## 4) The Hybrid Equivalent Model :

* We will begin with the general two-port system of Fig (5-13) which defined as a linear circuit that gives the same response at the o/p and i/p ports.

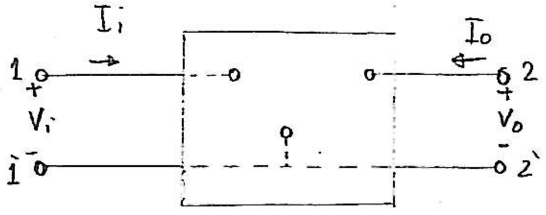



Fig (5-13)
Two-port system

* By equating the parameters of a network to the measured parameters of the transistor, a two-port equivalent circuit can be made to act as does the transistor in the circuit

* We can use :
  1) Impedance (Z) parameters / $V_i$, $V_o$ in terms of $I_i$ and $I_o$
  2) Admittance (Y) parameter / $I_i$, $I_o$ in terms of $V_i$ and $V_o$
  3) Input parameters
  4) Output parameters
  5) Hybrid (h) Parameters: which is the most frequently employed in transistor circuit analysis, however, and therefore is discussed in details:

$$V_i = h_{11} I_i + h_{12} V_o \quad \text{-----} (5-8)$$
$$I_o = h_{21} I_i + h_{22} V_o \quad \text{-----} (5-9)$$



* The term hybrid was chosen because the mixture of variables (V and I) in each equation results in a hybrid set of units of measurement for the h-parameters.

$$h_{11} = \left.\frac{V_i}{I_i}\right|_{V_o=0}$$ ohms (short-circuit input-impedance parameter) ------(5-10)

$$h_{12} = \left.\frac{V_i}{V_o}\right|_{I_i=0}$$ unitless (open cct. reverse transfer voltage ratio parameter) --(5-11)

$$h_{22} = \left.\frac{I_o}{V_o}\right|_{I_i=0}$$ siemens (open-Circuit output admittance parameter) --(5-12)

$h_{21} = \left.\dfrac{I_o}{I_i}\right|_{V_o=0}$ (short circuit forward transfer current ratio parameter) --- (5-13)

* apply KVL for equation (5-8) as an input cct.
apply KCL for equation (5-9) as an output cct.
we get the complete hybrid equivalent cct with a new set of subscripts for the h-parameters.

$h_{11} \rightarrow$ input resistance $\rightarrow h_i$
$h_{12} \rightarrow$ reverse transfer voltage ratio $\rightarrow h_r$
$h_{21} \rightarrow$ forward transfer current ratio $\rightarrow h_f$
$h_{22} \rightarrow$ output conductance $\rightarrow h_o$

* The circuit of Fig (5-14) is applicable to any linear three-terminal electronic device or system.

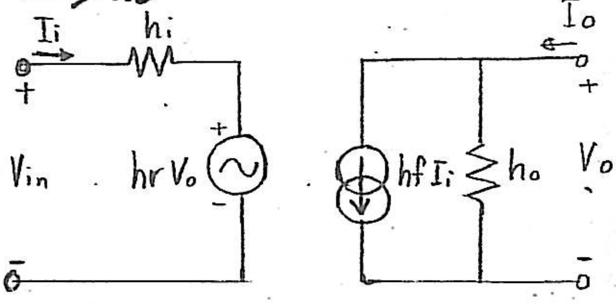


Fig (5-14)
Complete hybrid equivalent circuit

* Transistor is a three terminal device, even though it has three basic configuration.

* For C-E, a second subscript (e) has been added to the h-parameter notation.

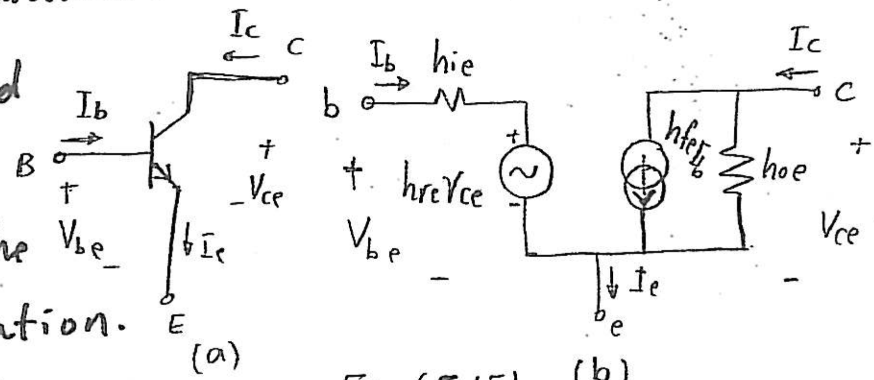


Fig (5-15)
C-E-C a) graphical Symbol
b) hybrid equivalent circuit

* For C·B·C of Fig (5-16) a subscript (b) to h-parameter notation.

