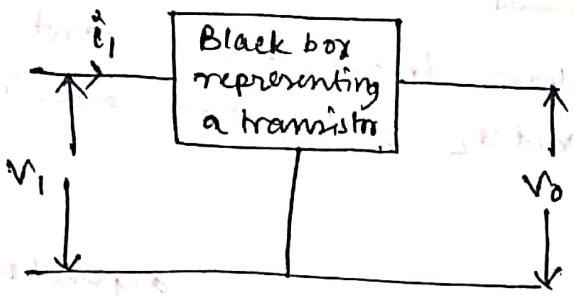
Two port analysis of a transistor.

Transistor — two port or four terminal network
↳ two voltages + two currents



i_1, v_o — independent variable

v_1, i_o — dependent variable.

$v_I = f_1(i_1, v_o)$ — ①

$i_o = f_2(i_1, v_o)$ — ②

i_I, i_o, v_I, v_o represent total instantaneous values consisting of d.c and a.c parts.

Let $i_I = I_I + i_i$ capitals — dc part.

$i_o = I_o + i_o$.   small — a.c part.

$v_I = V_I + v_i$ Assume a.c part << d.c part.

$v_o = V_o + v_o$.

Taylor's series expansion of ① and ②. about the dc operating point and neglecting higher order terms.

$$v_i = \left.\frac{\partial v_I}{\partial i_I}\right|_{v_o} \cdot i_i + \left.\frac{\partial v_I}{\partial v_o}\right|_{i_I} \cdot v_o.$$

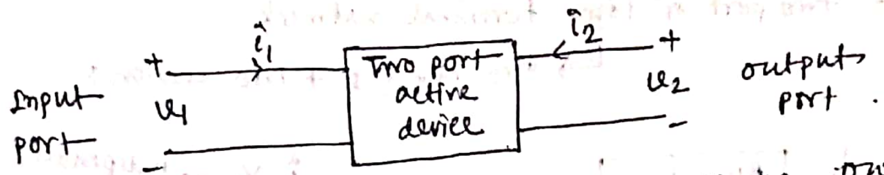
$$i_o = \left.\frac{\partial i_o}{\partial i_I}\right|_{v_o} \cdot i_i + \left.\frac{\partial i_o}{\partial v_o}\right|_{i_I} \cdot v_o.$$

As the transistor is assumed to behave linearly over the small region of operation, the partial derivatives becomes const.

$$v_i = h_i i_i + h_r v_o.$$

$$i_o = h_f i_i + h_o v_o.$$

Two port devices and different models of a transistor -



A two port network is shown in the figure. out of the four quantities i_1, v_1, i_2 and v_2, any two are independent while two are dependent.

	Independent		dependent
1.	i_1, v_1 . i_2, v_2	(not possible)	i_2, v_2 i_1, v_1 .
2.	i_1, v_2 i_2 v_1	(h-parameter)	i_2, v_1 i_1, v_2
3.	v_1, v_2 i_1, i_2	(Y- parameter) (Z parameter)	i_1, i_2 v_1, v_2 .

The table gives the lists of all possibilities of dependent and independent variables.

1. This possibility is practically not possible. As both i_1, v_1 and i_2, v_2 cannot be independent. (i_1, v_1) and (i_2, v_2) are interrelated. according to ohm's law.

Network modelling

1. Z (impedance) parameter model.
2. Y (admittance) " "
3. h (hybrid) " "

1. Z parameter model. (i_1, i_2 independent)

we assume that the device is linear.

$$v_1 = Z_{11} i_1 + Z_{12} i_2$$

$$v_2 = Z_{21} i_1 + Z_{22} i_2$$

$$\begin{pmatrix} v_1 \\ v_2 \end{pmatrix} = \begin{pmatrix} Z_{11} & Z_{12} \\ Z_{21} & Z_{22} \end{pmatrix} \begin{pmatrix} i_1 \\ i_2 \end{pmatrix} \equiv V = ZI.$$

$$Z_{11} = \left.\frac{v_1}{i_1}\right|_{i_2 = 0}.$$ Input impedance when output is open

$$Z_{12} = \left.\frac{v_1}{i_2}\right|_{i_1 = 0}$$ Reverse transfer impedance when input is open

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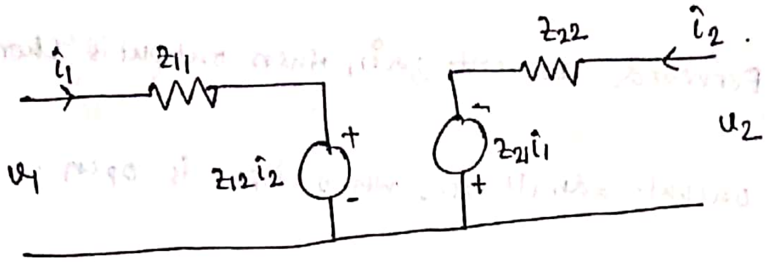
$Z_{21} = \left.\frac{v_2}{i_1}\right|_{i_2=0}$ Forward transfer impedance when output is open

$Z_{22} = \left.\frac{v_2}{i_2}\right|_{i_1=0}$ output impedance when input is open.



