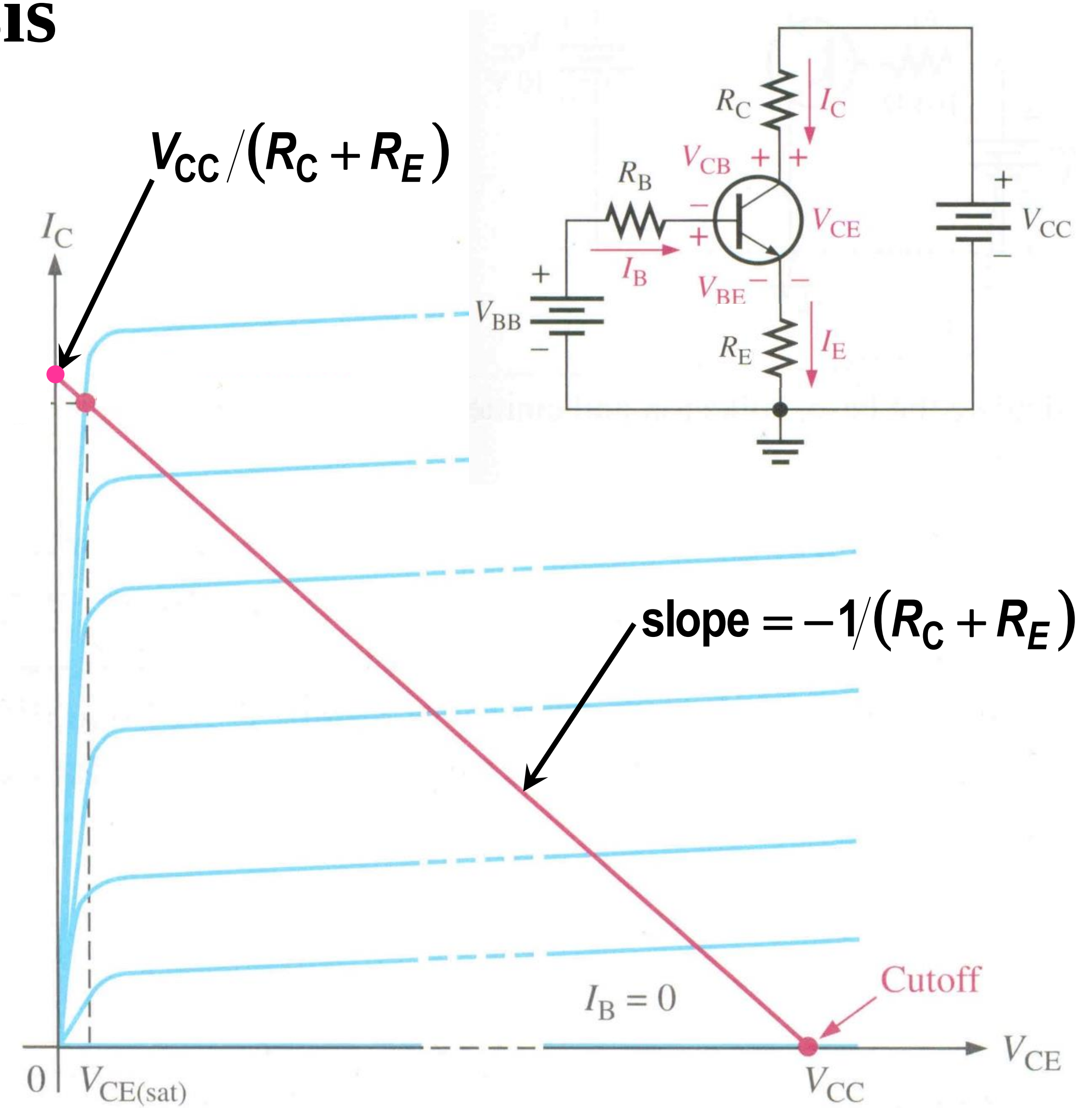
Load Line Analysis

The DC operating point (Q-point) of the BJT is the point of intersection between the two relations.

