TWO-PORT HYBRID TRANSISTOR MODEL

\[ i_1 \rightarrow \text{BLACK} \rightarrow i_2 \]
\[ \text{Box} \rightarrow \text{output} \]

\[ v_1 = h_{11}i_1 + h_{12}v_2 \]
\[ v_2 = \left( i_2 - h_{21}i_1 \right) \frac{v_2}{h_{22}} \]

\[ i_2 = v_2h_{21} + h_{22}i_1 \]

h parameters define transistor characteristics at one particular DC operating point.

To find h parameters &

\[ h_{ir} = \frac{v_1}{i_1} \bigg|_{v_2=0} = \text{input resistance with output short circuited} \]
\( h_{12} = \frac{\frac{V_1}{V_2}}{I_1} \mid I_1 = 0 \) \hspace{1cm} \text{reverse voltage gain with the input open-circuited (} I_1 = 0 \text{)}

\[ h_{21} = \frac{i_2}{i_1} \mid V_2 = 0 \] \hspace{1cm} \text{negative of Forward current gain with output short circuited}

\[ i_2 = h_{21} i_1 \]

\[ \frac{i_2}{i_1} = h_{21} \checkmark \]

\[ h_{22} = \frac{\frac{i_2}{V_2}}{I_1} \mid I_1 = 0 \] \hspace{1cm} \text{output conductance with open-circuit input}
Common-Emitter Transformer

$V_{BE}$ is a function of $I_B$ and $V_{BE}$

$I_C$ is a function of $I_B$ and $V_{CE}$

we can write

$V_{BE} = h_{fe} I_B + h_{fe} V_{CE}$

and

$I_C = h_{fe} I_B + h_{oe} V_{CE}$

where

$\frac{\partial V_{BE}}{\partial I_B} \bigg|_{V_{CE} = \text{constant}} = h_{ie}$

$\frac{\partial I_C}{\partial V_{CE}} \bigg|_{I_B = \text{constant}} = h_{oe}$

$\frac{\partial V_{BE}}{\partial V_{CE}} \bigg|_{I_B = \text{constant}} = h_{re}$
COMMON Emitter Hybrid Equivalent Circuit

Common Base Configuration
HYBRID VS Re MODEL
(COMMON Emitter)

Let $h_{ie}$ be very large (open)
$h_{re}V_{ce}$ be very small (short)

$\beta_{re} = \frac{I_c}{I_b}$

$\beta_{ac} = \frac{V_{ce}}{V_{be}}$
Hybrid Pi Model

\[ g_m = \frac{q_b}{I_c} \]

\[ r_\pi = \frac{hfe}{g_m} \]

\[ r_{6b'} = h_{lc} - r_\pi \]

\[ r_{6c'} = \frac{r_\pi}{h_{re}} \]

\[ \frac{1}{r_0} = h_{oc} - \frac{1 + hfe}{r_{6c}} \approx h_{re} - g_m h_{re} \]

Typical Values (PNP) Hybrid

@ \( I_c = -1 \text{mA} \), \( V_{CE} = -5 \text{V} \)

\( T = 25^\circ \text{C} \), \( f = 1 \text{KHz} \)

\( h_{fe} = 1800 \),  \( h_{fe} = 2 \times 10^{-4} \),  \( h_{oc} = 18 \mu \text{A} \)

hybrid Pi

\[ g_m = 0.038 \Omega \]

\[ r_\pi = 1600 \Omega \]

\[ r_{6b'} = 200 \Omega \]

\[ r_{6c'} = 8 \text{M} \Omega \]

\[ r_0 = 96,000 \Omega \]
\[
\begin{align*}
\beta_{ie} &= \frac{\partial V_e}{\partial I_i} = \frac{\partial V_{be}}{\partial I_b} = \frac{\Delta V_{be}}{\Delta I_b} \quad \left| V_{ce} \text{ constant} \right. \\
\beta_{rc} &= \frac{\partial V_i}{\partial V_o} = \frac{\partial V_{be}}{\partial V_{ce}} = \frac{\Delta V_{be}}{\Delta V_{ce}} \quad \left| I_b = \text{constant} \right. \\
\beta_{ce} &= \frac{\partial I_o}{\partial I_e} = \frac{\partial I_c}{\partial V_{ce}} = \frac{\Delta I_c}{\Delta V_{ce}} \quad \left| V_{ce} = \text{constant} \right. \\
\end{align*}
\]

GRAPHICAL DETERMINATION
OF PARAMETERS