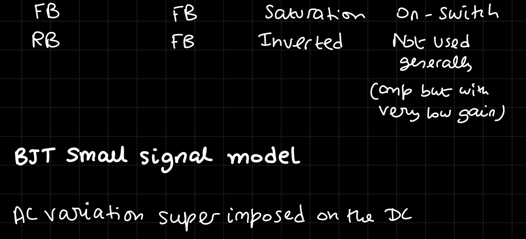
Simulation on Tuesday 19/02/25
Quiz on Friday 14/02/25 in the slot
Practice questions on next Friday (21/02/25)
Midterm on 25/02/25
↳ one A4 cheatsheet allowed

npn

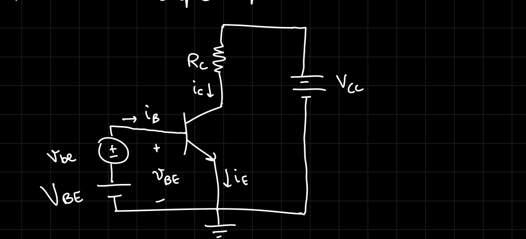
EBJ	CBJ	Mode	Application
FB	RB	Active	Amplifier
RB	RB	Cutoff	off-switch
FB	FB	Saturation	on-switch
RB	FB	Inverted	not used generally

BJT Small signal model

AC variation superimposed on the DC



↓ DC analysis



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

$V_{CE} > 0.4V$ to keep in active region

$v_{BE} = V_{BE} + v_{be}$

$i_C = I_S e^{v_{BE}/V_T} = I_S e^{V_{BE}/V_T} e^{v_{be}/V_T}$

$i_C = I_C e^{v_{be}/V_T}$

if $v_{be} \ll V_T$ (i.e. peak of v_{be} = 10mV) then,

$i_C = I_C \left(1 + \frac{v_{be}}{V_T}\right)$

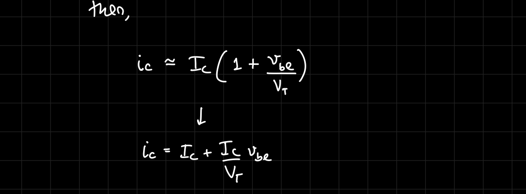
$i_C = I_C + \frac{I_C}{V_T} v_{be}$

AC part

$i_c = \frac{I_C}{V_T} v_{be} = g_m v_{be}$ $\quad g_m = \frac{I_C}{V_T}$

trans conductance

$i_C = I_C + i_c$



① $v_{be} = 0$, $i_C = I_C$

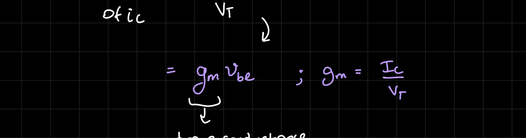
slope of ... $= \frac{I_C}{V_T}$

$m = \frac{I_C}{V_T} = g_m$

trans conductance

g_m was a slope of the output voltage

at g_m↑, more amplification, more power consumption, higher bias required



$g_m = \left.\frac{\partial i_C}{\partial v_{BE}}\right|_{i_C = I_C}$

* To determine resistance seen by v_{be}, we calculate the small base current (i_b using)

$i_B = \frac{i_C}{\beta} = \frac{I_C}{\beta} + \frac{1}{\beta}\frac{I_C}{V_T} v_{be}$

$i_B = I_B + i_b$

So, $i_b = \frac{1}{\beta}\frac{I_C}{V_T} v_{be} = \frac{g_m v_{be}}{\beta}$

$r_\pi = \frac{v_{be}}{i_b} = \frac{\beta}{g_m}$

$\boxed{r_\pi = \frac{\beta}{g_m}}$

$r_\pi = \frac{\beta}{g_m} = \frac{\beta V_T}{I_C} = \frac{V_T}{I_B}$

* Emmiter Current i_E

$\alpha = \frac{i_c}{i_E} \rightarrow i_E = \frac{i_c}{\alpha}$

$r_E = \frac{v_{be}}{i_E}$

$r_E = \frac{v_{be} \cdot \alpha}{i_c} = \frac{\alpha}{g_m} = \frac{V_T}{I_E}$

$i_e = \frac{i_c}{\alpha} = \frac{1}{\alpha}\frac{I_C}{V_T} v_{be} = \frac{I_E}{V_T} v_{be}$

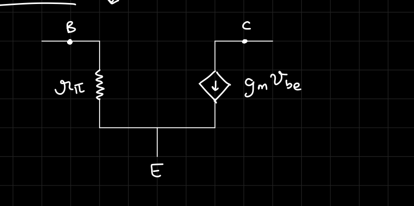
generally, $r_\pi \gg r_e$

$v_{be} = i_b r_\pi = i_e r_e$

$r_\pi = \left(\frac{i_e}{i_c}\right) r_e$ $\quad \frac{i_e}{i_c} = \alpha = \frac{\beta+1}{\beta}$

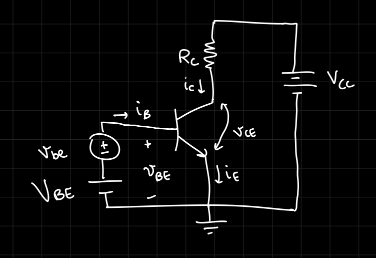
$r_\pi = (\beta+1) r_e$ $\quad \frac{i_e}{i_b} = \beta+1$

π-model



Voltage gain:

