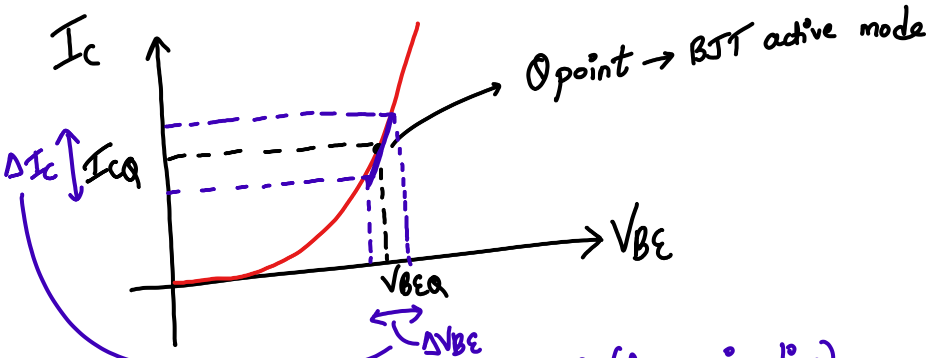
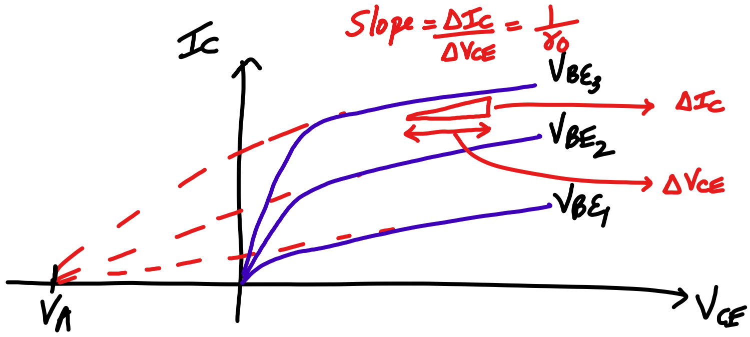
Analog Electronic Circuits lec 3 (online) 21/7/23

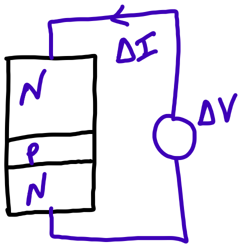


Small sig analysis (AC analysis) (Approximation)

* Output resistance:

$$I_C = I_S \exp\left(\frac{V_{BE}}{V_T}\right)\left(1+\frac{V_{CE}}{V_A}\right) \quad — \ (1)$$





$$\frac{\partial I_C}{\partial V_{CE}} = \underbrace{I_S \exp\left(\frac{V_{BE}}{V_T}\right)}_{I_C'} \frac{1}{V_A} = \frac{I_C'}{V_A}$$

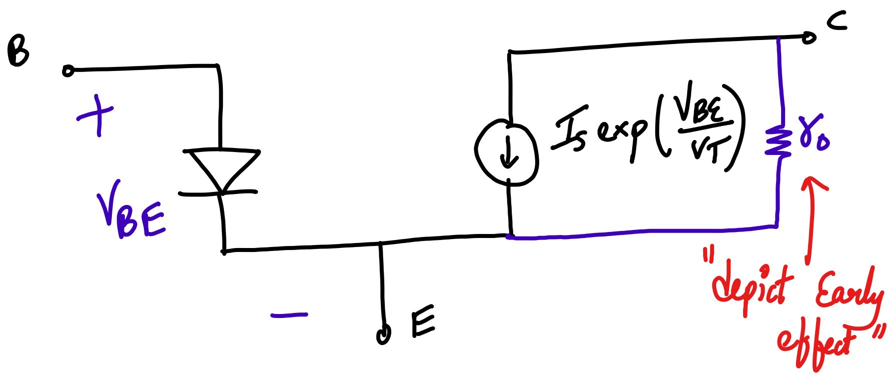
$$r_o = \frac{\partial V_{CE}}{\partial I_C}$$

$$r_o = \left(\frac{\partial I_C}{\partial V_{CE}}\right)^{-1}_{\text{fixed } V_{BE}} = \frac{V_A}{I_C'}$$

$$\boxed{r_o = \frac{V_A}{I_C}}$$ — o/p resistance of NPN BJT

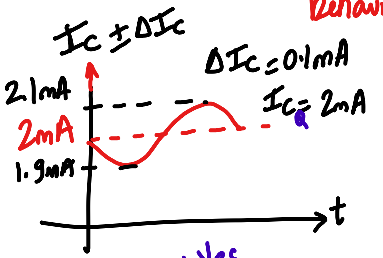
large signal model (NPN BJT)

