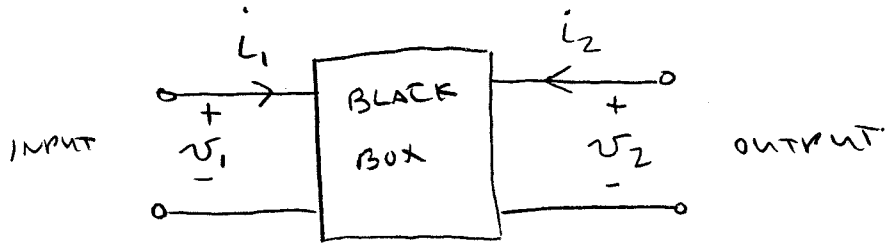
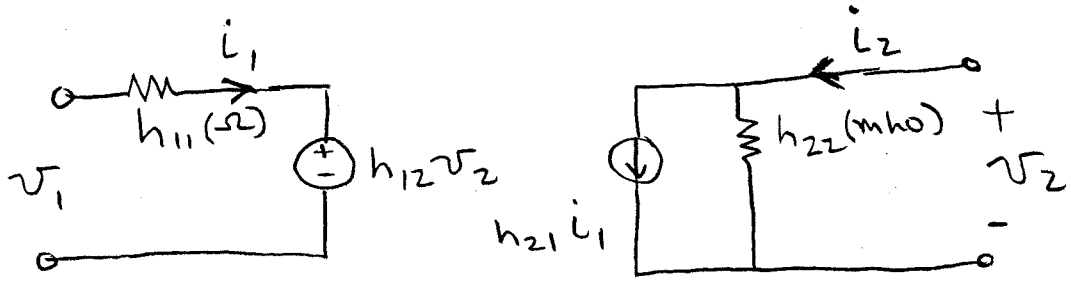
TWO-PORT HYBRID TRANSISTOR MODEL



HYBRID CIRCUIT MODEL



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

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

h parameters define transistor characteristics at one particular DC operating point

To find h parameters &

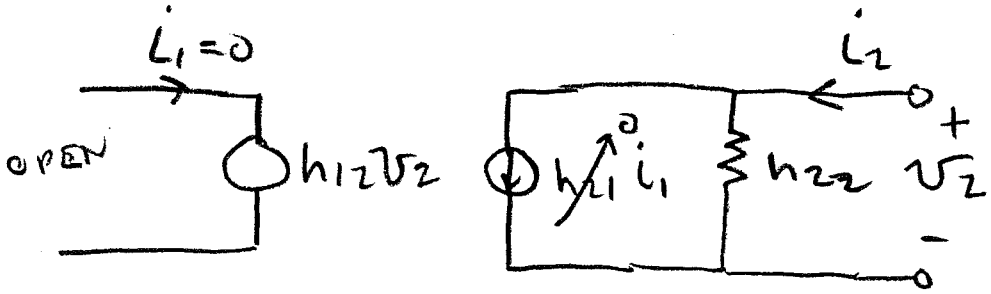
$$h_{11} = \left.\frac{v_1}{i_1}\right|_{v_2=0}$$ = input resistance with output short circuited

$$h_{12} = \left.\frac{v_1}{v_2}\right|_{i_1=0}$$ reverse voltage gain with the input open-circuited ($i_1=0$)

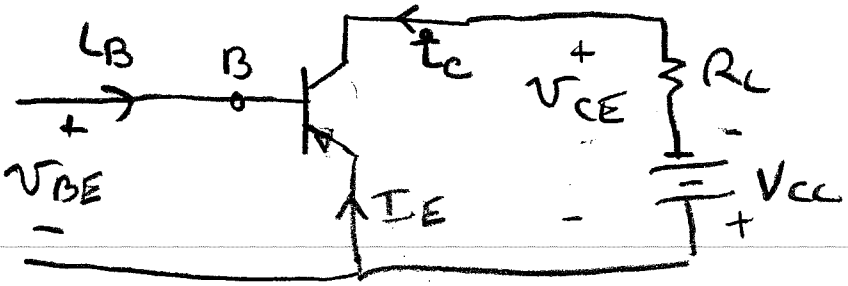
$$h_{21} = \left.\frac{i_2}{i_1}\right|_{v_2=0}$$ negative of forward current gain with output short circuited

