Hybrid model for trans at low frequency

~~of~~

h- Parameter

→ Vaccum Tubes before BJT

⇓

Analysis

⇓

1. Z- Parameters → Impedence parameters.
2. Y- Parameter ⇒ Admittance Parameter.

→ Transistor → 1947

By using these Parameter, analysis become problematics.

Third parameter developed :

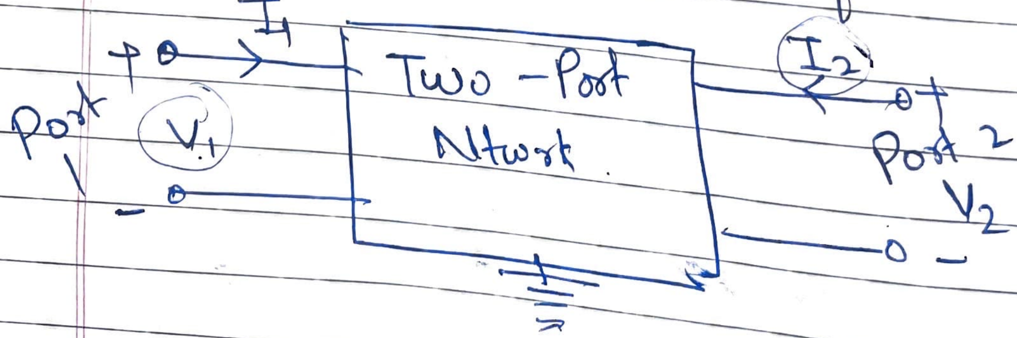
3. H- Parameters (Hybrid)

↓

Mix of constants with diff units.

H- Parameter

★ → are applicable for two port ntwork.



→ In BJT → it is considered to be as
→ 2- Port ntwk in any confi
→ 4 terminals
→ Estimation of BJT became easier using H-Parameter.

* → Mix of constants having different units

* – V_1, I_1, V_2 & I_2 are total current & voltages (AC & DC both).
(By using these, we will check the parameter)

→ AC signal is superimposed on DC sig.

→ Fundamental Relationship b/w dependable

→ V_1 & I_2 = Dependable Variable.

∴

Function Relation →

$$\begin{cases} V_1 = f(I_1, V_2) \\ I_2 = f(I_1, V_2) \end{cases}$$

⇒ I_1 & V_2 are independent Variables

For Small signal operation.

change in Voltage → $$dV_1 = \frac{\partial V_1}{\partial I_1} dI_1 + \frac{\partial V_1}{\partial V_2} dV_2 \quad \text{— (1)}$$

→ Rate of changes of

→ ratio of Reverse vtg.

→ small

I/P impedance change.

Eqn

→ Impedance ulta

" current → $$dI_2 = \frac{\partial I_2}{\partial I_1} dI_1 + \frac{\partial I_2}{\partial V_2} dV_2 \quad \text{— (2)}$$

→ F.C. gain current ratio

→ output Admitt.

$dV_1 = h_{11}\, dI_1 + h_{12}\, dV_2$ — (1)

$dI_2 = h_{21}\, dI_1 + h_{22}\, dV_2$ — (2)

change in vtg

equations

$v_1 = h_{11}\, i_1 + h_{12}\, V_2$ — (3)

$i_2 = h_{21}\, i_1 + h_{22}\, V_2$ — (4)

$$v_1 = h_{11} i_1 + h_{12} \overset{0}{V_2} \quad \text{— (3)}$$

$$i_2 = h_{21} i_1 + h_{22} V_2 \quad \text{— (4)}$$

Applicable for all co

We have to out value of

h_{11}, h_{12}, h_{21} & h_{22}

det $v_2 = 0$, O/P → S.C for A.C signal

$v_1 = h_{11} i_1$ — consid.

$$h_{11} = \frac{v_1}{i_1}$$

$$h_i = h_{11} = \frac{v_1}{i_i}\Bigg|_{V_2 = 0} \Rightarrow \text{I/P Impedance } (\Omega)$$