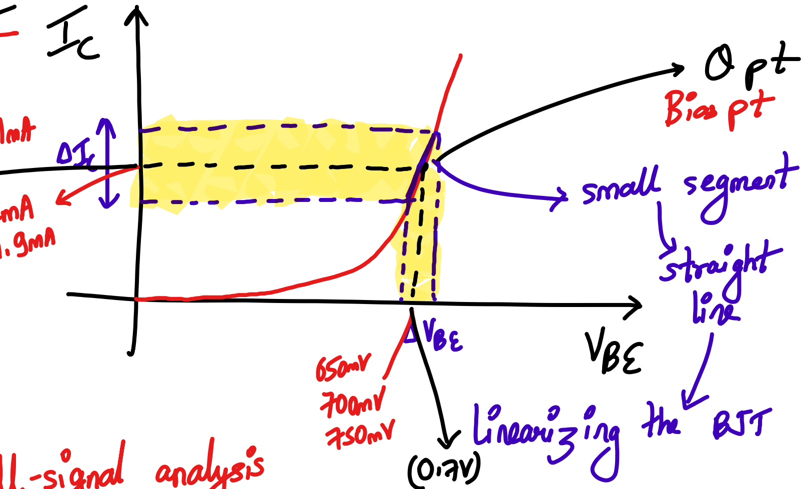
NPN BJT F/W Active region

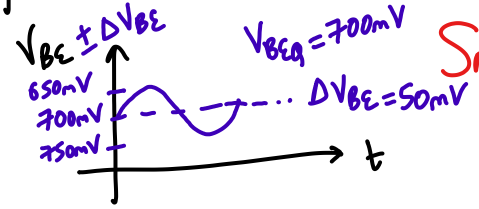


* Small-signal (AC) model of BJT

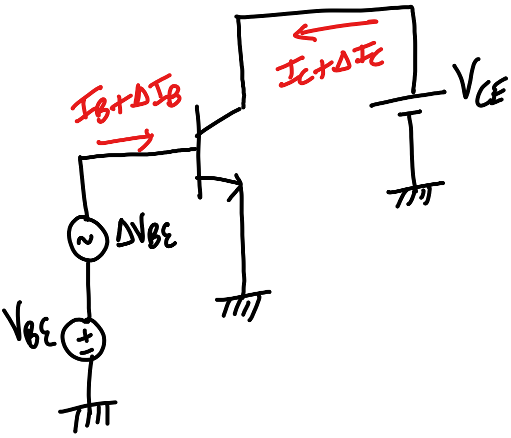
↳ Approximation → linearize BJT behaviour







Small-signal analysis
($\Delta V_{BE} \rightarrow \Delta I_C$)



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

2. $I_C + \Delta I_C = I_S \exp\left(\frac{V_{BE} + \Delta V_{BE}}{V_T}\right)$

3. $I_C + \Delta I_C = \underbrace{I_S \exp\left(\frac{V_{BE}}{V_T}\right)}_{I_C} \exp\left(\frac{\Delta V_{BE}}{V_T}\right)$

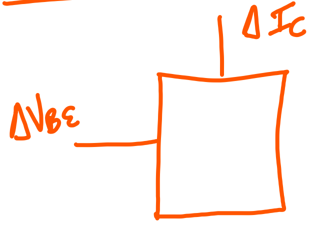
→ $I_C + \Delta I_C = I_C \exp\left(\frac{\Delta V_{BE}}{V_T}\right)$ → $<<1$

→ $\cancel{I_C} + \Delta I_C = \cancel{I_C}\left(1 + \frac{\Delta V_{BE}}{V_T}\right)$

$V_T = 26mV$ at R.T

→ $\boxed{\Delta I_C \cong \frac{\Delta V_{BE}}{V_T} I_C}$

Transconductance (g_m):

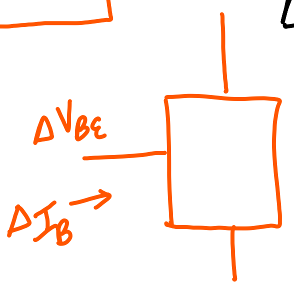


$\frac{\Delta I_C}{\Delta V_{BE}} = g_m$; $\boxed{g_m = \frac{I_C}{V_T}}$

Unit: $\frac{mA}{V}$

$V_T = 26mV$ at R.T

$\Delta I_C = g_m \Delta V_{BE}$



→ $\Delta V_{BE} \rightarrow \Delta I_B$

Input resistance (R_{in}) of BJT

$I_C = \beta I_B$
$\Delta I_C = \beta \Delta I_B$

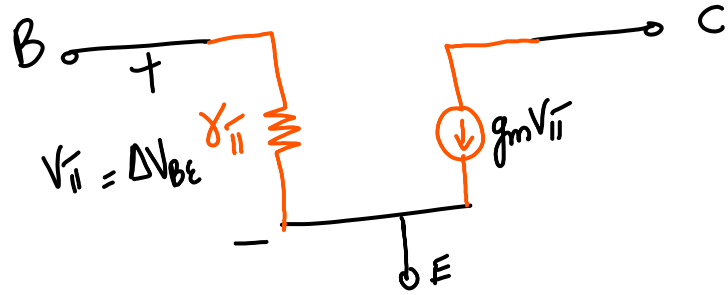
$r_{\pi} = \frac{\Delta V_{BE}}{\Delta I_B} = \frac{\Delta I_C / g_m}{\Delta I_C / \beta}$