$i_2 = h_{21} i_1$ — $\frac{i_2}{i_1} = h_{21}$ ✓

$$h_{22} = \left.\frac{i_2}{v_2}\right|_{i_1=0}$$ OUTPUT CONDUCTANCE WITH OPEN-CIRCUIT INPUT



COMMON-EMITTER TRANSISTOR



v_{BE} is a function of i_B and v_{BE}

i_C is a Function of i_B and v_{CE}

we can write

$$v_{BE} = h_{ie} i_B + h_{re} v_{CE}$$

and

$$i_C = h_{fe} i_B + h_{oe} v_{CE}$$

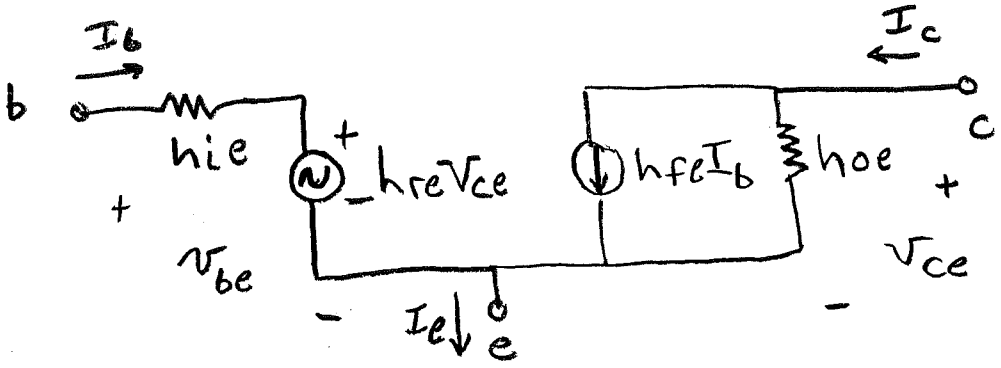
where

$$h_{ie} = \left.\frac{\partial v_{BE}}{\partial i_B}\right|_{V_{CE} = \text{constant}}$$ INPUT RESISTANCE (ohms)

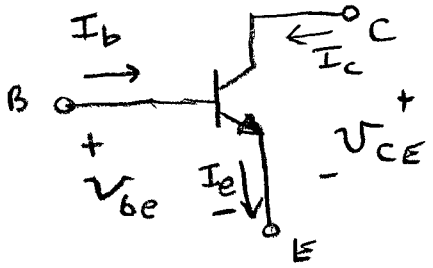
$$h_{re} = \left.\frac{\partial v_{BE}}{\partial v_{CE}}\right|_{i_B = \text{constant}}$$ REVERSE TRANSFER VOLTAGE RATIO (UNITLESS)

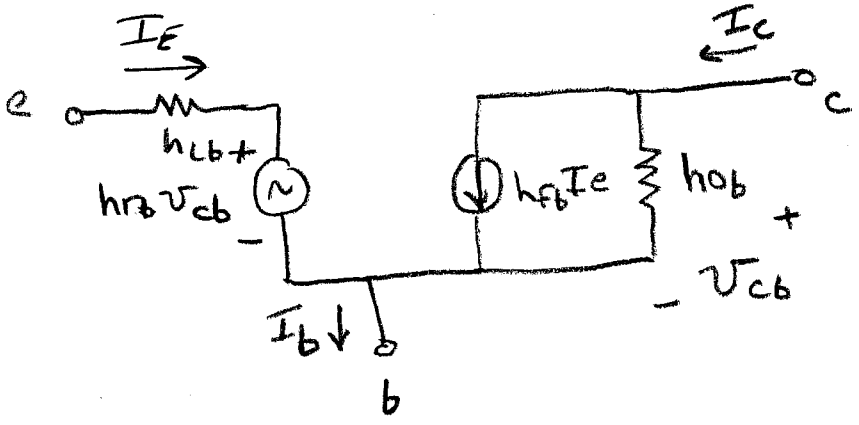
$$h_{fe} = \left.\frac{\partial i_C}{\partial i_B}\right|_{V_{CE} = \text{CONSTANT}}$$ FORWARD TRANSFER CURRENT RATIO (unitless)

$$h_{oe} = \left.\frac{\partial i_C}{\partial v_{CE}}\right|_{i_B = \text{constant}}$$ (SIEMENS) (OUTPUT conductance)