Unit

Date
Page

When $v_2 = 0$

$i_2 = h_{21} i_1$

$h_f = h_{21} = \left.\frac{i_2}{i_1}\right|_{v_2=0} \Rightarrow$ Forward current gain

denoted by

Now $i_1 = 0 \rightarrow$ I/P $\rightarrow$ O.C for AC

$v_1 = 0 + h_{12} v_2$

$h_r = h_{12} = \left.\frac{v_1}{v_2}\right|_{i_1=0} \Rightarrow$ Reverse voltage gain

$i_2 = 0 + h_{22} v_2$

$h_o \Rightarrow h_{22} = \left.\frac{i_2}{v_2}\right|_{i_1=0} \Rightarrow$ Output Admittance (mho) (Siemens) Unit

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

Now,

$$\begin{cases} v_1 = h_i i_i + h_r v_2 \\ i_2 = h_f i_1 + h_o v_2 \end{cases}$$

h_i = Input Impedence = Ω
h_r = const quant = R.V.G
h_f = dimension less
h_o = Siemens

different units so hybrid.

Now for C-E confi,

$h_i \Rightarrow h_{ie}$

$h_f \Rightarrow h_{fe}$

$h_r \Rightarrow h_{re}$

$h_o \Rightarrow h_{oe}$

⇒ Manufacturer provides h - value,
they are not interchangeble

⇒ Conditional parameters

⇒ Popular model

dynamic I/P resist

By using h-paramete →
$$\left[\begin{matrix} r_i \\ r_o \\ A_i \\ A_v \end{matrix}\right]$$
gain

→ can be calc of ma.

H-parameter Equivalent crkt

$$v_1 = h_{11} i_1 + h_{12} v_2 \quad -(1)$$

$$i_2 = h_{21} i_1 + h_{22} v_2 \quad -(2)$$

Depedent Variable

Depedent on & calculate h.

→ Matrix Representation.

$$\underset{2\times1}{\begin{bmatrix} v_1 \\ i_2 \end{bmatrix}} = \underset{2\times2}{\begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix}} \underset{2\times1}{\begin{bmatrix} i_1 \\ v_2 \end{bmatrix}}$$

h-para matrix

Indepedent Variable

→ $v_1 = h_i i_1 + h_r v_2 \quad -(3)$ → Reverse vtg ratio.

$i_2 = h_f i_1 + h_o v_2 \quad -(4)$

h_o → o/p Admittance.

→ By using these two equation, the equivalent model ⇒ π-Model

Make

Equation (3)

$$v_1 = h_i i_1 + h_r v_2 \;] \to \text{Voltage}$$

$h_i i_1$ → resistance × current

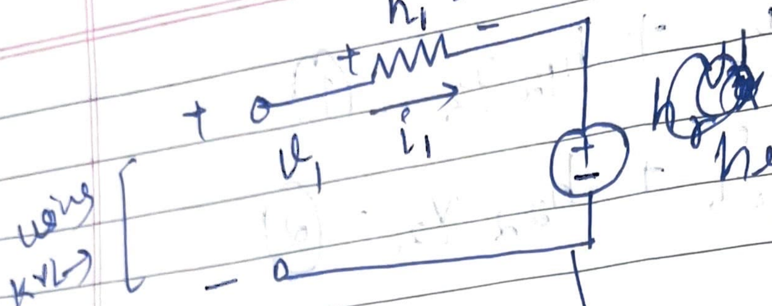
h_i → Ω, i_1 → V

h_r → Dimension less

Use ~~Acc~~ to KVL, for eq - (3)

v_1 = dct I/P voltage.

h_i = Resistance



$h_r v_2 \rightarrow$ Voltage Source

$$+v_1 - h_i i_1 - h_r v_2 = 0$$

$$v_1 = h_i i_1 + h_r v_2 \quad - (3)$$

same

Voltage controlled vtg source because in 2-port ntwk O/P vtg is V_2

Now eq (4)

$$i_2 = \underbrace{h_f}_{} i_1 + h_o v_2$$

Current ~~Ampere~~ form, current form.

