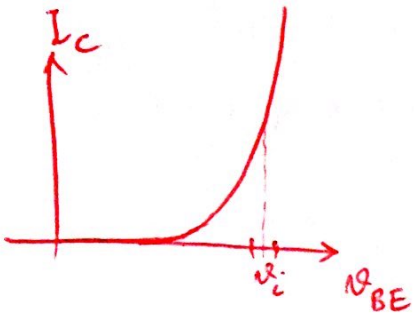
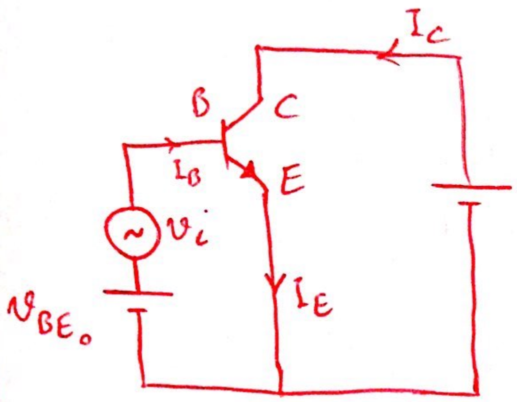
EP Dr. Fakharzadeh Se 5 ۹۳/۱۱/۲۵



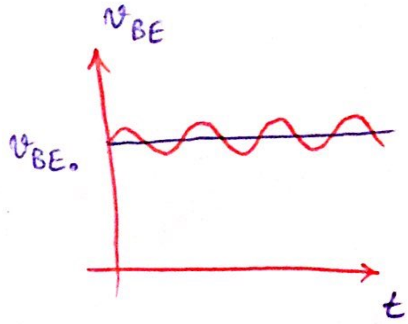
$$I_C = I_S \exp\left(\frac{v_{BE}}{v_T} - 1\right)$$

$$v_i \ll v_T \rightarrow \underbrace{\Delta I_C}_{i_C} = \frac{v_i}{v_T} I_C \Rightarrow \Delta I_C = \Delta v_{BE} \times \frac{I_C}{v_T}$$



Active $\longrightarrow$ $v_{BE} \simeq ۰/۶ \sim ۰/۷\,V$

$v_{CE} > ۰/۳$

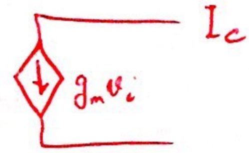


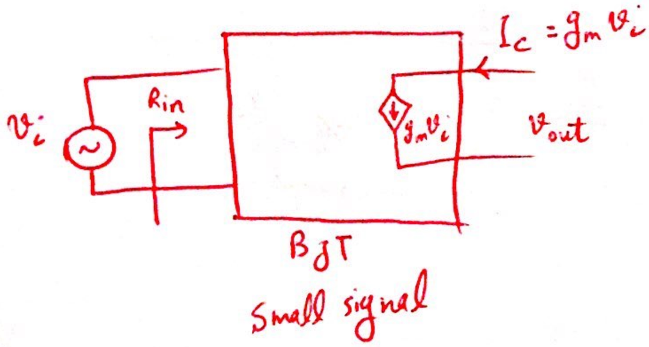
$$\frac{\Delta I_C}{\Delta v_{BE}} \simeq \frac{dI_C}{dv_{BE}} \simeq \frac{I_C}{v_T} = \frac{I_S}{v_T}\exp\left(\frac{v_{BE}}{v_T}\right)$$

$\frac{I_C}{v_T}$ → trans conductance

$$\boxed{g_m = \frac{I_C}{v_T} = \frac{I_C}{KT/q} = \frac{q}{KT} I_C}$$

→ مدل خطی بین جریان خروجی و ولتاژ ورودی AC





$$\begin{cases} I_C = I_S \exp\frac{v_{BE}}{v_T} \\ g_m = \frac{I_C}{v_T} \\ I_C = \beta_F I_B \rightarrow (\Delta I_C = \beta_F \Delta I_B) \end{cases}$$

$$\frac{\Delta I_B}{\Delta v_{BE}} = \frac{1/\beta_F \, \Delta I_C}{\Delta v_{BE}} \longrightarrow \frac{\Delta I_B}{\Delta v_{BE}} = \frac{1}{\beta_F}\left(\frac{\Delta I_C}{\Delta v_{BE}}\right) = \frac{g_m}{\beta_F} = \frac{1}{R_{in}}$$

$$\rightarrow \boxed{R_{in} = \frac{\Delta v_{BE}}{\Delta I_B} = \frac{\beta_F}{g_m} = r_\pi}$$

BJT → 2 port network →

- input resistance $= \frac{dv_{in}}{dI_{in}} = r_\pi = \frac{\beta_F}{g_m}$
- output resistance $= \frac{dv_{out}}{dI_{out}} = r_o = \frac{v_A}{I_C}$
- effect of input on output → g_m
- effect of output on input

