BJT Small Signal Analysis.

→ They are two types of Signal Analysis Available

* Small Signal Amplifier
* large Signal. Amplifier.

parameters of Amplifier.

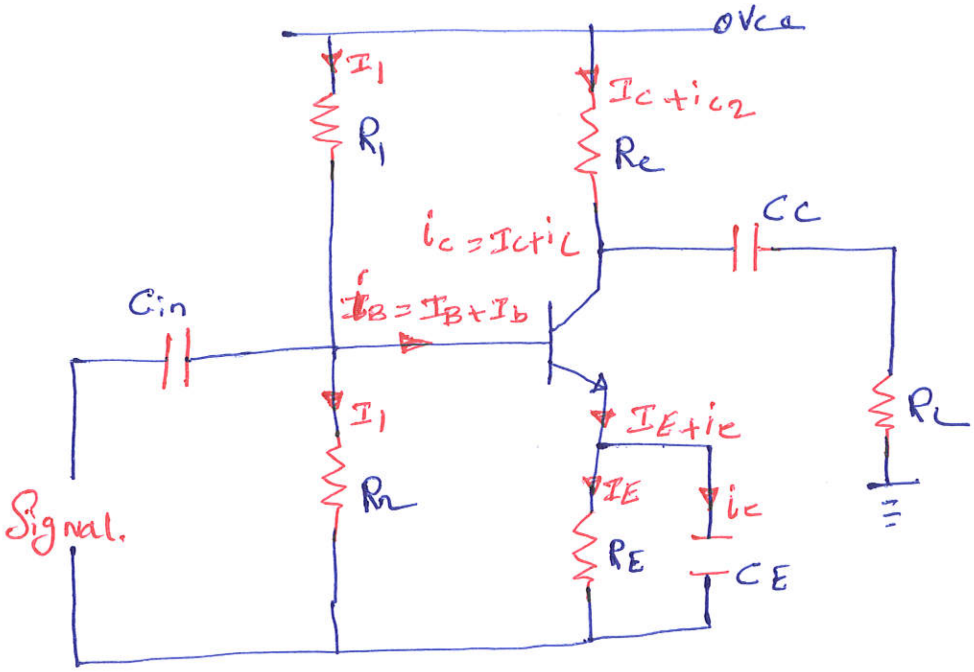
* parameters are factors, those decide the performance of an amplifier.

* Input Impedance * Output Impedance
* Amplification factor *
  - ↳ Voltage gain
  - ↳ current gain
  - ↳ power gain.

Practical circuit of Transistor Amplifier.

basic Components.

* Biasing ckts
* Input capacitor Cin
* Emitter bypass capacitor
* Coupling Capacitor



i) <u>Biasing circuits.</u>

* The Resistance R1, R2, & R_E from the biasing and stabilisation circuit.

* The biasing circuit must establish proper operating point.

* otherwise a part of the negative half cycle of the signal may be cut off in the output.

ii) <u>Input capacitance.</u> ($\simeq$ 10NF)

* capacitor used to couple the signal to the base of the transistor.

iii] Emitter bypass capacitor C_E — 100NF

→ CE is used to parralel with RE to ~~with~~ provide Low ~~Resistance~~ Reactance path to the amplified a.c. signal. If it is not used.

* Amplified a.c. Signal flowing through R_E will cause a voltage drop across it. thereby reducing the output voltage.

iv) Coupling capacitor C_C — 10NF

* The coupling capacitor couples one stage of amplification to the next stage. If it is not used.

* The bias conditions of next stage will be drastically changed due to the shunting effect of R_C

In Short

C_C isolates d.c. of one stage from next stage. but allows passage of a.c. Signal.

Various Circuit currents.

i) Base current

$$i_B = I_B + i_b.$$

* when no Signal is applied in the base circuit, d.c. base current I_B flows due to biasing circuits.

* when a.c. Signal is applied, a.c base current i_b also flows. ∴

total current $$i_B = I_B + i_b$$

ii) Collector current

no Signal ⇒ I_C flows → biasing ckts.

a.c. Signal ⇒ i_c flows.

$$i_C = I_C + i_c$$

$I_C = \beta I_B$ Zero Signal Collector cnt

$i_c = \beta i_b$ Collector cnt due to Sgl.

iii] **Emitter Cnt**

no Signal = I_E flows → biasing ckt.

Signal applied = i_e

$\therefore$ ~~I_E~~ $i_E = I_E + i_e$

$\therefore$ wkt $I_E \simeq I_C$ $i_e \simeq i_c$ $\therefore$ Base cnt is very very small.