h_f → Forward current ratio → Dimensionless

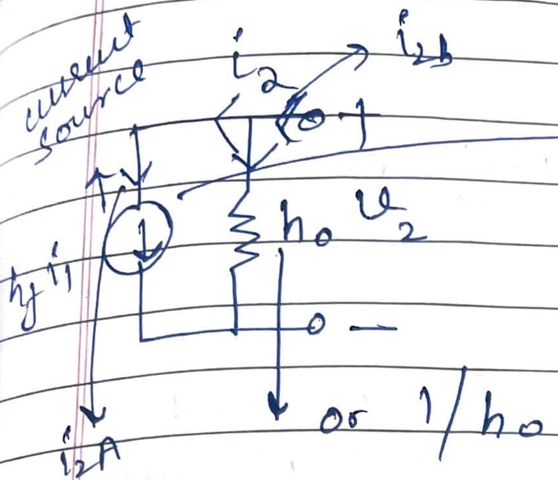
h_o → Admittance (Reciprocal of Resistance or Impedence)

$$i = \frac{V}{R}$$

$$= \frac{V}{1/R} \rightarrow \text{ulta}$$

$$i = VR = v_2 h_o$$

Use KCL for eq 4,



current controlled current source.

$$i_2 = i_{2a} + i_{2b}$$

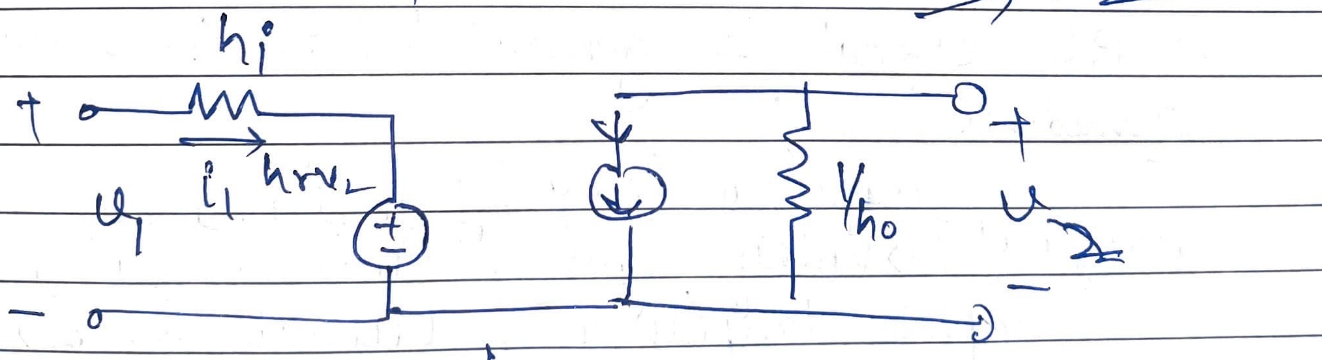
h_o = Admit

$$= h_f i_1 + \frac{v_2}{1/h_o}$$

$1/h_o \rightarrow$ o/p impedence.

