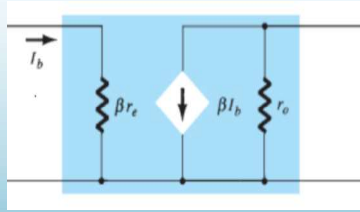
## Small Signal Model & Analysis.....

## Example




Given $\beta = 120$ and $I_E = 3.2$ mA for a common-emitter configuration with $r_o = \infty\ \Omega$, determine:
(a) $Z_i$.
(b) $A_v$ if a load of 2 kΩ is applied.
(c) $A_i$ with the 2 kΩ load.

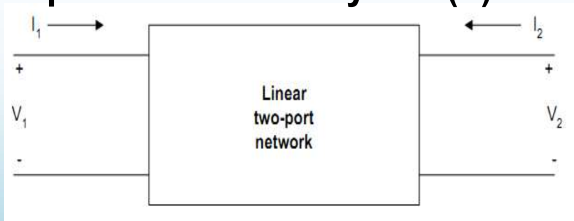
$Z_i = \beta r_e$ $\quad r_e = \frac{26\text{ mV}}{I_E} = \frac{26\text{ mV}}{3.2\text{ mA}} = 8.125\ \Omega$

$A_v = -\frac{R_L}{r_e}$

$A_i = \frac{I_o}{I_i} = \beta = \mathbf{120}$

## Hybrid Equivalent Model

## Two-port Network & Hybrid (h) Parameter




A two-port network can be represented using the h-parameters.
$I_1$ and $V_2$ are independent variables and
$V_1$ and $I_2$ are dependent variables.

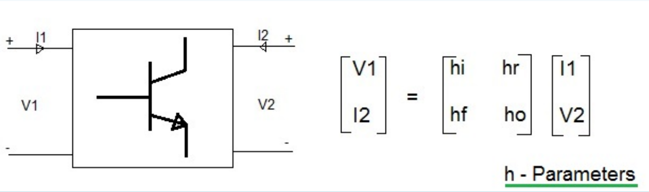
$$V_1 = h_{11}I_1 + h_{12}V_2$$
$$I_2 = h_{21}I_1 + h_{22}V_2$$

The h-parameters can be found as follows:

$$h_{11} = \frac{V_1}{I_1}\Big|_{V_2=0} \qquad h_{21} = \frac{I_2}{I_1}\Big|_{V_2=0}$$
$$h_{12} = \frac{V_1}{V_2}\Big|_{I_1=0} \qquad h_{22} = \frac{I_2}{V_2}\Big|_{I_1=0}$$

The term hybrid was chosen because the mixture of variables (V and I) in each equation results in a “hybrid” set of units

## h-parameter for BJT




The hybrid parameters:

$h_{11} = h_i$

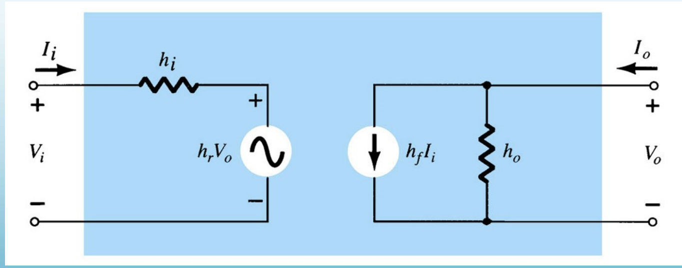
$h_{12} = h_r$

$h_{21} = h_f$

$h_{22} = h_o$

are developed and used to model the transistor. These parameters can be found in a specification sheet for a transistor.

## General h-Parameters for any Transistor Configuration



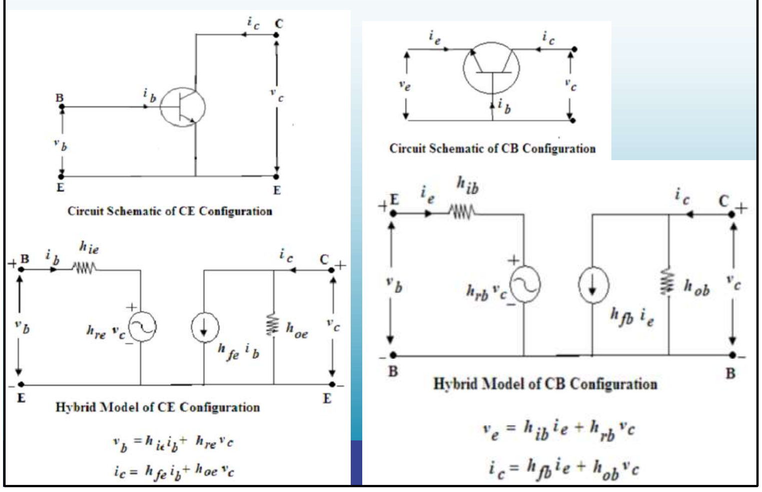

$h_i$ = input resistance

$h_r$ = reverse transfer voltage ratio (Vi/Vo)

$h_f$ = forward transfer current ratio (Io/Ii)

