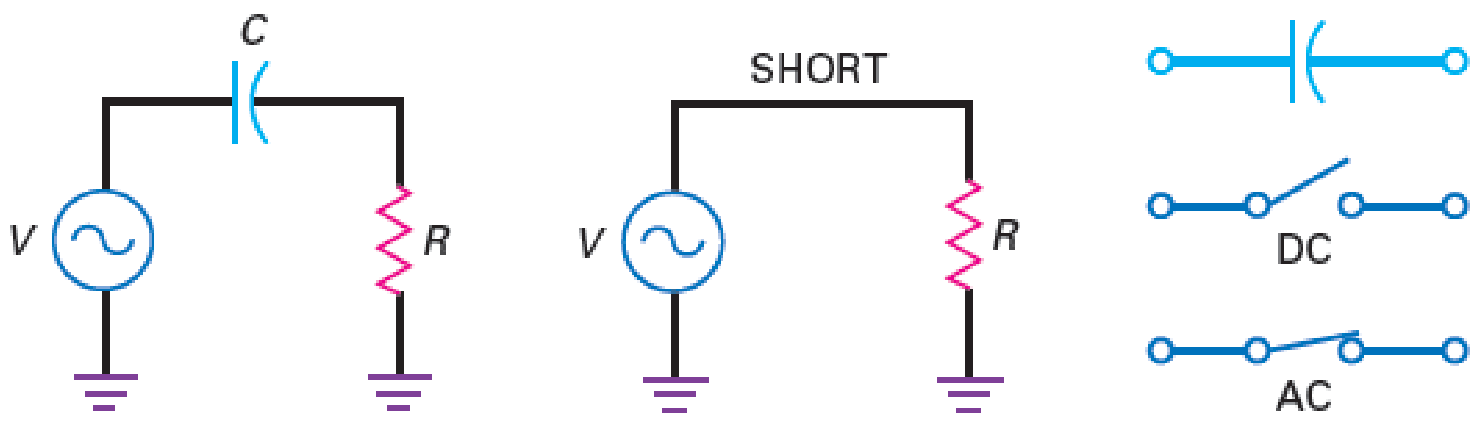
Bipolar Junction Transistor (BJT)