$$\underline{i_2 = h_f i_1 + h_o v_2}$$

Now, Equivalent Model. $\rightarrow$ π-model

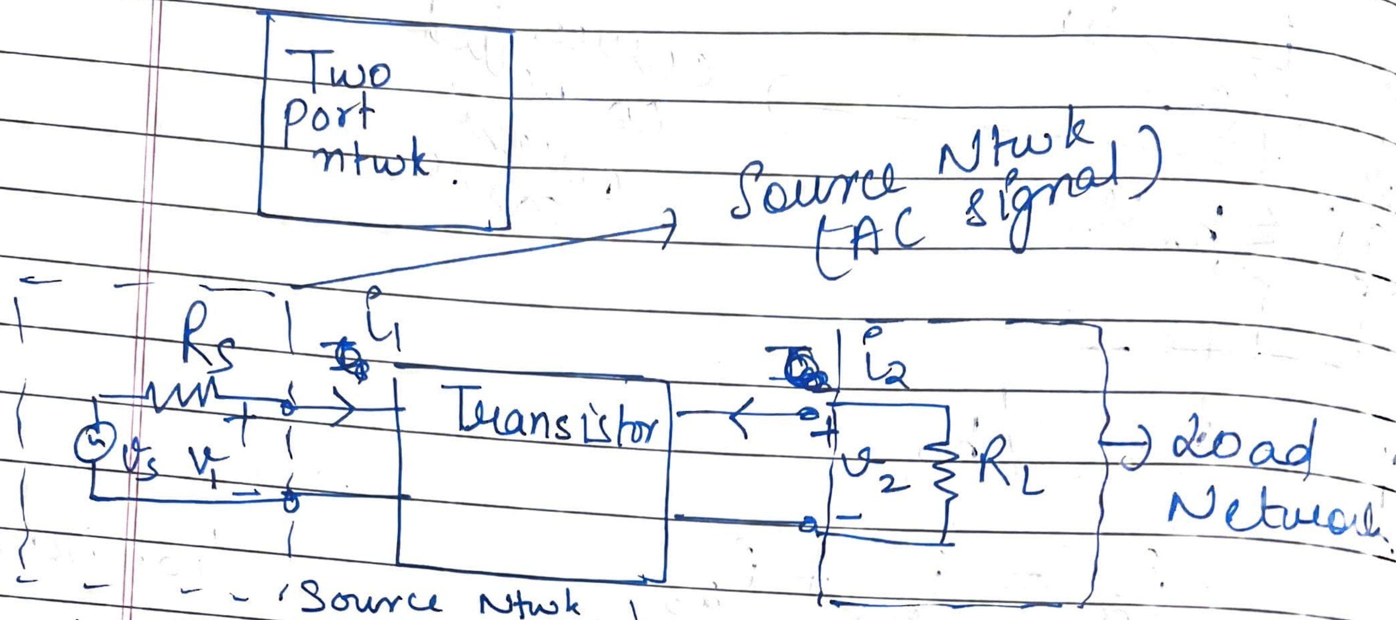


Join

Generalised model for all config.

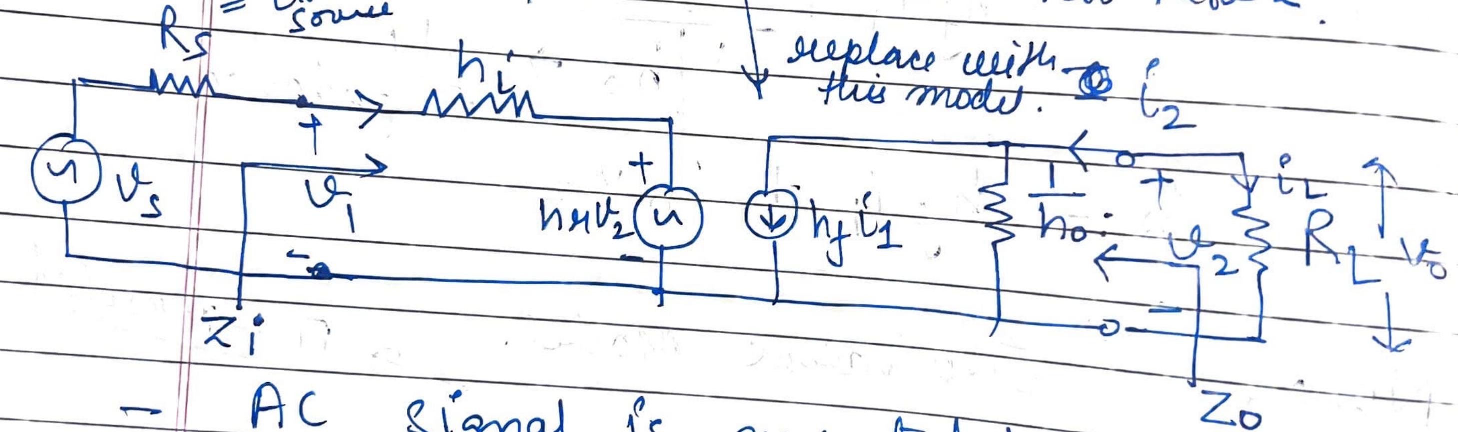
Current source dependent on i_1
& Vtg " dep on v_2
→ Replace transi by h-model.

Small Signal Amplifier using h - Parameter



1. Transformer is also 2 - Port Ntwk.

= Ext Source



- AC signal is generated from Generator, transducer
For Transistor (Amplifier) find Parameter.
- Analysis of 1 → Voltage gain, Current gain, Input Impedence, Output Impedence

(1) Voltage Gain
(2) Current gain
(3) Input Impedence
(4) Output ,,

→ Indep v.

$$\left[\begin{array}{l} v_1 = h_i i_1 + h_r v_2 \quad -(1) \\ i_2 = h_f i_1 + h_o v_2 \quad -(2) \end{array}\right] \text{Already found.}$$

Dependent variable

∴ h-parameters are provided by manufacturers. h_i, h_r, h_f & h_o ⇒ Non-Parameters

→ we have to find

$i_1 = ?$, $v_2 = ?$, $i_1 = ?$, $i_2 = ?$ v_1, i_1, v_2, i_2

⇒ Unknown Parameters.