The cutoff point is the intersection of the DC load line with $I_B = 0$ curve (horizontal axis). At this point:

$$I_{B(cutoff)} = 0, \quad I_{C(cutoff)} = 0,$$

$$V_{CE(cutoff)} = V_{CC}$$



Saturation

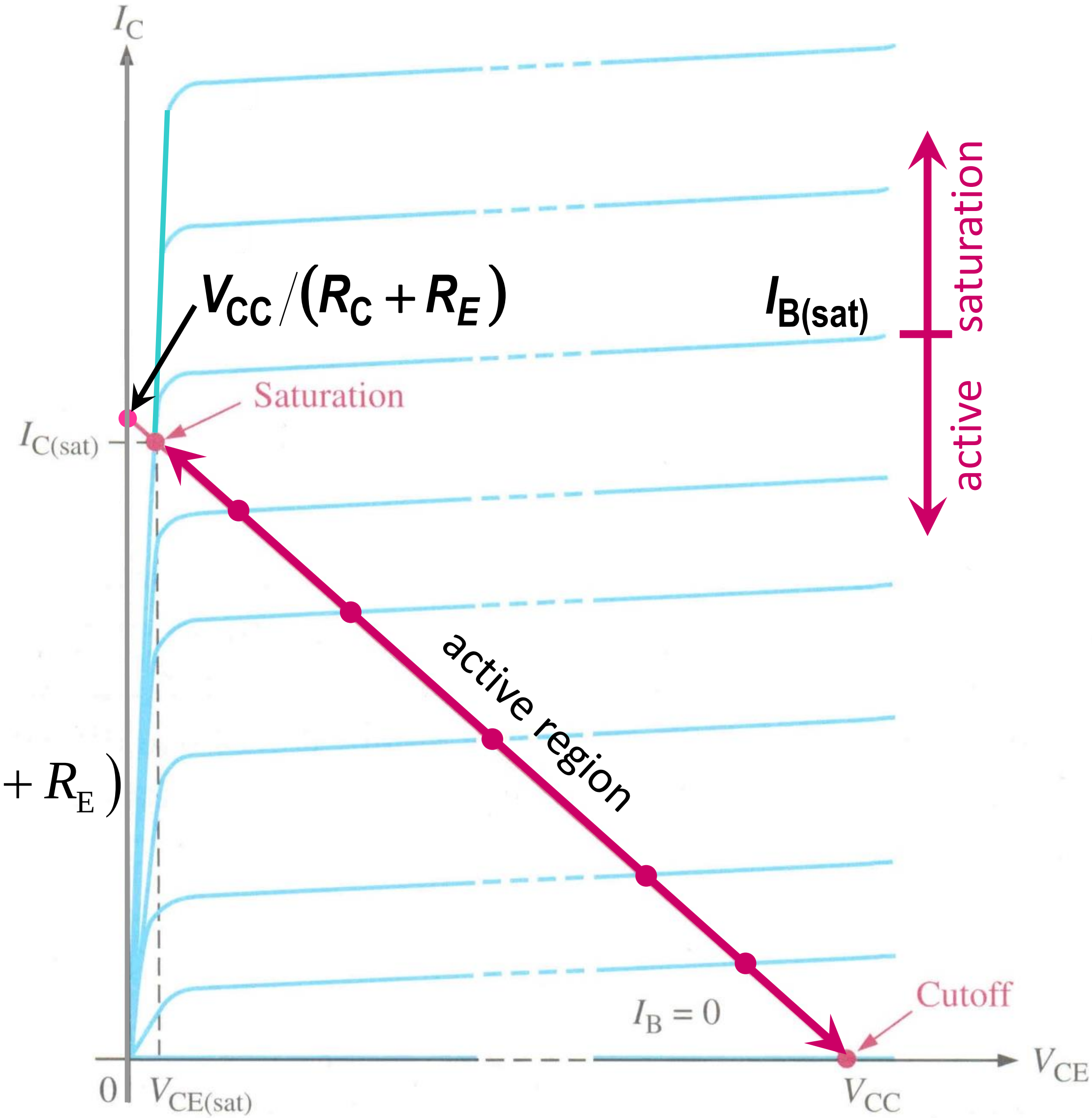
At the saturation point, several collector characteristic curves, with $I_B \geq I_{B(\text{sat})}$, intersect with the DC load line. At this point I_C and V_{CE} are fixed:

$$V_{\text{CE}} = V_{\text{CE(sat)}} \leq 0.7\ \text{V}$$

$$I_{\text{C}} = I_{\text{C(sat)}} = \left(V_{\text{CC}} - V_{\text{CE(sat)}}\right) / \left(R_{\text{C}} + R_{\text{E}}\right)$$