BJT as Amplifier

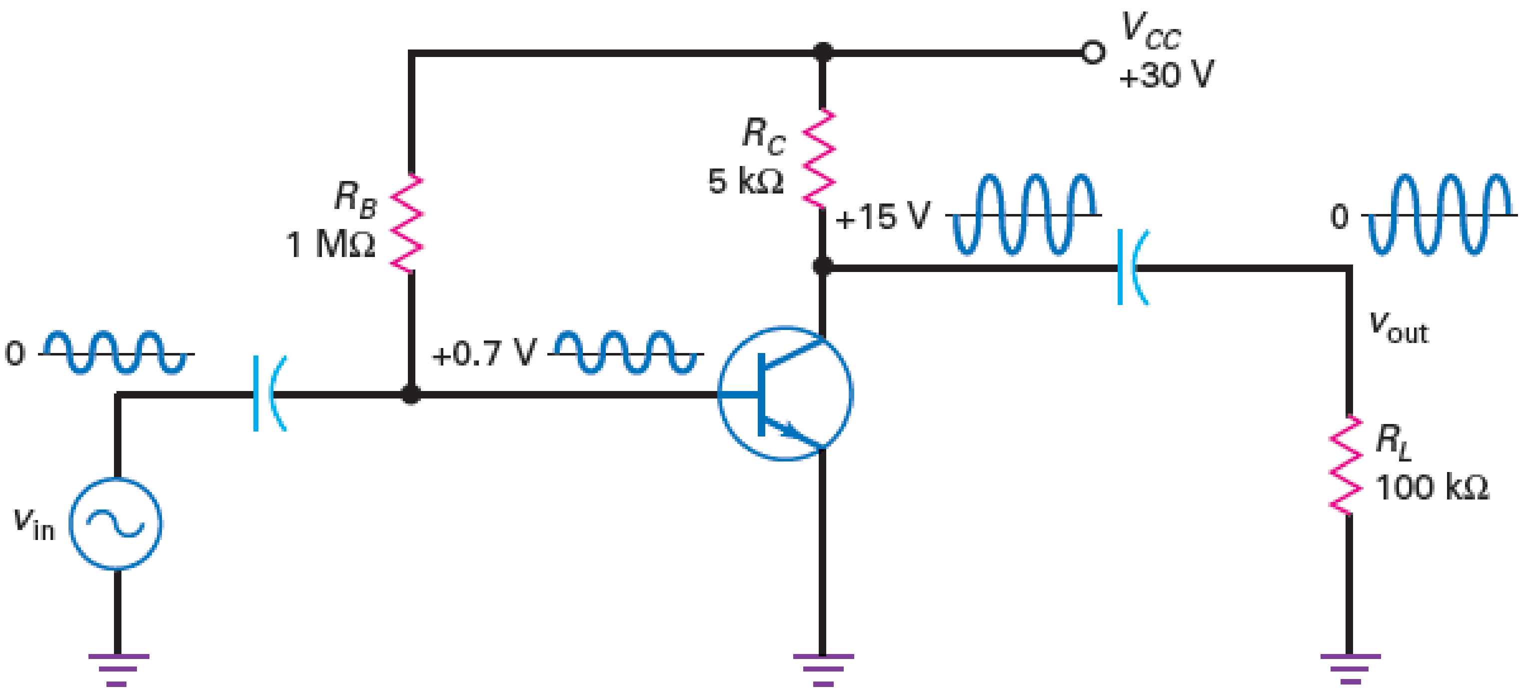
Coupling Capacitor



For a coupling capacitor to work properly, its reactance must be much smaller than the resistance at the *lowest frequency of the ac source.*