Types of Analysing.

1) D.C. Analysis

2) A.C. Analysis.

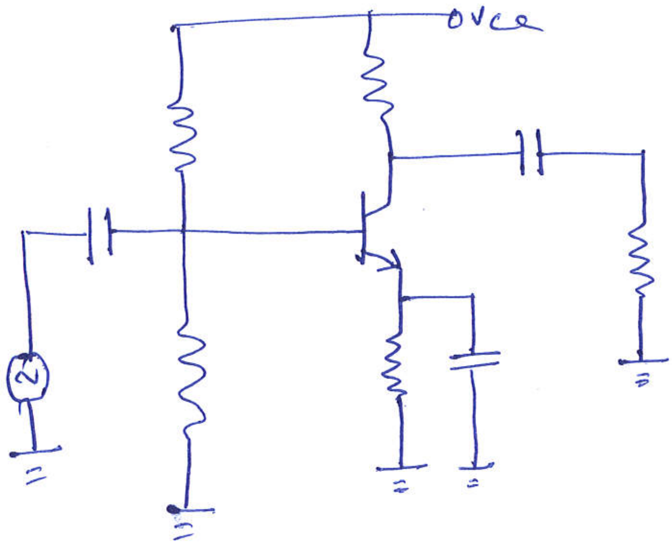
D.C. equivalent circuits.

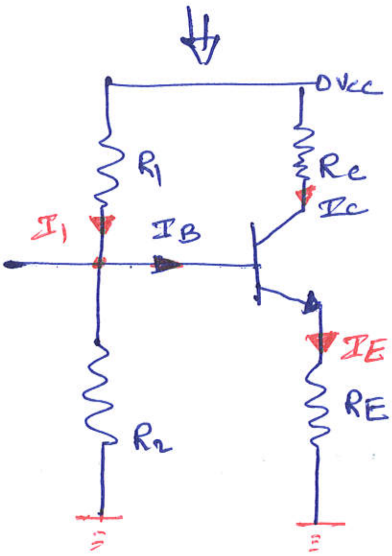
→ In the d.c. equivalent circuit of a transistor amplifier,

→ As direct current cannot flow through a capacitor.

→ all the capacitors looks like open circuits in the d.c. equivalent circuit.

* Reduces all a.c. Sources to zero.
* open all the capacitors.
* calculate all the d.c. operating values.





The A.c. Analysis.

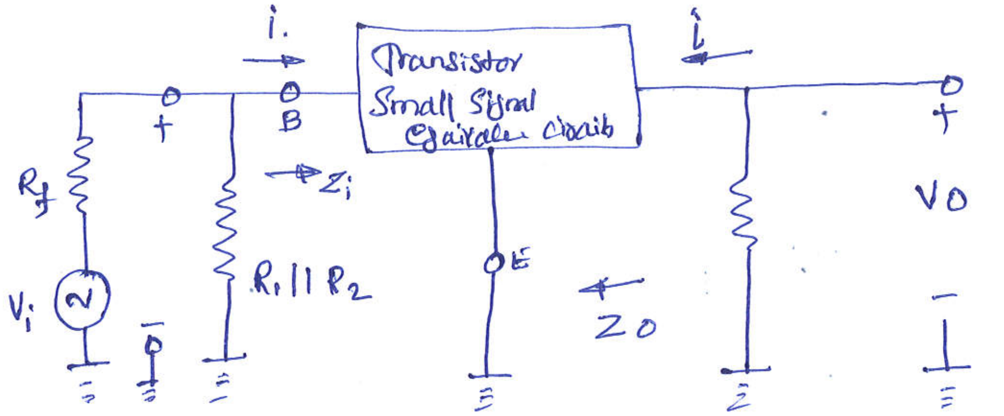
* only a.c. conditions are to be considered.

In order to draw the a.c. equivalent circuit. the following two steps are applied.

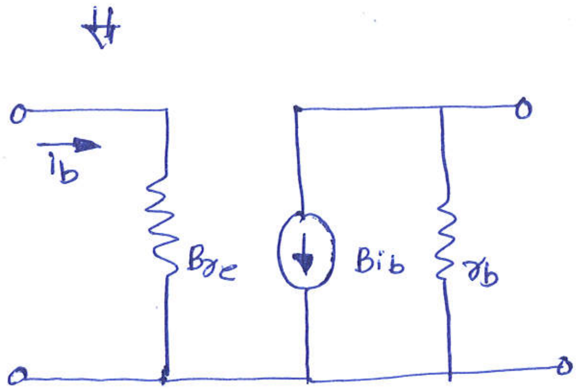
a) Reduce all d.c. Sources to zero.

b) Short all the capacitors.

c) Calculate all necessary ac values.