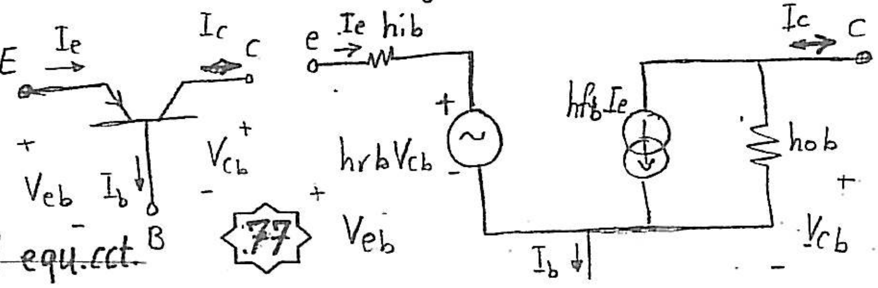


Fig (5-16)
C·B·C a) Symbol
~~b) hybrid equ.cct.~~

* For the common-emitter and Common-base configurations the magnitude of $h_r$ and $h_o$ is often such that the results obtained for the important parameters such as $Z_i$, $Z_o$, $A_v$ and $A_i$ are only slightly affected if $h_r$ and $h_o$ are not included in the model.

* set $h_r \cong 0$ so $h_r V_o \cong 0$ (S.C equivalent)

set resistance $\frac{1}{h_o}$ large enough to be ignored in Comparision to aparallel load (O.C equivalent).

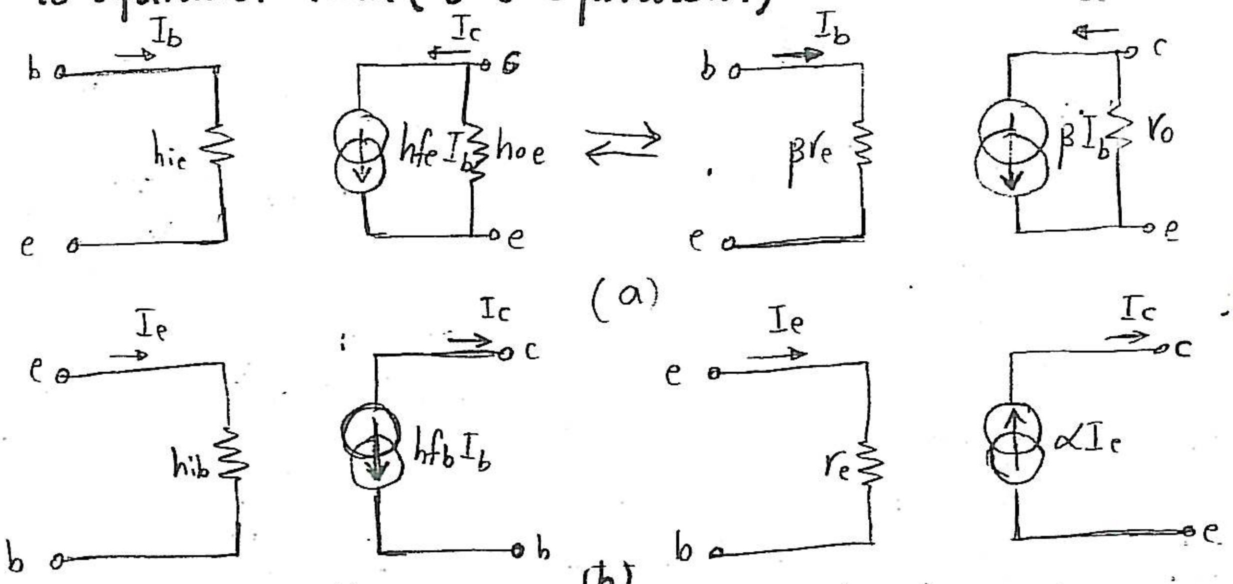



Fig (5-17) Hybrid versus $r_e$ model a) C.E.C
b) C.B.C



* It should be reasonably clear from Fig (5-17) a that

$$h_{ie} = \beta r_e \quad \text{------ (5-14)}$$

$$h_{fe} = \beta_{ac} \quad \text{------ (5-15)}$$

From Fig (2-17) b

$$h_{ib} = r_e \quad \text{------ (5-16)}$$

$$h_{fb} = -\alpha \cong -1 \quad \text{------ (5-17)}$$

* With some approximate conversion equations

$$h_{ie} = \frac{h_{ib}}{1+h_{fb}} \cong \beta r_e \qquad h_{oe} \cong \frac{h_{ob}}{1+h_{fb}} \qquad h_{ic} \cong \frac{h_{ib}}{h_{fb}+1} \cong \beta r_e$$