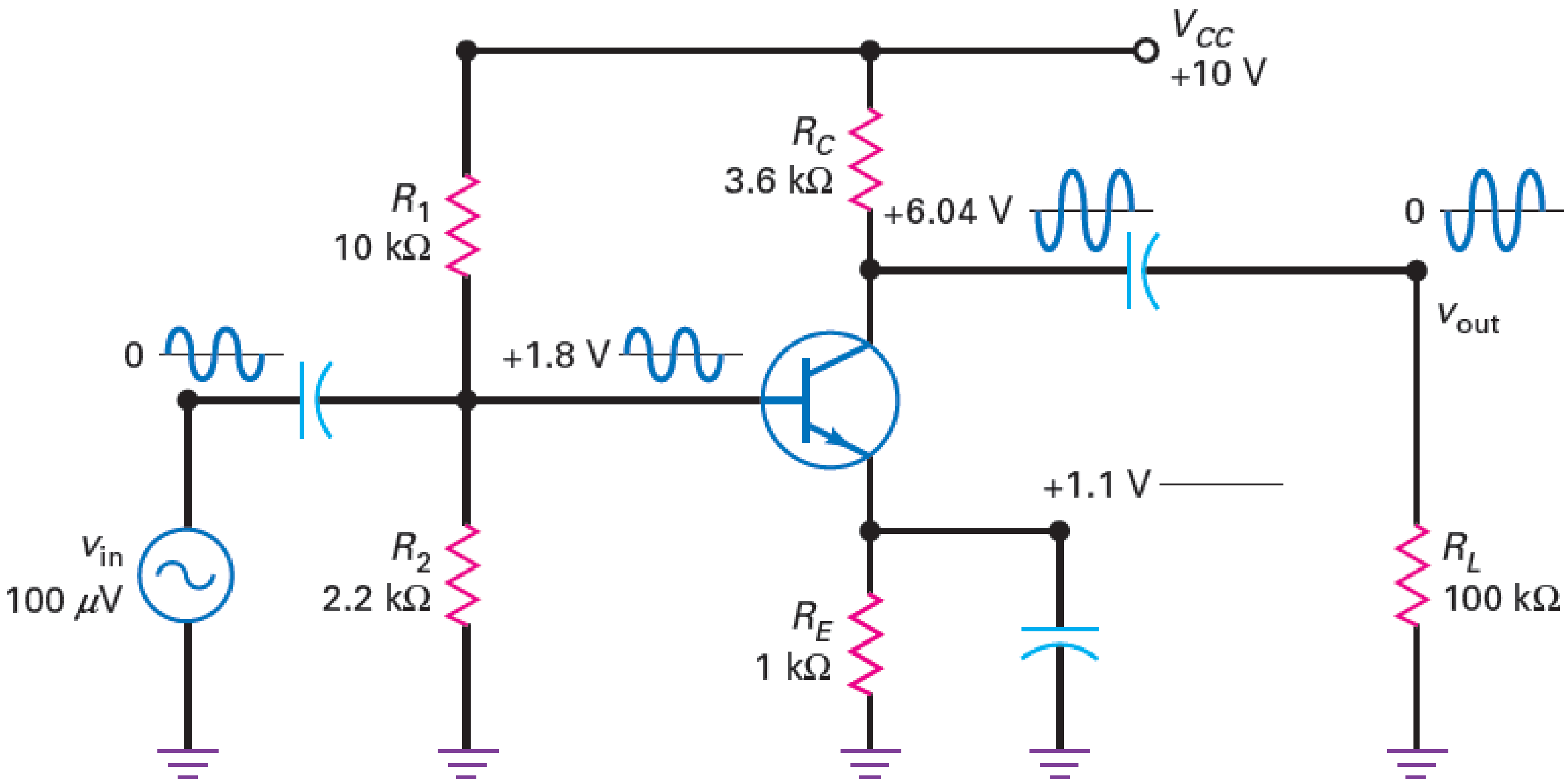
$$\text{Good coupling: } X_C < 0.1R$$

Base biased Amplifier circuit with waveform



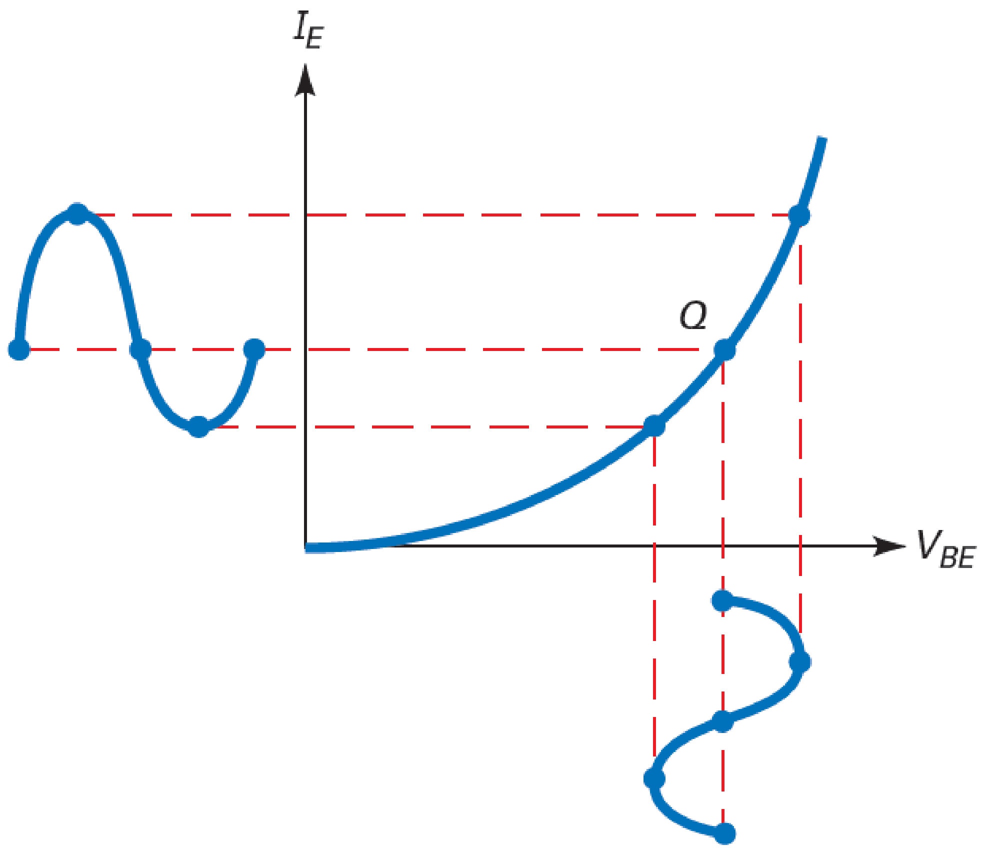
Voltage gain : $A_V = \frac{v_{out}}{v_{in}}$

VDB Amplifier circuit with waveform



Bypass Capacitor: A bypass capacitor is similar to a coupling capacitor because it appears open to direct current and shorted to alternating current. But it is not used to couple a signal between two points. Instead, it is used to create an ac ground.