Input Impedance Z_i.



Base current is Input current

I_c is the output current

$$I_C = \beta I_B.$$

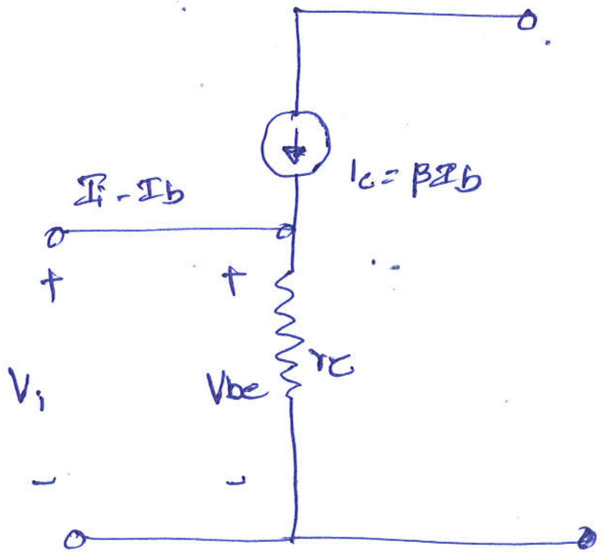
$$I_e = I_c + I_b$$

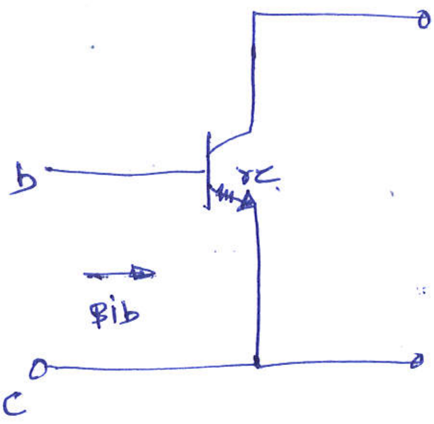
$$= \beta I_b + I_b$$

$$I_e = (\beta + 1) I_b$$

Since in Ac, β is much grater than 1

$$\therefore \quad I_e = \beta I_b$$





$$Z_i = \frac{V_i}{I_i} = \frac{V_{be}}{I_b}$$

The Voltage V_{be} → Across EBJ → Diode Resistance-r_e

$$V_i = V_{be} = I_e r_e \simeq \beta I_b r_e$$

$$Z_i = \frac{V_{be}}{I_b} = \frac{\beta I_b r_e}{I_b}$$

$$\boxed{Z_i = \beta r_e} \quad \simeq \quad Z_i = r_b \| \beta r_e$$

Output Impedance

$$Z_o = R_c \| r_o \qquad\qquad R_c \| r_o \simeq R_c$$

$$\boxed{Z_o = R_c}$$

Voltage gain (A_v)

$$V_o = -I_o [R_c \| r_o] \quad \text{and} \quad V_i = I_i Z_i$$

$$\boxed{V_i = I_b \beta r_e}$$

$$= -[\beta I_b][R_c \| r_o]$$

$$A_v = \frac{V_o}{V_i} \simeq \frac{-[\beta I_b][R_c \| r_o]}{I_b \beta r_e}$$

–ve sign Indicates 180° phase shift

$$= -\frac{R_c \| r_o}{r_e}$$

$$\boxed{A_v = -\frac{R_c}{r_e}}$$

r_o is very less or open.

Current gain (A_i)

$$A_i = \frac{I_o}{I_i} = \frac{I_c}{I_b} = \frac{\beta I_b}{I_B} = \beta$$

$$\boxed{A_i \simeq \beta}$$

or $A_i = \frac{I_o}{I_i} = \frac{V_o/R_c}{V_i/Z_i} = \left[\frac{V_o}{V_i}\right]\left[\frac{Z_i}{R_c}\right]$