(1) Voltage Gain

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

$$v_2 = v_o = i_L R_L \quad \text{(From circuit)}$$

$$= -i_2 R_L$$

direction of i_L is opp to i_2

$$v_2 = -i_2 R_L$$

$$\boxed{i_2 = -\frac{v_2}{R_L}}$$

Put value of i_2 in eq (2)

$$-\frac{v_2}{R_L} = h_f i_1 + h_o v_2$$

$$-\frac{v_2}{R_L} - h_o v_2 = h_f i_1$$

$$-v_2\left[\frac{1}{R_L}+h_o\right] = h_f i_1$$

$$i_1 = \frac{-v_2}{h_f}\left[h_o+\frac{1}{R_L}\right]$$

Put in eq (1)

$$v_1 = h_i\left[\frac{-v_2}{h_f}\left(h_o+\frac{1}{R_L}\right)\right] + h_r v_2 \quad -(2)$$

We have to find out $\frac{v_2}{v_1}$

$$= \frac{-v_2 h_i}{h_f}\left(\frac{h_o R_L+1}{R_L}\right) + h_r v_2$$

$$= -v_2\left[\frac{h_i(h_o R_L+1)}{h_f R_L} + h_r\right]$$

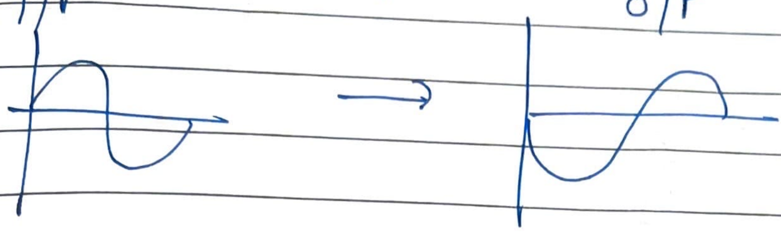
$$v_1 = -v_2\left[\frac{h_i(1+h_o R_L)+h_r h_f R_L}{h_f R_L}\right]$$

$$\boxed{\text{Voltage gain } A_v = \frac{v_2}{v_1} = \frac{-h_f R_L}{h_i(1+h_o R_L)+h_r h_f R_L}}$$

This is called Exact Analysis

Negative sign indicate that o/P vtg is out of phase by 180°

If I/P o/P



Interest should be in eq (1)

(2) Current Gain

$$A_i = \frac{i_L \rightarrow \text{output current}}{i_1 \rightarrow \text{I/P current}} = \frac{-i_2}{i_1}$$

In eq (2)

v_2 = Unknown

we know $\Rightarrow v_0 = i_L R_L$

$$\Rightarrow v_2 = v_0 = i_L R_L \Rightarrow -i_2 R_L$$

$$v_2 = -i_2 R_L \quad — (1)$$

Put value in eq (2)

$$i_2 = h_f i_1 + h_o v_2$$

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

$$i_2 = h_f i_1 - h_o i_2 R_L$$

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

$$A_i = \frac{i_2}{i_1} = \frac{h_f}{(1 + h_o R_L)}$$

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

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

for C-E conf

$$A_i = \frac{-h_{fe}}{(1 + h_o R_L)}$$ e suffix

③ Input Impedence

Z_i = Internal Input Impedence.