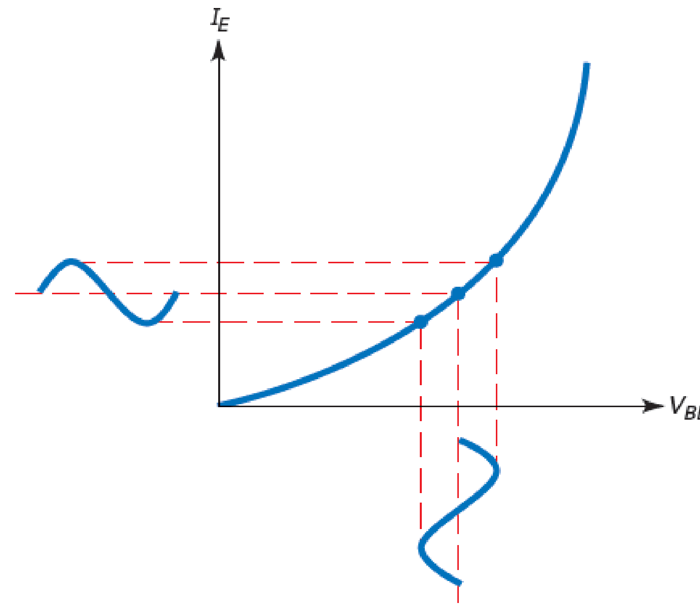
Small-Signal Operation



When an ac voltage is coupled into the base of a transistor, an ac voltage appears across the base-emitter diode. The ac emitter current is not a perfect replica of the ac base voltage because of the curvature of the graph.

Since the graph is curved upward, the positive half-cycle of the ac emitter current is elongated (stretched) and the negative half-cycle is compressed. This stretching and compressing of alternate half-cycles is called distortion. One way to reduce distortion in Fig. 8-10 is by keeping the ac base voltage small.

