Transistor Hybrid Model

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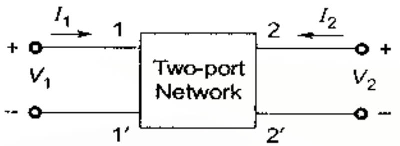
Introduction

The h-parameter model of BJT is defined by two-port network as



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

Input impedance h_{11}/h_i

$$h_{11} = \left.\frac{V_1}{I_1}\right|_{V_2=0}$$

Current gain h_{21}/h_f

$$h_{21} = \left.\frac{I_2}{I_1}\right|_{V_2=0}$$

Reverse voltage gain h_{12}/h_r

$$h_{12} = \left.\frac{V_1}{V_2}\right|_{I_1=0}$$

Output Admittance h_{22}/h_o

$$h_{22} = \left.\frac{I_2}{V_2}\right|_{I_1=0}$$

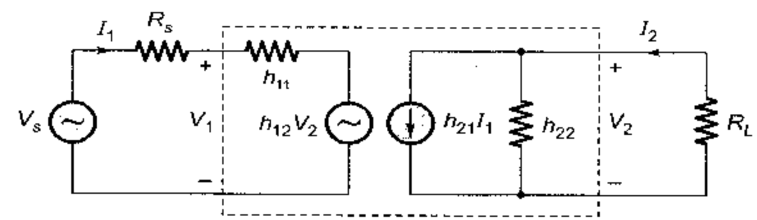
Typical h-paramter Values for Transistors

Parameters	*CE*	*CC*	*CB*
$h_{11} = h_i$	1.1 kΩ	1.1 kΩ	21.6 Ω
$h_{12} = h_r$	2.5×10^{-4}	; 1	2.9×10^{-4}
$h_{21} = h_f$	50	–51	–0.98
$h_{22} = h_o$	24 μA/V	24 μA/V	0.49 μA/V
$1/h_o$	40 kΩ	40 kΩ	2.04 MΩ

Approximated Conversion Formulaes for h-paramters

CE to *CC*	*CE* to *CB*
$h_{ic} = h_{ie}$	$h_{ib} = \frac{h_{ie}}{1 + h_{fe}}$
$h_{rc} = 1$	$h_{rb} = \frac{h_{ie} h_{oe}}{1 + h_{fe}} - h_{re}$
$h_{fc} = -(1 + h_{fe})$	$h_{fb} = \frac{-h_{fe}}{1 + h_{fe}}$
$h_{oc} = h_{oe}$	$h_{ob} = \frac{h_{oe}}{1 + h_{fe}}$

Hybrid Model



Current gain

$$A_I = \frac{I_2}{I_1} = \frac{-h_{21}}{1 + h_{22} R_L} = \frac{-h_f}{1 + h_o R_L}$$

where, I_1 = AC input current

I_2 = AC output current

Voltage gain

$$A_V = \frac{V_2}{V_1}$$

where, V_1 = AC input voltage

V_2 = AC output voltage

$$A_V = \frac{-h_{21} R_L}{h_{11} + (h_{11} h_{22} - h_{12} h_{21}) R_L} = \frac{-h_f R_L}{h_i + (h_i h_o - h_f h_r) R_L}$$

Input impedance

$$Z_{in} = \frac{V_1}{I_1} = h_{11} - \frac{h_{12} h_{21} R_L}{1 + h_{22} R_L} = h_i - \frac{h_f h_r R_L}{1 + h_o R_L}$$

Output impedance

$$Z_{out} = \frac{V_2}{I_2} = \frac{R_s + h_{11}}{(R_s + h_{11})h_{22} - h_{12}h_{21}} = \frac{R_s + h_i}{(R_s + h_i)h_o - h_r h_f}$$

$$Y_{out} = h_o - \frac{h_r h_f}{h_i + R_s}$$

Multistage Amplifier

- Upper cutoff frequency of overall configuration is

$$f_H^* = f_H\sqrt{2^{1/n} - 1}$$ (For identical amplifiers in cascade)

where, n = number of amplifiers in cascade

f_H = upper cutoff frequency of one amplifier

- Lower cutoff frequency of overall configuration

$$f_l^* = \frac{f_l}{\sqrt{2^{1/n} - 1}}$$ where, n = number of identical amplifiers in cascade

Approximate BW of amplifier in cascade is f_H^*.

- When amplifiers are non-identical then

$$f_l^* = 1.1\sqrt{f_{l1}^2 + f_{l2}^2 + f_{l3}^2 + \ldots + f_{ln}^2}$$ and $$\frac{1}{f_H^*} = 1.1\sqrt{\frac{1}{f_{H1}^2} + \frac{1}{f_{H2}^2} + \ldots + \frac{1}{f_{Hn}^2}}$$

- Rise time $t_r^* = 1.1\sqrt{t_{r1}^2 + t_{r2}^2 + \ldots + t_{rn}^2}$

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