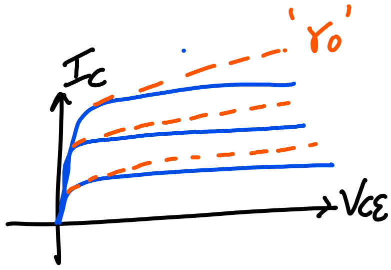
$\boxed{r_{\pi} = \frac{\beta}{g_m}}$ Ω → Input resistance of BJT

Small-signal model of NPN BJT:

(Approximate model) "hybrid-pi model"

$\Delta I_C = g_m \Delta V_{BE}$





→ Inclusion of Early effect:

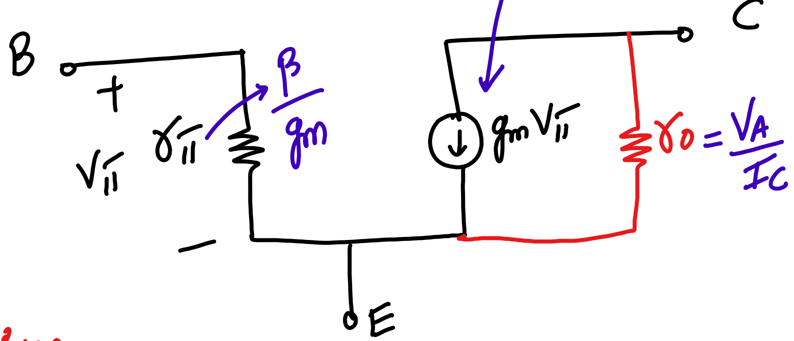
$$I_C = I_S \exp\left(\frac{V_{BE}}{V_T}\right)\left(1 + \frac{V_{CE}}{V_A}\right)$$

$$\frac{dI_C}{dV_{CE}} = \underbrace{I_S \exp\left(\frac{V_{BE}}{V_T}\right)}_{I_C} \frac{1}{V_A} \simeq \frac{I_C}{V_A}$$

$$\boxed{r_o = \left(\frac{\Delta I_C}{\Delta V_{CE}}\right)^{-1} = \frac{V_A}{I_C}}$$

$\boxed{V_\pi = \Delta V_{BE}}$

dependent current source



Small signal hybrid-π model of NPN BJT

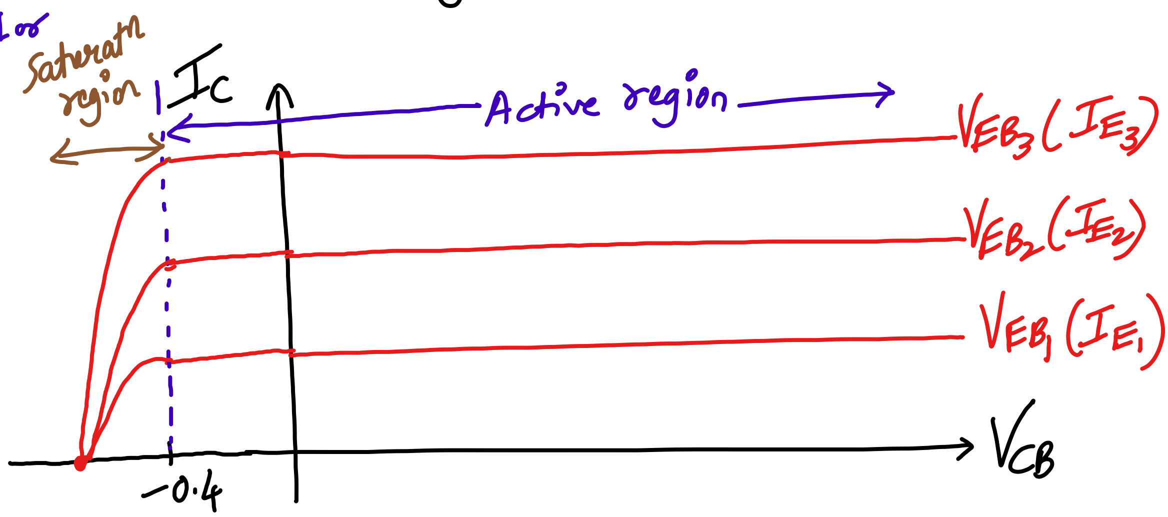
β, V_A: given

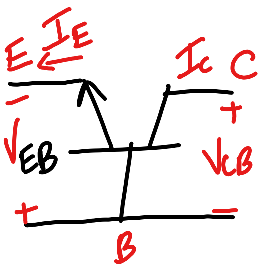
"AC analysis"

Approximate mode:

1. F/w active mode
2. I_C
3. $\beta \to r_\pi$
4. $r_o \to V_A$

Satn: BC: F.B (biased or) BE: F.B





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

$I_C = f^n(V_{BE}, V_{CE})$

BEJ^n: FB

BCJ^n: R.B

$$\boxed{V_{CB} = V_{CE} - V_{BE}}$$

$V_{CB} \to -0.4V$, $V_{CE} \to 0.3V$, $V_{BE} \to 0.7V$

$\boxed{I_C \approx I_E}$ → Active region

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

Next time: BJT configurations

1) Common Base (CB)
2) Common Emitter (CE)
3) Common collector (CC)

Configurations

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