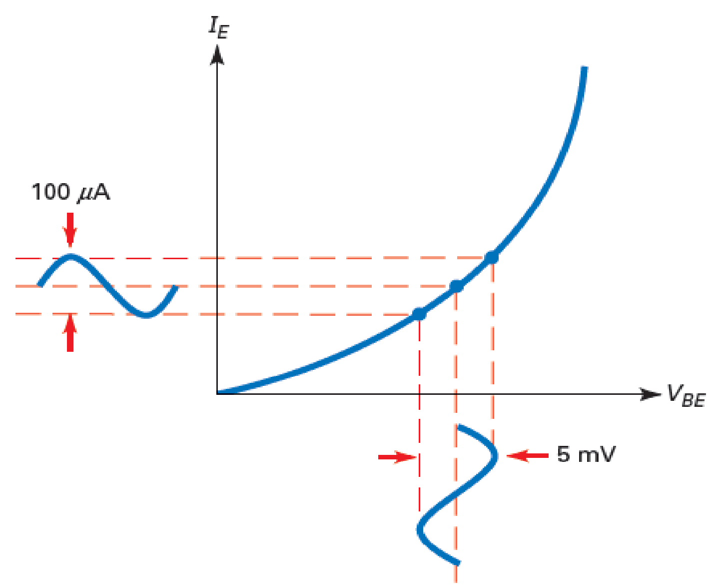
AC Beta: $\beta = \dfrac{i_c}{i_b}$



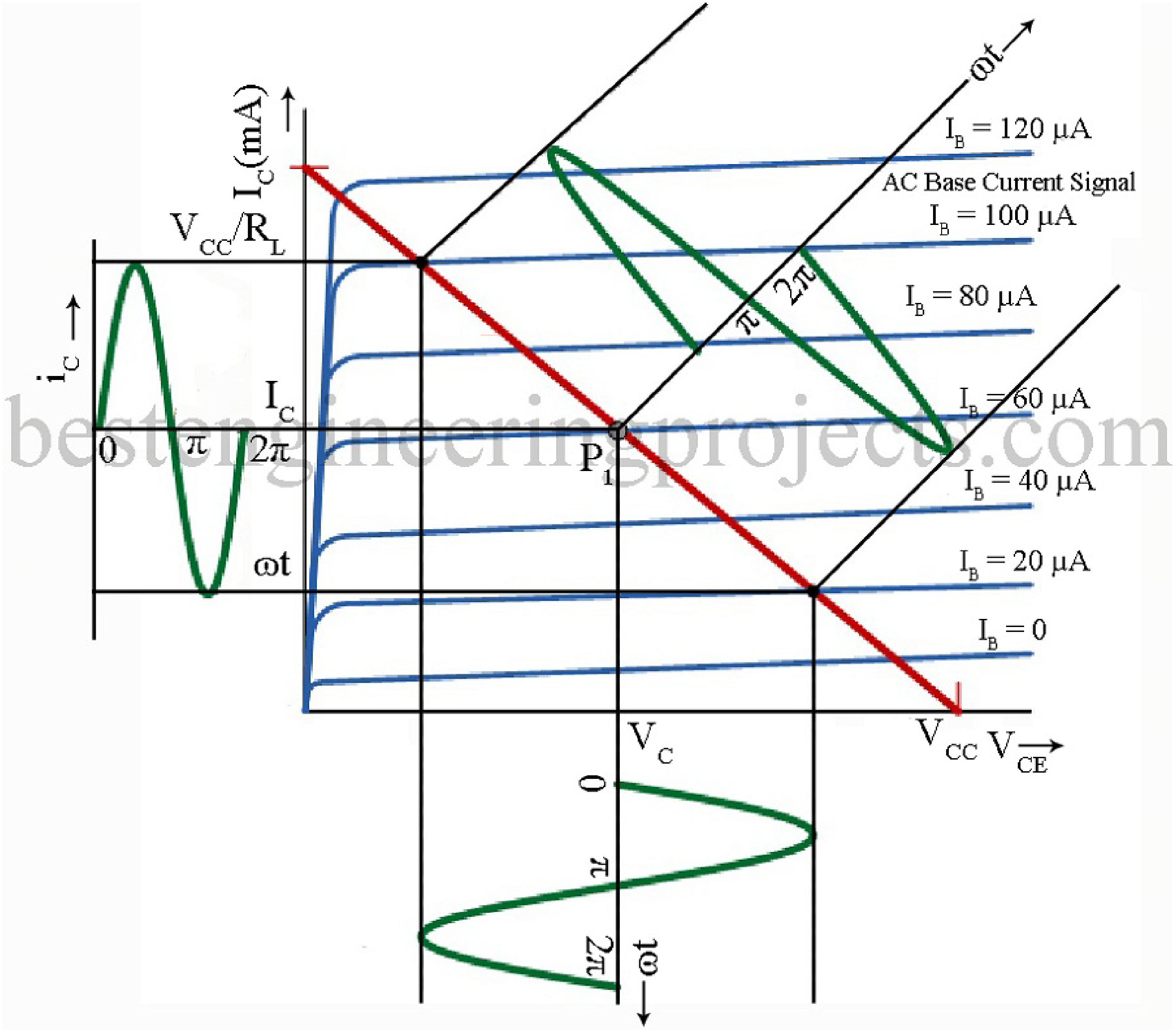
AC resistance of emitter diode: $r_e{}' = \dfrac{v_{be}}{i_e}$

Using solid-state physics and calculus, it is possible to derive the following remarkable formula for the ac emitter resistance:

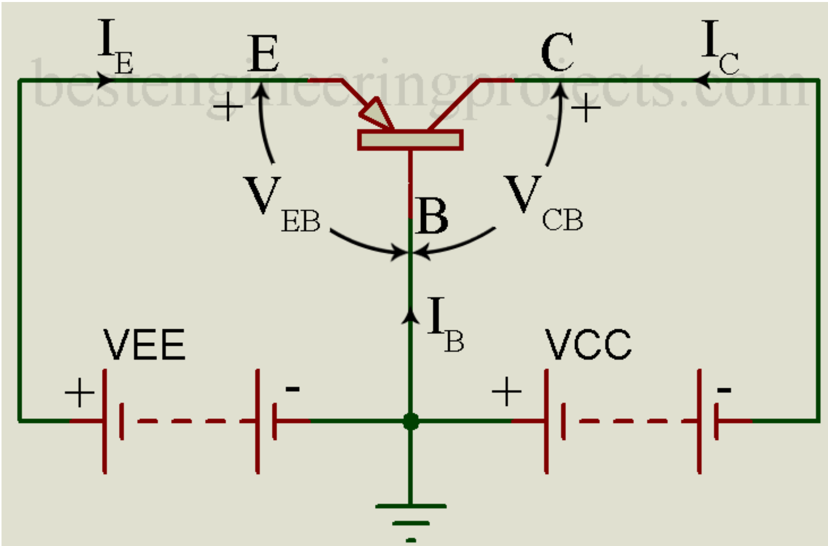
$$r_e' = \frac{25\ \text{mV}}{I_E}$$

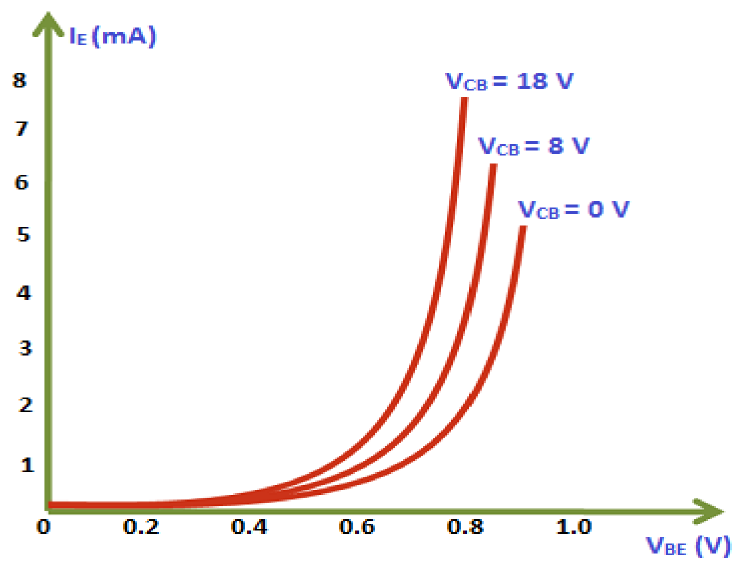


Graphical analysis of transistor amplifier