$v_{CE} = V_{CC} - i_C R_C$



$v_{CE} = V_{CC} - (I_C + i_c) R_C$

$v_{CE} = (V_{CC} - I_C R_C) - i_c R_C$

$v_{CE} = \underset{DC}{V_{CE}} - \underset{AC}{i_c R_C}$

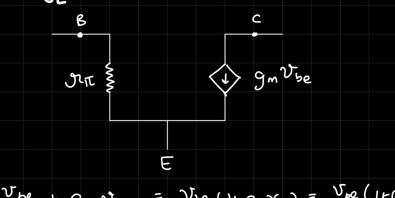
$v_{ce} = -i_c R_C = -g_m v_{be} R_C = (-g_m R_C) v_{be}$

$A_v = \frac{-I_C R_C}{V_T}$

every volt/current in the amplifier has
↳ dc component
↳ signal component

MODELS

π-MODEL



$i_e = \frac{v_{be}}{r_\pi} + g_m v_{be} = \frac{v_{be}}{r_\pi}(1 + g_m r_\pi) = \frac{v_{be}(1+\beta)}{r_\pi}$

$= v_{be}\left(\frac{r_\pi}{1+\beta}\right) = \frac{v_{be}}{r_e}$

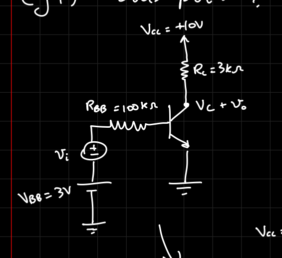
$i_e = \frac{v_{be}}{r_e}$

Voltage controlled current source

hybrid-π model
↳ used to carry out small signal analysis of any transistor circuit

Sometimes, the **T model** is more convenient.

eg1) bias point ?



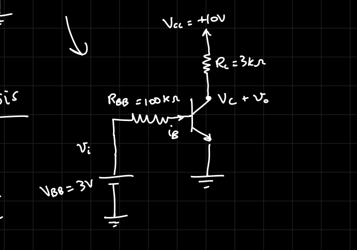
assume $\beta = 100$

$V_{BE} = 0.7\ V$

$V_{CC} = 10V$

DC analysis

$V_{DC} \rightarrow SC$
$A_{ac} \rightarrow OC$
$L \rightarrow SC$
$C \rightarrow OC$



$-V_{BB} + i_B \cdot 100k + V_{BE} = 0$

$-10 + V_{CE} + I_C \cdot 3k = 0$
$V_{CE} + I_C \cdot 3k = 10$

$I_B = \frac{3 - 0.7}{100}$ mA

$I_C = \beta I_B = 2.3mA$

V_{BE} = biasing point

$g_m = \frac{I_C}{V_T} = \frac{2.3m}{25m} = 92mA/V$

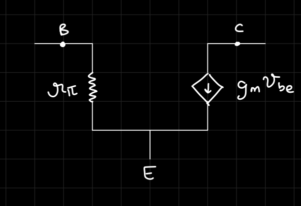
$r_\pi = \frac{\beta}{g_m} = 1.09k\Omega$

$V_C = V_{CC} - I_C R_C = 10 - 2.3 \times 3$

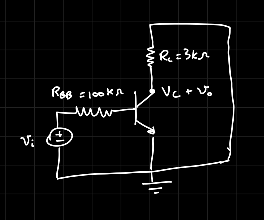
$V_C = 3.1V$

pi-model

DC sources in AC model



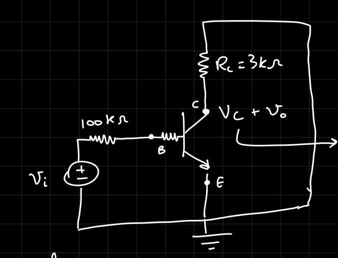
AC equivalent ckt



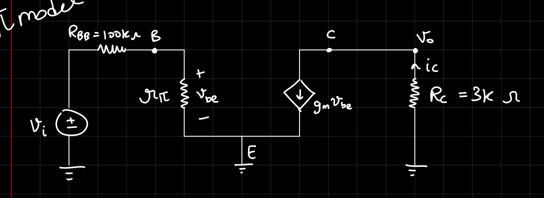
$-v_i + i_B \cdot 100k + v_{BE} = 0$

$i_B \cdot 100k + v_{BE} = v_i$

$i_c \cdot 3k + V_{CE} = 0$
$V_{CE} = i_c \cdot 3k$
$V_{CE} = 2.3 \times 3\ V$



π model



$v_o = -i_c R_C = -g_m v_{be} R_C$

$v_{be} = v_i \frac{r_\pi}{r_\pi + R_{BB}} = v_i \frac{1.09}{101.09} = 0.011 v_i$

$v_o = -92 \cdot 0.011 v_i \cdot 3 = -3.04 v_i$

gain: $A_v = \frac{v_o}{v_i} = -3.04\ V/V$

V_{CB} should be $> -0.4V$

$v_{be} = 0.011\ v_i$

$v_i = \frac{v_{be}}{0.011} = \frac{10}{0.011} = 0.91V$

$v_{CE} = V_{CE} + |v_o|$

$= 3.1 \pm 2.77 = (5.83, 0.33)$

* to satisfy small signal approximation, $v_{be} < 10mV$ peak

$v_{BE} = 0.71 \pm 0.01 = (0.72, 0.7)$

$V_{CB} = -0.38V$ # forward Bias

for saturation, $V_{CB} < -0.4$
but $V_{CB} > -0.4$
So, amp is in active mode