$h_o$ = output conductance

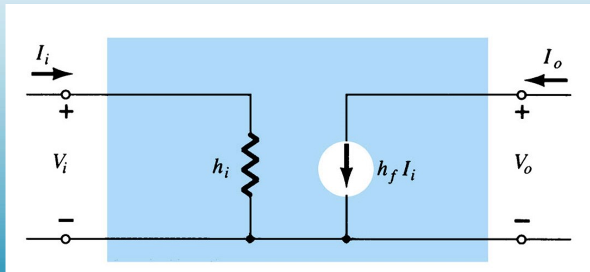
## *CE* and *CB* hybrid model



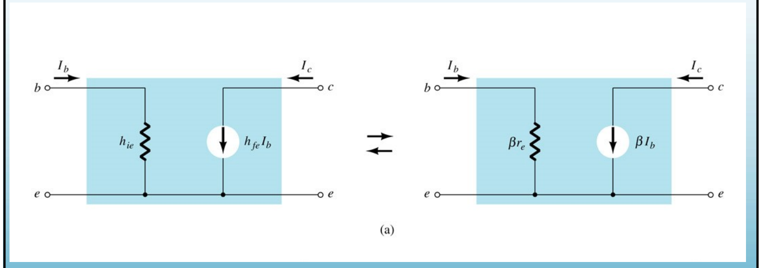

## Simplified General *h*-Parameter Model

The above model can be simplified based on these approximations:

$h_r \cong 0$ therefore $h_r V_o = 0$ and $h_o \cong \infty$



## Common-Emitter $r_e$ vs. $h$-Parameter Model



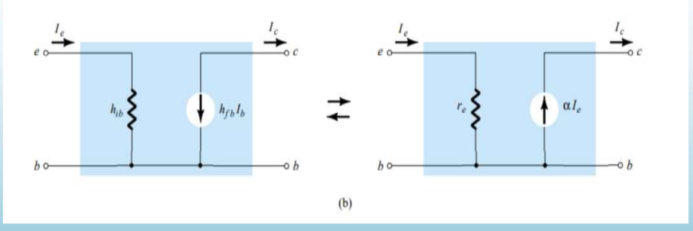

$h_{ie} = \beta re$
$h_{fe} = \beta$
$h_{oe} = 1/r_o$

## Common-Emitter $h$-Parameters

$$h_{ie} = \beta r_e$$ [Formula 7.28]

$$h_{fe} = \beta_{ac}$$ [Formula 7.29]

## Common-Base $r_e$ vs. $h$-Parameter Model




$h_{ib} = r_e$
$h_{fb} = -\alpha$

## Common-Base $h$-Parameters

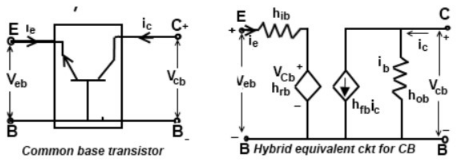
$$h_{ib} = r_e$$ [Formula 7.30]

$$h_{fb} = -\alpha \cong -1$$ [Formula 7.31]

# Asignment

$V_{be} = h_{ib}.i_b + h_{rb}.V_c$

$i_e = h_{fb}.i_b + h_{ob}.V_c$




## Example

A transistor used in a common base amplifier has the following vaules of h-parameters:

**$h_{ib}$** = 28 **Ω**, **$h_{fb}$** = -0.98, **$h_{rb}$ = 5 x $10^{-4}$** and **$h_{ob}$** = 0.34 X **$10^{-6}$** S

Calculate the values of input resistance, output resistance, current gain and voltage gain, if the load resistance is 1.2 KΩ. Assume source resistance as zero.

# Example: CE hybrid equivalent ckt

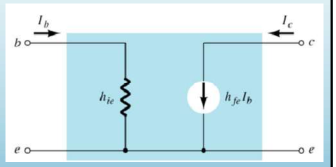
Given $I_E = 2.5$ mA, $h_{fe} = 140$, $h_{oe} = 20\ \mu$S ($\mu$mho), and $h_{ob} = 0.5\ \mu$S, determine:
(a) The common-emitter hybrid equivalent circuit.
(b) The common-base $r_e$ model.

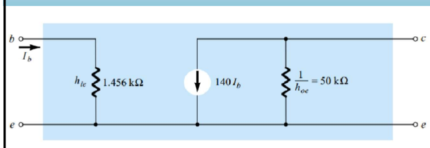
**Solution**

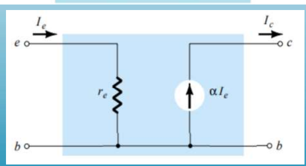
(a) $r_e = \dfrac{26\text{ mV}}{I_E} = \dfrac{26\text{ mV}}{2.5\text{ mA}} = 10.4\ \Omega$

$h_{ie} = \beta r_e = (140)(10.4\ \Omega) = \mathbf{1.456\ k\Omega}$

$r_o = \dfrac{1}{h_{oe}} = \dfrac{1}{20\ \mu S} = 50\ k\Omega$




# Example: Cpmmon-Base re model

(b) $r_e = \mathbf{10.4\ \Omega}$

$\alpha \cong 1, \quad r_o = \dfrac{1}{h_{ob}} = \dfrac{1}{0.5\ \mu S} = \mathbf{2\ M\Omega}$