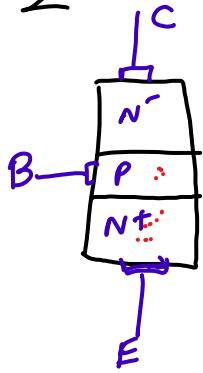


NPN BJT



Forward-active region

- 1) B-E J^n : F.B
- 2) B-C J^n : R.B

$$I_E = I_B + I_C$$

$$(V_{BE}/V_T)$$

$$I_C = I_S \exp\left(\frac{V_{BE}}{V_T}\right) = I_S e^{(V_{BE}/V_T)}$$

$$I_E = \frac{I_S}{\alpha} \exp\left(\frac{V_{BE}}{V_T}\right)$$

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

$$I_C = \beta I_B$$

$$; I_E = \frac{I_C}{\alpha}$$

$$I_E > I_C > I_B$$

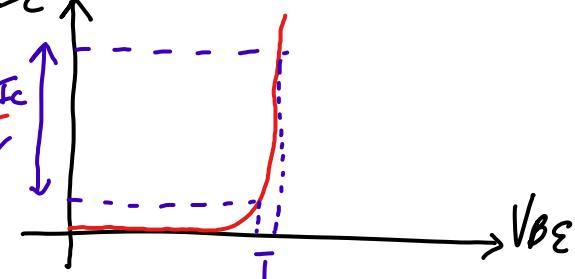
$\approx MA$ $\downarrow MA$

I_C depends upon how much F.B V_{BE} is.

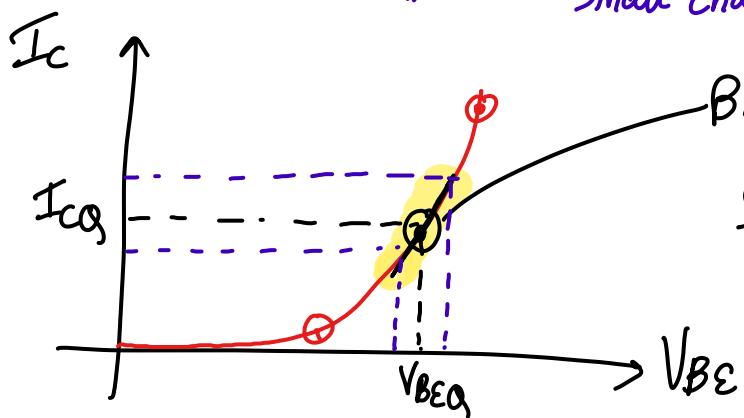
large signal behaviour

- Non-Linear

large change
in collector current



Small change in base current



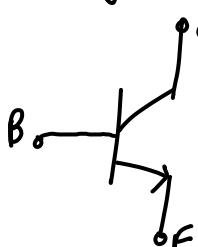
Bias point (Q-point)
operating near Q-point

Small-sig analysis of BJT

$\nearrow \alpha_{opt}$

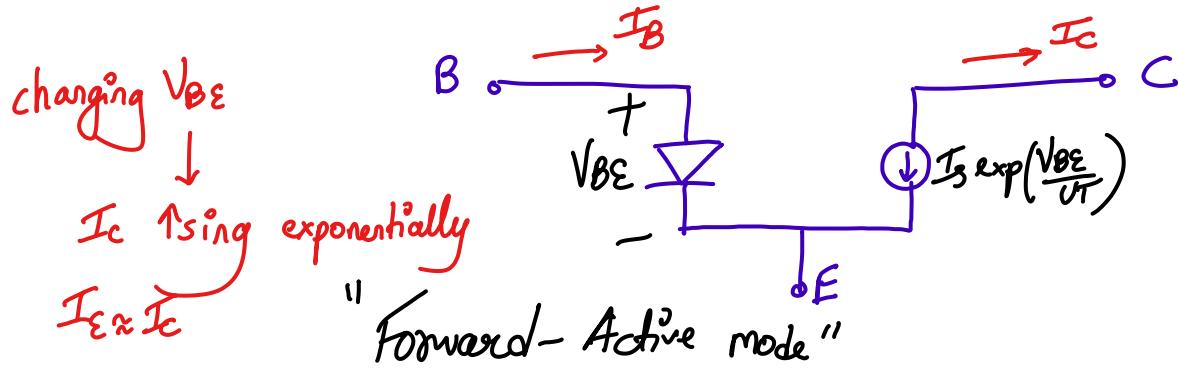
Linearizing Non-Linear behavior of BJT

* large signal equivalent model (Only Read)