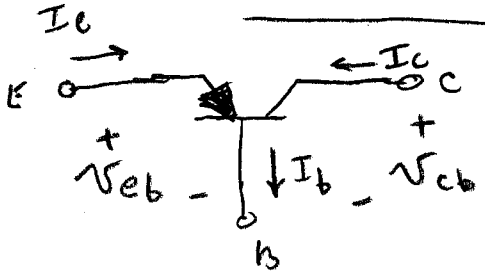


COMMON EMITTER HYBRID EQUIVALENT CIRCUIT



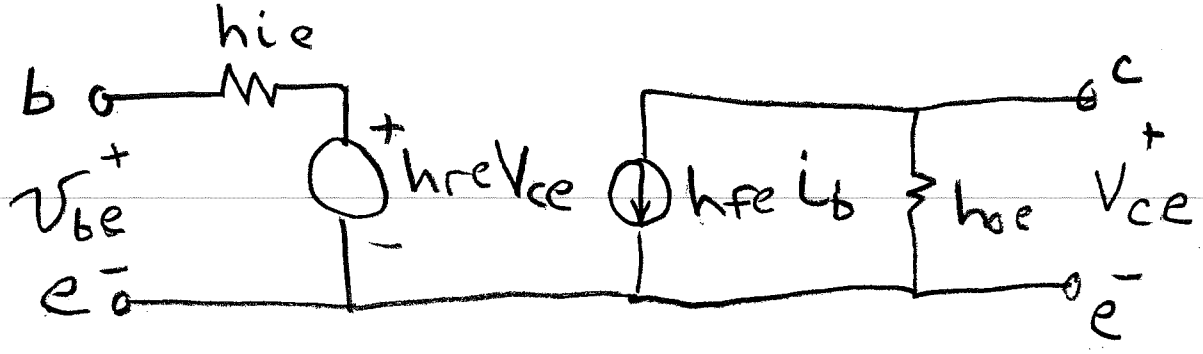


COMMON BASE CONFIGURATION



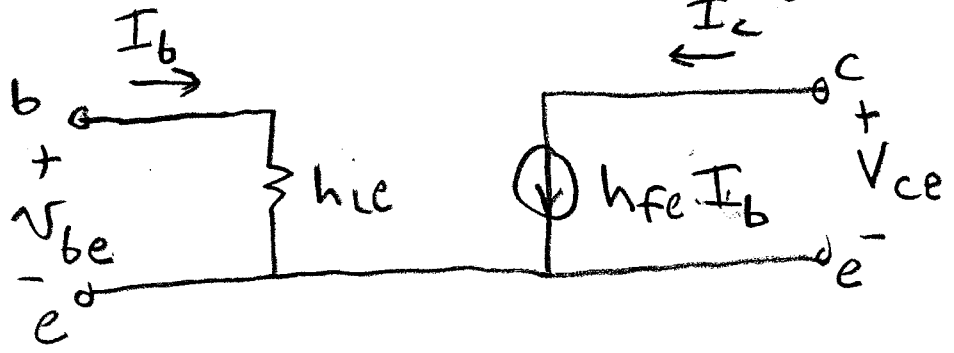
HYBRID VS re MODEL

(COMMON EMITTER)