$$\boxed{A_i = A_v \frac{\beta r_e}{R_c}}$$

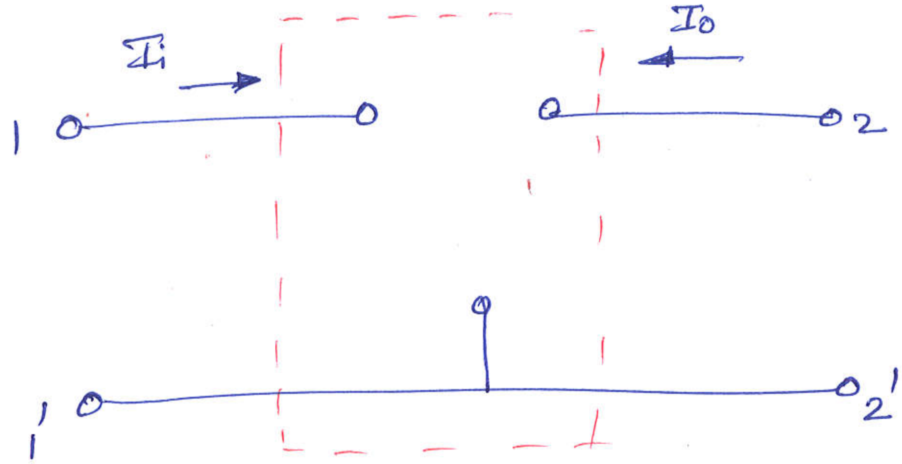
power gain.

$$A_p = \frac{P_o}{P_i}$$

$$= \frac{V_o I_o}{V_i I_i}$$

$$\boxed{A_p = A_v \times A_i}$$

hybrid equivalent circuit ac Analysis.



$$V_i = h_{11} I_i + h_{12} V_o$$

$$I_o = h_{21} I_i + h_{22} V_o$$

The four variables are called h-parameters.

→ hybrid

$$h_{11} = \left.\frac{V_i}{I_i}\right|_{V_o=0} \qquad h_{12} = \left.\frac{V_i}{V_o}\right|_{I_i=0}$$

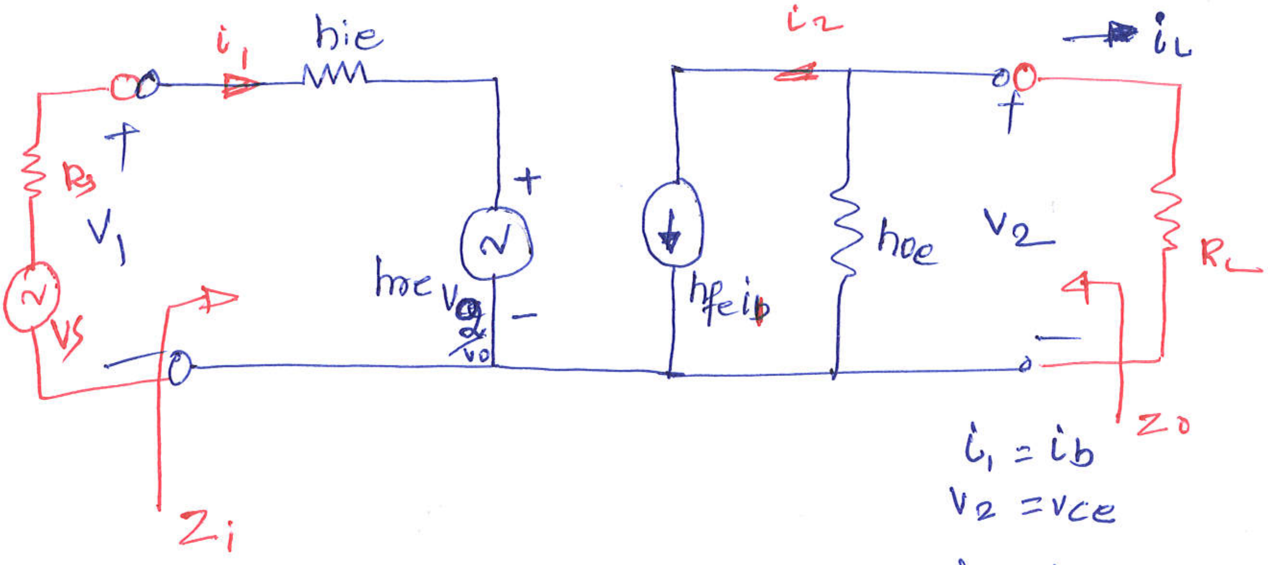
$$h_{21} = \left.\frac{I_o}{I_i}\right|_{V_o=0} \qquad h_{22} = \left.\frac{I_o}{V_o}\right|_{I_i=0}$$