$$I_C = I_B \exp\left(\frac{V_{BE}}{V_T}\right)$$

$$I_E = \frac{I_S}{\alpha} \exp\left(\frac{V_{BE}}{V_T}\right)$$

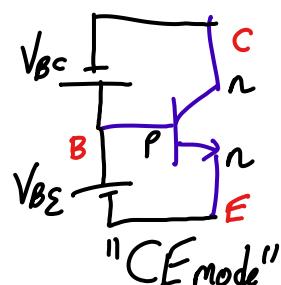


* Saturation mode:

i) $BC \in \text{F.B}$

$BE \in \text{F.B}$

$V_{BE} = 0.7V$



$V_{BC} > 0.4V$

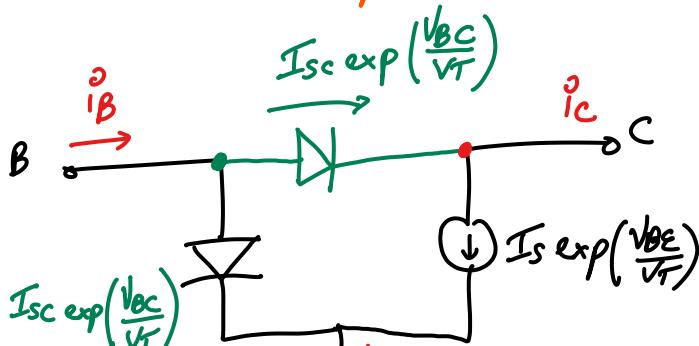
$$V_{BC} = V_{BE} - V_{CE}$$

$$\frac{V_{BC}}{0.4} = \frac{V_{BE}}{0.7} \approx 0.9V$$

$V_{CE} \approx 0.3V \rightarrow$ entering saturation region.

$V_{CE} \approx 0.2V \rightarrow$ deep saturation

Saturation mode



$$I_C = I_S \exp\left(\frac{V_{BE}}{V_T}\right) - I_S \exp\left(\frac{V_{BC}}{V_T}\right)$$

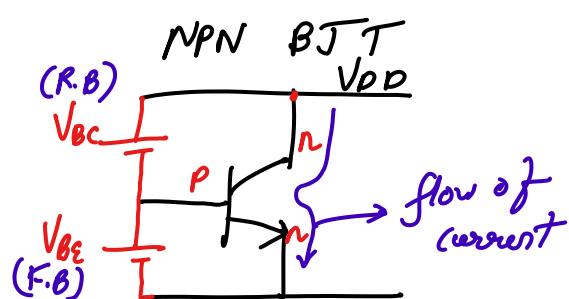
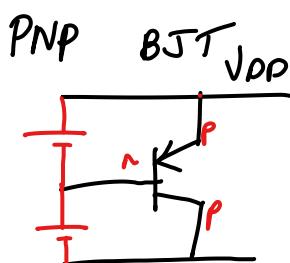
$$I_B = \frac{I_S}{\beta} \exp\left(\frac{V_{BE}}{V_T}\right) + I_S \exp\left(\frac{V_{BC}}{V_T}\right)$$