Equivalent circuit.

2. Y parameter model. (v_1, v_2 independent)

$$i_1 = Y_{11} v_1 + Y_{12} v_2$$

$$i_2 = Y_{21} v_1 + Y_{22} v_2,$$

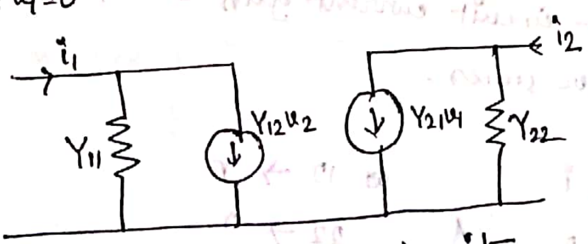
$$\begin{pmatrix} i_1 \\ i_2 \end{pmatrix} = \begin{pmatrix} Y_{11} & Y_{12} \\ Y_{21} & Y_{22} \end{pmatrix} \begin{pmatrix} v_1 \\ v_2 \end{pmatrix} \equiv I = Y.V.$$

$Y_{11} = \left.\frac{i_1}{v_1}\right|_{v_2=0}$ Input admittance when output is short circuited.

$Y_{12} = \left.\frac{i_1}{v_2}\right|_{v_1=0}$ Reverse transfer admittance when input is short circuited

$Y_{21} = \left.\frac{i_2}{v_1}\right|_{v_2=0}$ Forward transfer admittance when output is short circuited

$Y_{22} = \left.\frac{i_2}{v_2}\right|_{v_1=0}$ output admittance when input's short circuited.



Equivalent circuit.

3. h - (hybrid) parameter model. (v_1, i_2 independent; i_1, v_2 dependent).

$$v_1 = h_{11} i_1 + h_{12} v_2$$

$$i_2 = h_{21} i_1 + h_{22} v_2$$

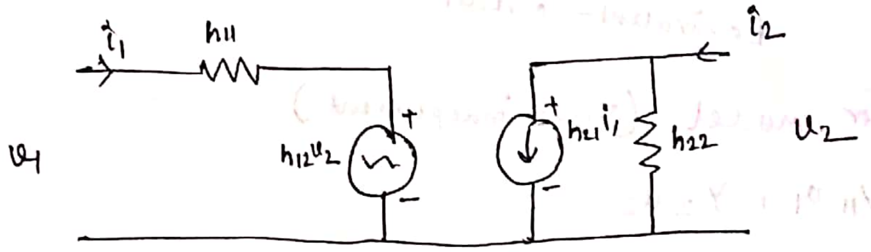
$$\begin{pmatrix} v_1 \\ i_2 \end{pmatrix} = \begin{pmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{pmatrix} \begin{pmatrix} i_1 \\ i_2 \end{pmatrix}$$

$h_{11} = \left.\frac{v_1}{i_1}\right|_{v_2=0}$ Input impedance when output is short circuited

$h_{12} = \left.\frac{v_1}{v_2}\right|_{i_1=0}$ Reverse voltage gain when input is open

$h_{21} = \left.\frac{i_2}{i_1}\right|_{v_2=0}$ Forward current gain when output is short circuited

$h_{22} = \left.\frac{i_2}{v_2}\right|_{i_1=0}$ output admittance when input is open.



Equivalent circuit.

This model is called hybrid parameter model because the coefficients (h's) have different dimensions.

Advantages of h-parameter model

1. h-parameters are easy to measure. They can also be easily determined from the transistor static characteristic curves.
2. h-parameters are real numbers at audio frequencies.
3. Manufacturers usually supply these parameters.
4. h_{fe} represents short circuit current gain. — important quantity in transistor amplifier stages.

Symbols.

11 → i 12 → r.
21 → f 22 → o

For CE configuration, suffix e is used — h_{ie}, h_{re}, h_{fe}, h_{oe}
For CB and CC, b and c suffix ~~used~~ are used

Are hybrid parameters constant?
value of h parameter depend on the characteristic curve
i) position of Q point on the transistor.
ii) temperature of the