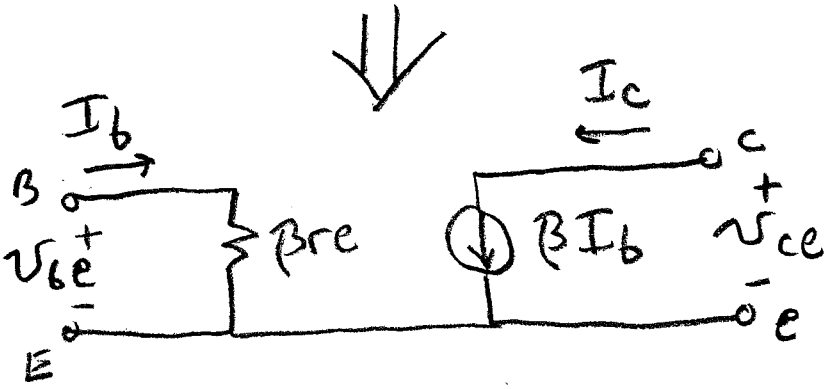


let h_{oe} be very large (OPEN)

" $h_{re}V_{ce}$ be very small (short)



APPROXIMATE HYBRID MODEL

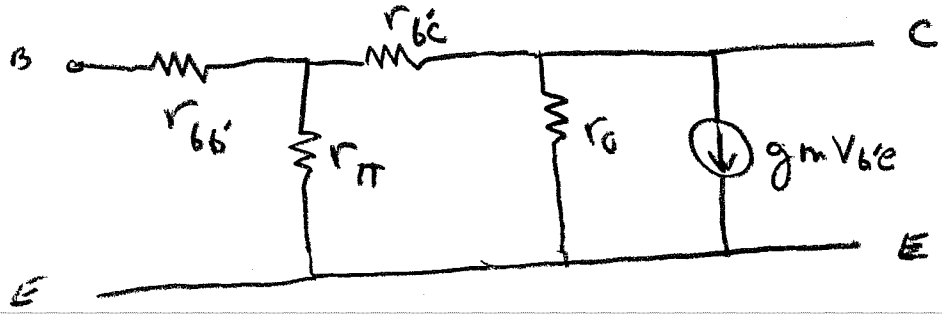


re MODEL

$h_{ie} = \beta re$

$h_{fe} = \beta ac$

Hybrid π MODEL



$$g_m = \frac{q|I_c|}{kT}$$

$$r_\pi = \frac{h_{fe}}{g_m}$$

$$r_{bb'} = h_{ie} - r_\pi$$

$$r_{b'c} = \frac{r_\pi}{h_{re}}$$

$$\frac{1}{r_o} = h_{oe} - \frac{1 + h_{fe}}{r_{b'c}} \cong h_{oe} - g_m h_{re}$$

Typical values (PNP) HYBRID

@ $I_c = -1mA$ $V_{CE} = -5V$

$T = 25°C$ $f = 1KHz$

$h_{ie} = 1800\Omega$ $h_{re} = 2 \times 10^{-4}$

$h_{fe} = 60$ $h_{oe} = 18\mu\mho$

hybrid π

$g_m = 0.038\ \mho$

$r_\pi = 1600\Omega$

$r_{bb'} = 200\Omega$

$r_{b'c} = 8M\Omega$

$r_o = 96{,}000\Omega$

$$h_{ie} = \frac{\partial v_i}{\partial i_i} = \frac{\partial v_{be}}{\partial i_b} \approx \frac{\Delta v_{be}}{\Delta i_b}\Bigg|_{V_{CE}\ \text{constant}} \quad (\text{OHMS})$$

$$h_{re} = \frac{\partial v_i}{\partial v_o} = \frac{\partial v_{be}}{\partial v_{ce}} \approx \frac{\Delta v_{be}}{\Delta v_{ce}}\Bigg|_{I_B = \text{constant}} \quad (\text{unitless})$$

$$h_{oe} = \frac{\partial i_o}{\partial v_o} = \frac{\partial i_c}{\partial v_{ce}} \approx \frac{\Delta i_c}{\Delta v_{ce}}\Bigg|_{I_B = \text{CONSTANT}} \quad (\text{SIEMENS})$$

$$h_{fe} = \frac{\partial i_o}{\partial i_i} = \frac{\partial i_c}{\partial i_b} \approx \frac{\Delta i_c}{\Delta i_b}\Bigg|_{V_{CE} = \text{CONSTANT}} \quad (\text{UNITLESS})$$

GRAPHICAL DETERMINATION OF PARAMETERS