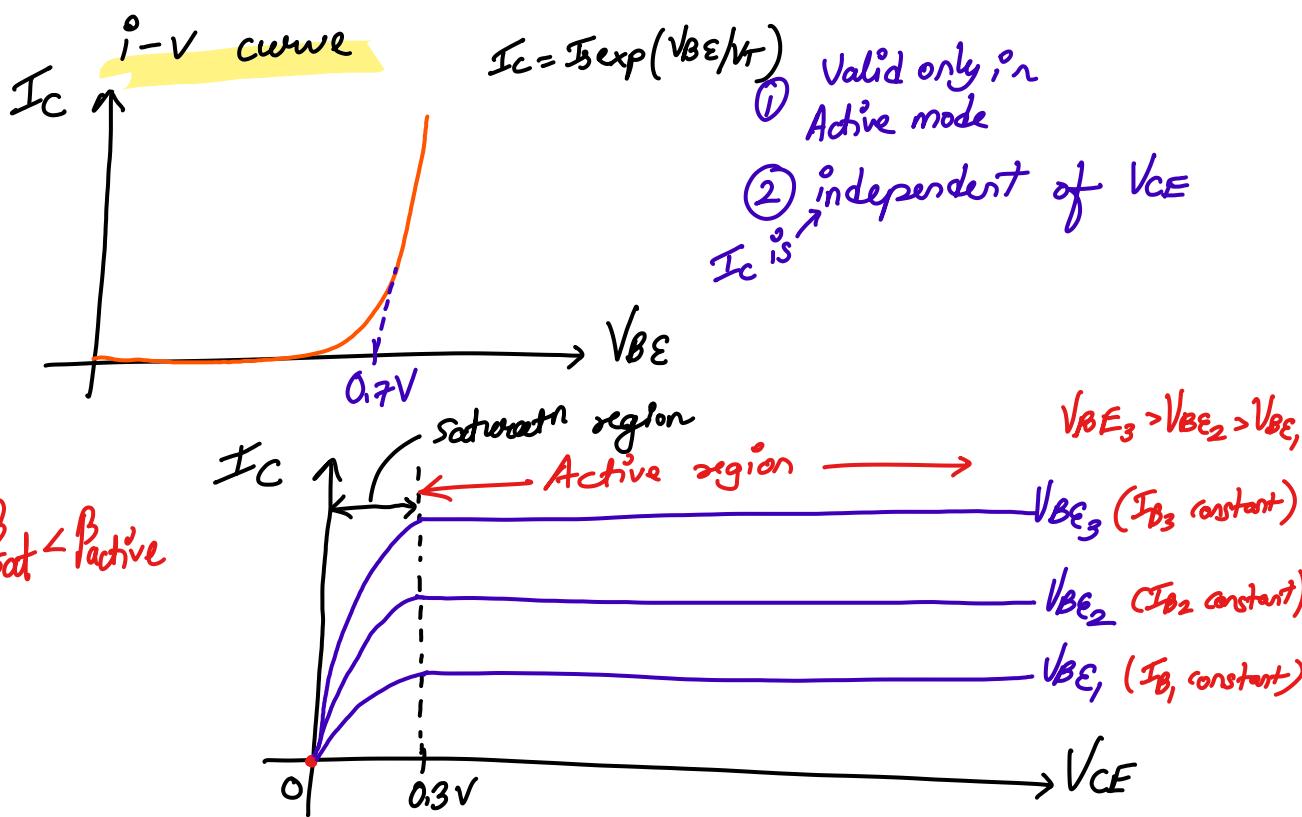
$$V_{CE(\text{sat})} \approx 0.3V$$

$$\frac{I_C}{I_B} \uparrow$$

$$\beta_{\text{sat}} = \frac{I_C}{I_B} < \beta_{\text{active}}$$

β in saturation mode is less than that in active mode





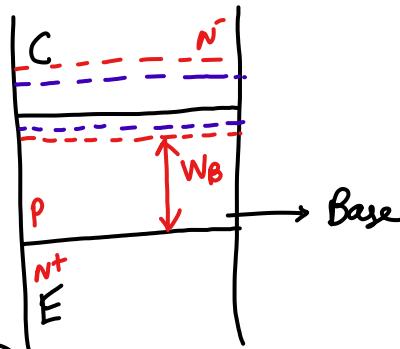
* Concept of Early effect / Base width modulation:

① If $V_{CE} \uparrow \rightarrow$ B.C junction is more R.B

effective Base width (W_B) reduces

$I_c \uparrow \propto$

$$I_c = I_s \exp\left(\frac{V_{BE}}{V_t}\right) \left(1 + \frac{V_{CE}}{V_A}\right)$$



V_A - Early voltage

$$V_{BC} = V_{BE} - V_{CE}$$

$\downarrow 1.3V$ $\downarrow 0.7V$ $\downarrow 2V$
 $\downarrow -3.3V$ \downarrow (more R.B.) $\downarrow 4V$

69, 67, 72, 84, 58, 26

Attendance for AEC lec 2 (20/9/23)

Early effect (i.e. I_c becomes dependent on V_{BE} and V_{CE})