$\frac{\Delta I_C}{\Delta v_{CE}} \Longrightarrow \frac{dI_C}{dv_{CE}} = I_S \exp\left(\frac{v_{BE}}{v_T}\right) \times \frac{1}{v_A}$

if $v_{CE} \ll v_A \rightarrow 1 + \frac{v_{CE}}{v_A} \simeq 1$

$\rightarrow \frac{dI_C}{dv_{CE}} = \frac{I_C}{v_A} = \frac{1}{R_{out}} \Rightarrow \boxed{R_{out} = \frac{v_A}{I_C} = r_o}$

effect of output on input

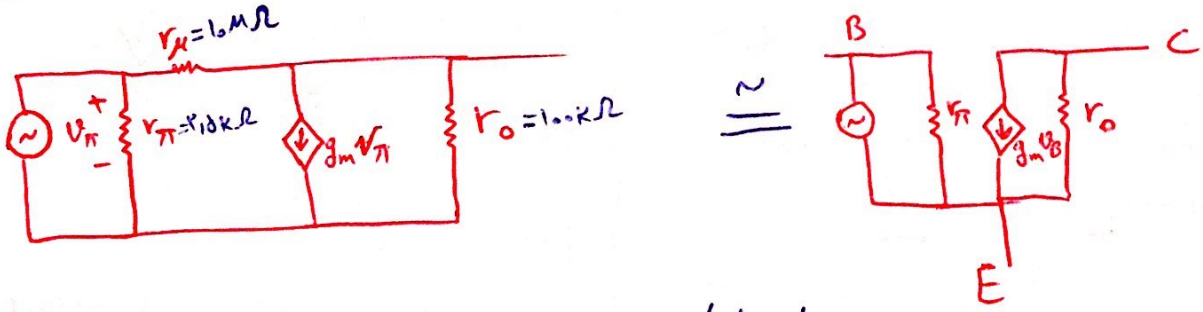
$\frac{\Delta I_B}{\Delta v_{CE}} = \frac{1}{\beta_F} \frac{\Delta I_C}{\Delta v_{CE}} = \frac{1}{\beta_F r_o} \rightarrow \frac{\Delta v_{CE}}{\Delta I_B} = \beta_F r_o = r_\mu$

Examples:

$v_A = 100\,v$

$I_C = 1\,mA$ v_{bb} $\beta_F = 100 \rightarrow g_m = \frac{I_C}{v_T} = 40\,mv$

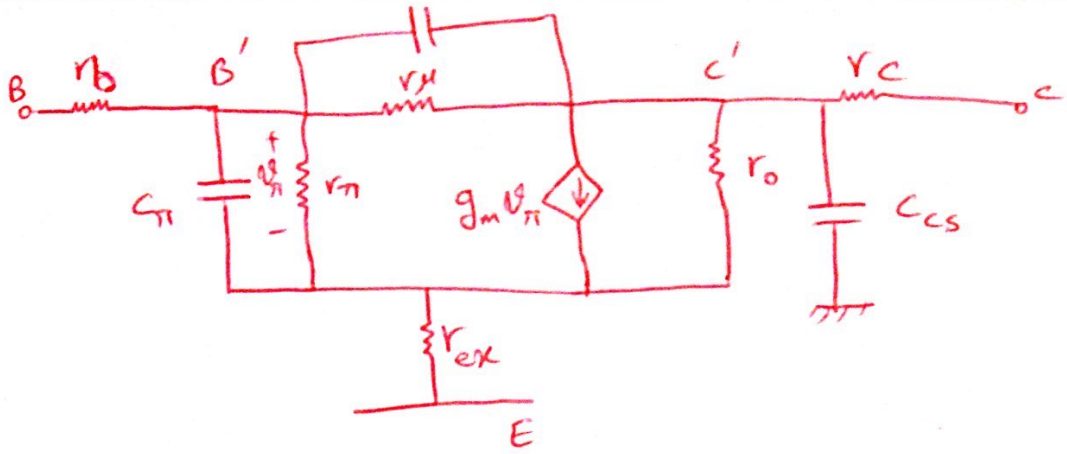
$r_\pi = \frac{\beta_F}{g_m} = 2.5\,K\Omega$ $\quad r_o = \frac{v_A}{I_C} = 100\,K\Omega$ $\quad r_\mu = \beta_F r_o = 10\,M\Omega$



مدل سیگنال کوچک BJT در ناحیه فعال

Hybrid-π model

مدل کامل سیگنال کوچک



$r_b = 50 \sim 500\ \Omega$

$r_{ex} = 1 \sim 2\ \Omega$

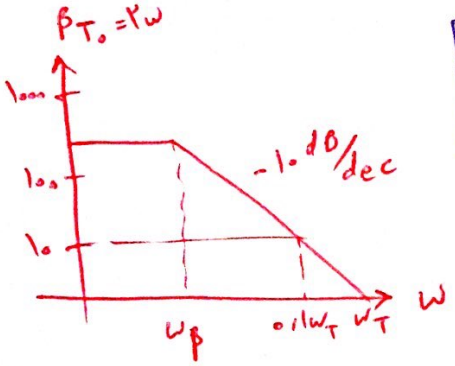
$r_c = 20 \sim 500\ \Omega$

$C_{\mu_0} \cong 1.0\ fF$

$C_{cs_0} = 20\ fF$

مدل کامل ترانزیستور

$\beta \rightarrow \frac{i_{out}}{i_{in}} \rightarrow |\beta(j\omega)|$



$$\omega_T = \frac{g_m}{C_\pi + C_\mu}$$

فرکانس قطع ترانزیستور

$$\omega_\beta = \frac{\omega_T}{\beta_0}$$

$\omega_T = \frac{20 \times 10^{-3}}{20\ fF} = 2 \times 10^{12}$

$f_T = 2 \times 10^{11} = 200\ GHz$

$f_\beta = 1\ GHz \rightarrow f_\beta < 1\ GHz$