$$\cong V_{\text{CC}} / \left(R_{\text{C}} + R_{\text{E}}\right)$$

$$I_{\text{B}} \geq I_{\text{B(sat)}} = I_{\text{C(sat)}} / \beta_{\text{DC}}$$



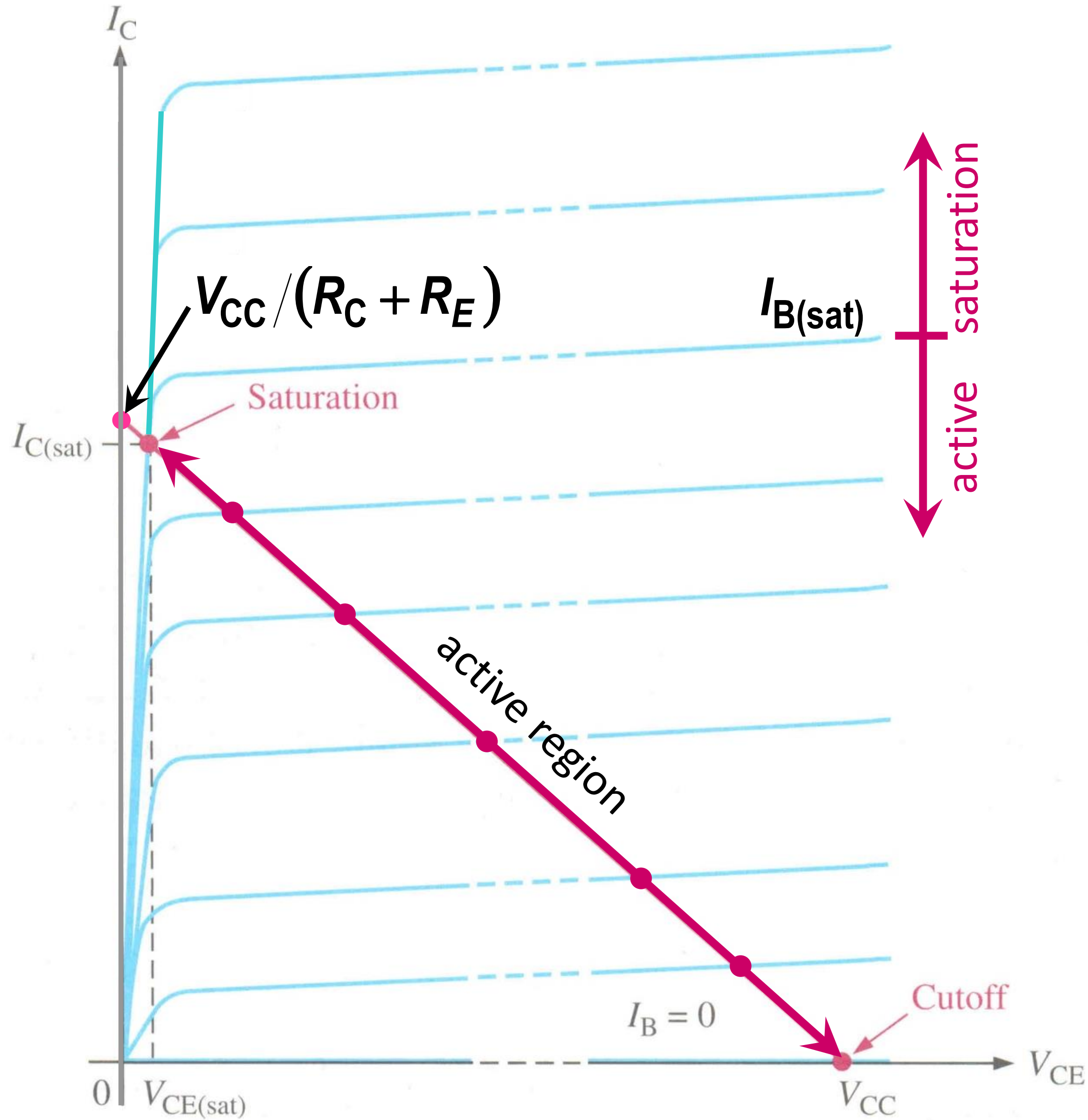
Active Region

The active region of the transistor operation, is the region along the DC load line between cutoff and saturation points:

$$I_B \le I_{B(sat)} = I_{C(sat)} / \beta_{DC}$$

$$I_C = \beta_{DC} \ I_B$$

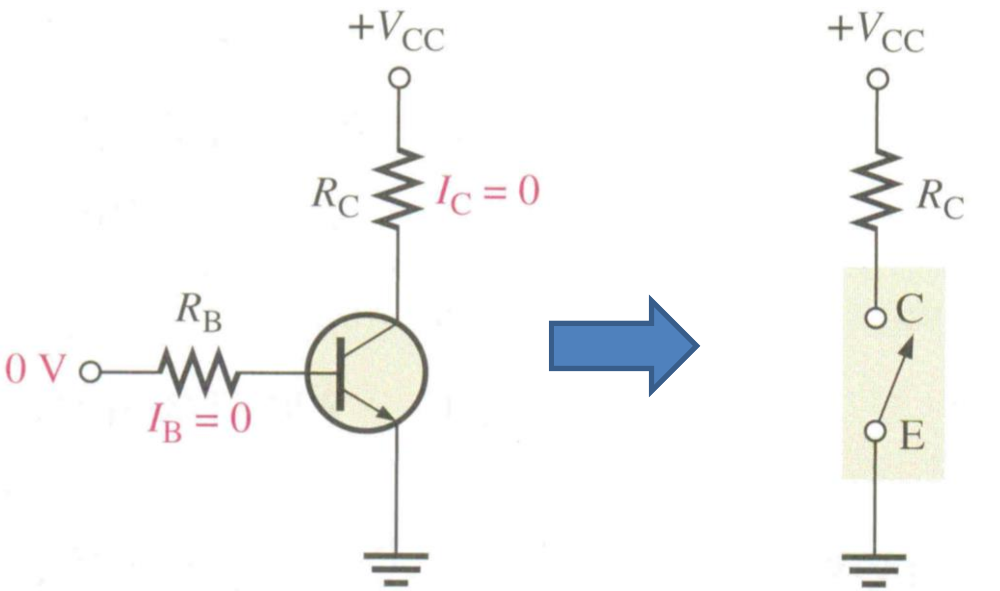
$$V_{CE} = V_{CC} - I_C \left(R_C + R_E \right)$$



Regions of Operations

Attribute	*Cutoff*	*Active*	*Saturation*
BE Junction	RB	FB	FB
BC Junction	RB	RB	FB
I_B	0	$\le I_{B(sat)}$	$\ge I_{B(sat)}$
I_C	0	$\beta_{DC} I_B$	$I_{C(sat)}$
V_{CE}	V_{CC}	$V_{CC} - I_C(R_C + R_E)$	$V_{CE(sat)}$
Application	Opened Switch	Current Amplifier	Closed Switch

Transistor as a Switch



$$I_{B} = I_{B(cutoff)} = 0$$

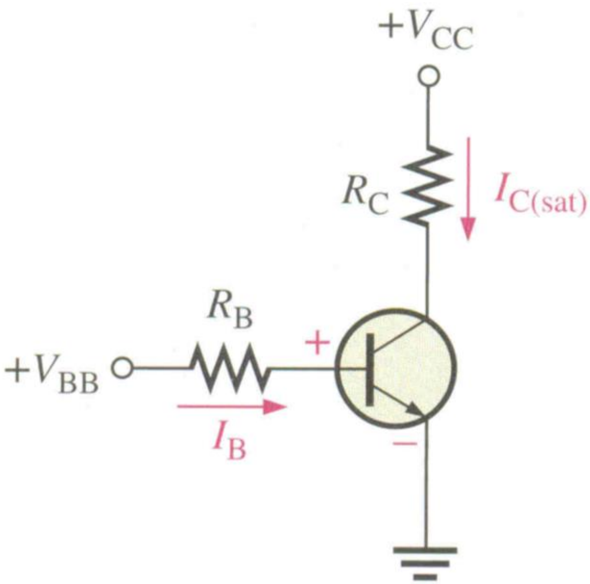
$$I_{C} = I_{C(cutoff)} \cong 0$$

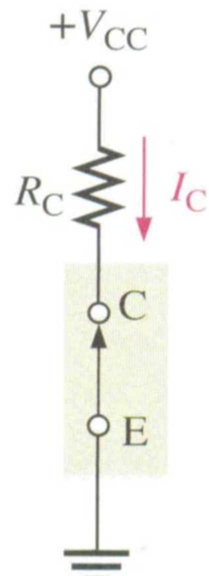
$$V_{CE} = V_{CE(cutoff)} \cong V_{CC}$$

$$I_{C} = 0$$

$$V_{CE} = V_{CC}$$

Transistor as a Switch (Cont'd)





$$I_B > I_{B(sat)}$$

$$V_{CE} = V_{CE(sat)} \cong 0$$

$$I_C = I_{C(sat)} \cong V_{CC}/R_C$$

$$V_{CE} = 0$$

$$I_C = V_{CC}/R_C$$