Z_i or R_i is same for low frequency

$$R_i = Z_i = \frac{v_1}{i_1}$$ ⇒ Unconditional

From $v_1 = h_i i_1 + h_r v_2$ — ①

$i_2 = h_f i_1 + h_o v_2$ — ②

$\Rightarrow v_2 = v_o = i_L R_L$

$$v_2 = -i_2 R_L$$

$$i_2 = -\frac{v_2}{R_L}$$

Put value of i_2 in eq (2)

$$-\frac{v_2}{R_L} = h_f i_1 + h_o v_2$$

$$-v_2\left(\frac{1}{R_L} + h_o\right) = h_f i_1$$

$$-v_2\left(\frac{1 + h_o R_L}{R_L}\right) = h_f i_1$$

$$v_2 = \frac{-h_f i_1}{\left(\frac{1 + h_o R_L}{R_L}\right)}$$

$$v_2 = -\frac{h_f i_1 R_L}{1 + h_o R_L}$$

Put value of v_2 in eq (1)

$$v_1 = h_i i_1 + h_r\left(\frac{-h_f i_1 R_L}{1 + h_o R_L}\right)$$

$$= i_1\left(h_i - \frac{h_f h_r R_L}{1 + h_o R_L}\right)$$

Input Impedence

$$\boxed{Z_i = \frac{v_1}{i_1} = h_i - \frac{h_f h_r R_L}{1 + h_o R_L}}$$

Z_i depend on R_L

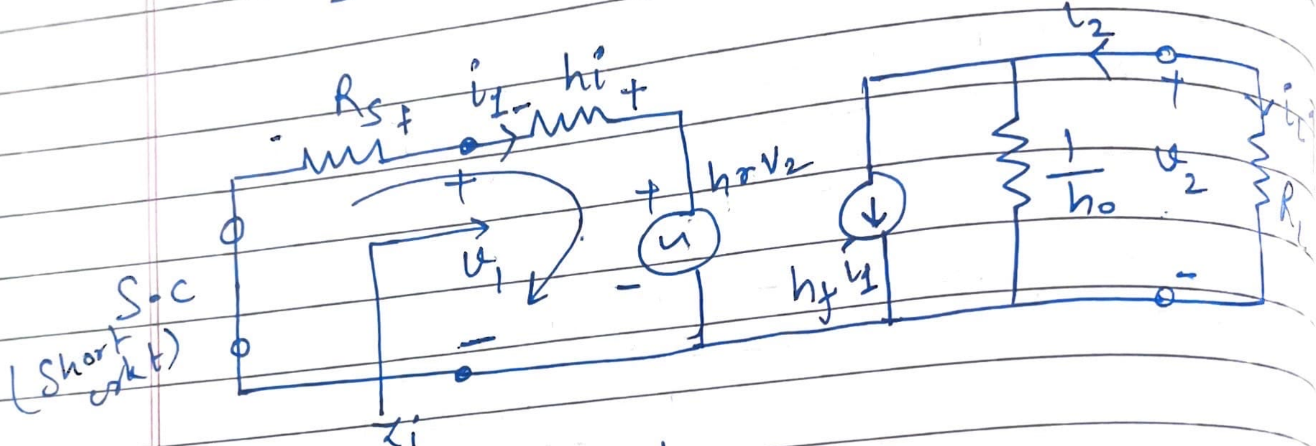
For C-E, suffix e

(4) Output Impedence

$Z_o = ?$

Independent Source will be reduced to zero.

v_s = Independent Source = 0 = Short Circuit



$$Z_o = \frac{v_2}{i_2} \Bigg| \text{ when } v_s = 0$$

We know that →

$$v_1 = h_i i_1 + h_r v_2 \quad —(1)$$

$$i_2 = h_f i_1 + h_o v_2 \quad —(2)$$

find out

Apply KVL to I/P section,

$$0 + i_1 R_s + i_1 h_i + h_r v_2 = 0$$

$$i_1 (h_i + R_s) = -h_r v_2$$

$$i_1 = \frac{-h_r v_2}{h_i + R_s}$$

Put value of i_1 in eq ②

$$i_2 = h_f \left(\frac{-h_r v_2}{h_i + R_s} \right) + h_o v_2$$

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

$$\Rightarrow$$

$$Y_o = \frac{i_2}{v_2} = \left[h_o - \frac{h_r h_f}{h_i + R_s} \right]$$

output Impedance $Z_o = \frac{v_2}{i_2} = \frac{1}{h_o - \frac{h_r h_f}{h_i + R_s}}$

for C-E conf,

$$Z_o = \frac{1}{h_{oe} - \frac{h_{re} h_{fe}}{h_i + R_s}}$$

$\Rightarrow$ Exact Values $\Rightarrow$ Exact Analysis of Small signal transistor