$h_{11} = h_i$

$h_{12} = h_r$

$h_{21} = h_f$

$h_{22} = h_o$



$i_1 = i_b$

$v_2 = v_{ce}$

$i_2 = i_c$

$v_1 = v_{be}$

* current gain $(A_i) = \frac{o/p\ i}{i/p\ i} = \frac{i_L}{i_1} = \frac{-i_2}{i_1}$

$V_2 = i_L R_L$

$\boxed{V_2 = -i_2 R_L}$

$i_2 = h_f i_1 + h_o(-i_2 R_L)$

$i_2 + h_o i_2 R_L = h_f i_1$

$i_2(1 + h_o R_L) = h_f i_1$

$i_2 = \frac{h_f i_1}{1 + h_o R_L}$ ×by $-1/i_1$

$$= \frac{i_2}{i_1} = \frac{-h_f}{1+h_o R_L}$$

$$A_i = \frac{-h_f}{1+h_o R_L}$$

Voltage gain, A_v

$$A_v = \frac{O/P_v}{I/P_v} = \frac{v_2}{v_1}$$

$$v_2 = -i_2 R_L$$

$$= \frac{-i_2 R_L}{v_1}$$

$$\therefore A_i = \frac{-i_2}{i_1}$$

$$-i_2 = i_1 A_i$$

$$\Rightarrow \frac{i_1 A_i R_L}{v_1}$$

$\div$ by both side i_1

$$\frac{V_1}{i_1} = Z_i$$

$$= \frac{\frac{i_1 A_i R_L}{i_1}}{\frac{V_1}{i_1}} \Rightarrow \frac{A_i R_L}{Z_i}$$

WKT

$$A_i = \frac{-h_f}{1+h_o R_L}$$

$$Z_i = h_i - \frac{h_r h_f}{1/R_L + h_o}$$

$$= \frac{-h_f R_L}{h_i + (h_i h_o - h_r h_f) R_L}$$

Δh.

$$A_v = \frac{-h_f R_L}{h_i + \Delta h R_L}$$

power gain (A_p)

$$A_p = A_v \times A_i$$

$$A_p = \left(\frac{-h_f R_L}{h_i + \Delta h R_L} \right) \times \left(\frac{-h_f}{1 + h_o R_L} \right)$$

$$A_p = \frac{h_f^2 R_L}{(h_i + \Delta h R_L)(1 + h_o R_L)}$$

Input Impedance.

from ohm law.

$$V_1 = i_1 \times Z_i$$

$$Z_i = \frac{V_1}{i_1}$$

from equ $V_1 = h_i i_1 + h_r V_2$

$$V_1 = h_i i_1 + h_r V_2 \quad \text{--- (3)}$$
$$i_2 = h_f i_1 + h_o V_2 \quad \text{--- (4)}$$

$\therefore V_2 = -i_2 R_L$

$$V_1 = h_i i_1 + h_r(-i_2 R_L)$$

$\div$ both side by i_1

$$\frac{V_1}{i_1} = h_i - \frac{h_r i_2 R_L}{i_1}$$

$$\left[A_i = \frac{-i_2}{i_1}\right] = \frac{-h_f}{1+h_o R_L}$$

$$\frac{V_1}{i_1} = h_i + h_r A_i R_L$$

$$Z_i = h_i + h_r\left[\frac{-h_f}{1+h_o R_L}\right]$$

$$Z_i = h_i - \frac{h_r h_f}{\frac{1}{R_L} + h_o}$$

Output Impedance.

$R_L = \alpha \rightarrow (1)$

$V_S = 0 \rightarrow (2)$

* we need to SC V_S
* we need to OS output terminal

$$Z_o = \frac{v_2}{i_2}$$

COKT

$$i_2 = h_f i_1 + h_o V_2$$

$$Z_o = \frac{v_2}{h_f i_1 + h_o V_2} \rightarrow (1)$$

Apply KVL in input side

$$-i_1 R_s - i_1 h_i - h_r V_2 = 0$$

$$i_1 (R_s + h_i) + h_r V_2 = 0$$

$$i_1 = \frac{-h_r V_2}{R_s + h_i} \rightarrow (2)$$

$$Z_o = \frac{v_2}{h_f \left[\frac{-h_r V_2}{R_s + h_i} \right] + h_o V_2}$$

$$Z_o = \frac{R_s + h_i}{[h_o h_i - h_f h_r] + h_o R_s}$$

$$\boxed{Z_o = \frac{R_s + h_i}{\Delta h + h_o R_s}}$$