$$h_{re} \cong \frac{h_{ib} h_{ob}}{1+h_{fb}} - h_{rb} \qquad h_{ib} \cong \frac{h_{ie}}{h_{fe}+1} \cong -\frac{h_{ie}}{h_{fe}} \cong r_e \qquad h_{rc} \cong 1$$

$$h_{fe} \cong \frac{-h_{fb}}{1+h_{fb}} \cong \beta \qquad h_{fc} \cong \frac{-1}{h_{fb}+1} \cong -\beta$$

$$h_{fb} \cong \frac{-h_{fe}}{h_{fe}+1} \cong -1 = -\alpha$$

## 5) Hybrid π Model :

* The hybrid π model appear in Fig (2-18) with all the parameters necessary for a full-frequency analysis.

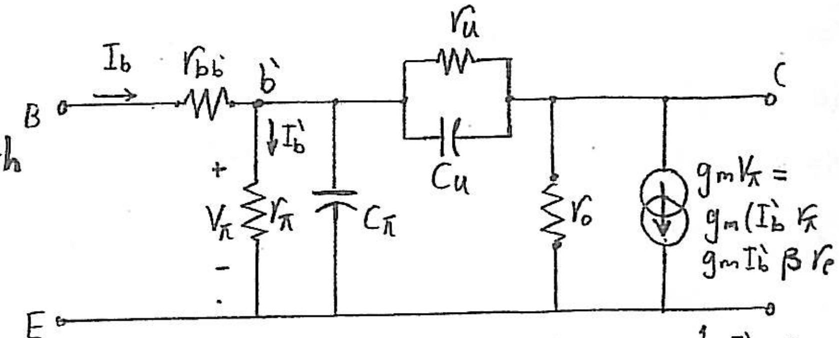



Fig (5-18)
Hybrid π high frequency transistor small-signal ac equivalent circuit

* All the capacitors that appear in Fig (5-18) are stray parasitic capacitors between the various junction of the device, play at high frequencies. For low to mid-frequencies their reactance is very large and can be consider open circuits. $C_u$: few picofarads (PF).
* The resistors $r_\pi$, $r_u$ and $r_o$ are the resistances between the indicated terminals of the device
* The resistance $r_u$ (the subscript u refers to the union, is very large resistance, and provides a feedback path from output to input circuits.

$$r_\pi = \beta r_e \qquad (5\text{-}18)$$

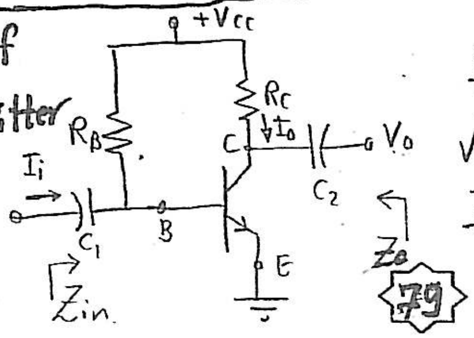
$$g_m = \frac{1}{r_e} \qquad (5\text{-}19)$$

$$r_o = \frac{1}{h_{oe}} \qquad (5\text{-}20)$$

$$h_{re} = \frac{r_\pi}{r_\pi + r_u} \cong \frac{r_\pi}{r_u} \qquad (5\text{-}21)$$

## 6) COMMON-EMITTER FIXED-BIAS CONFIGURATION :

* Circuit of Common-emitter fixed-bias network of Fig (2-19)



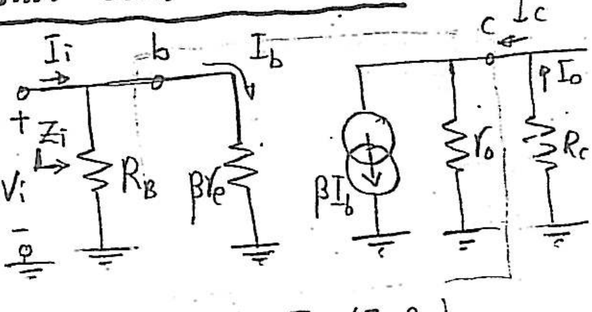




Fig (5-20) ~~re model into the network~~