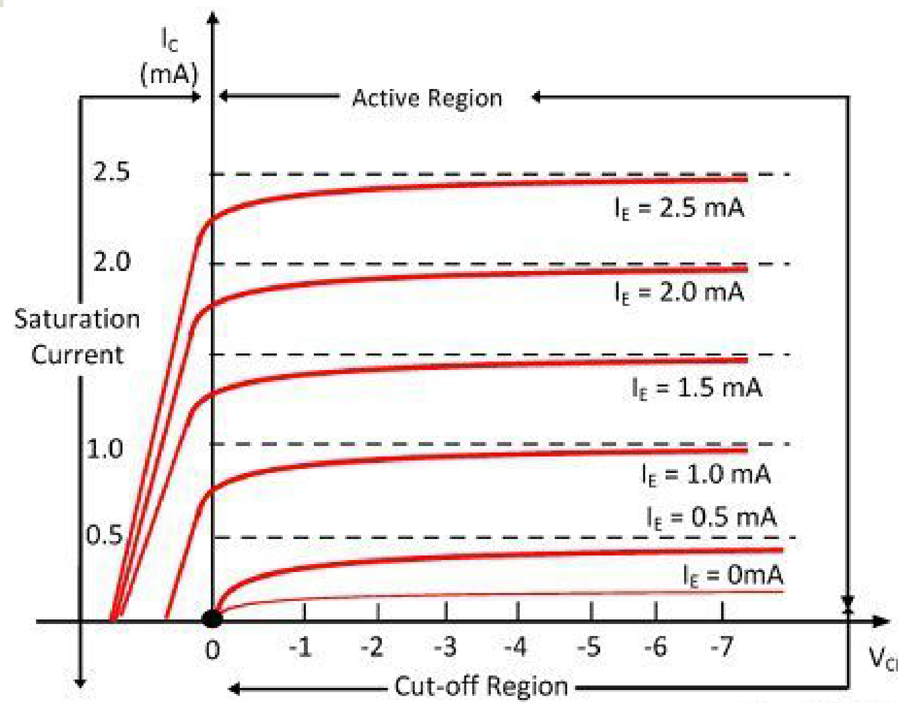


Common Base mode

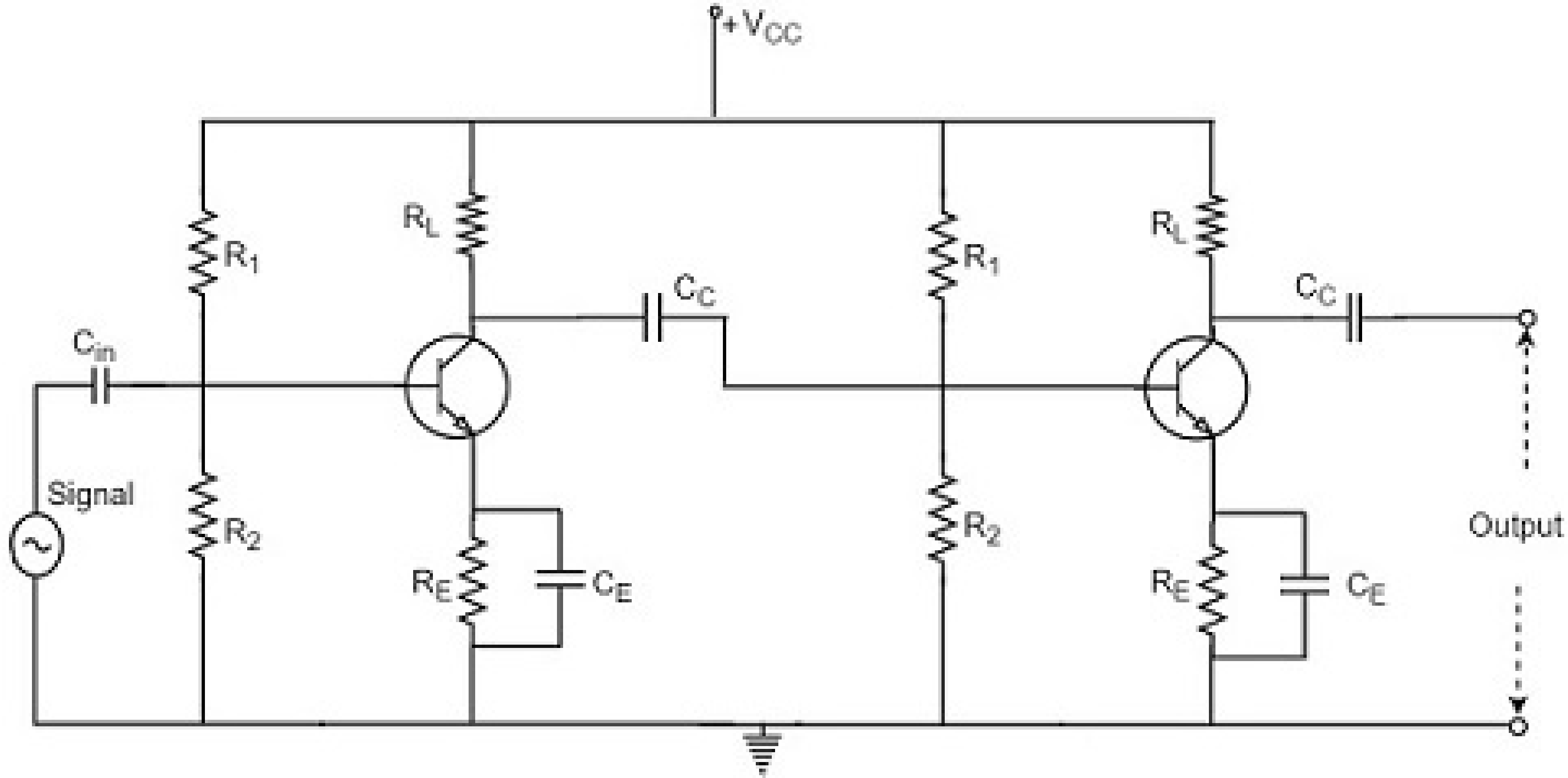




I/p characteristics CB configuration

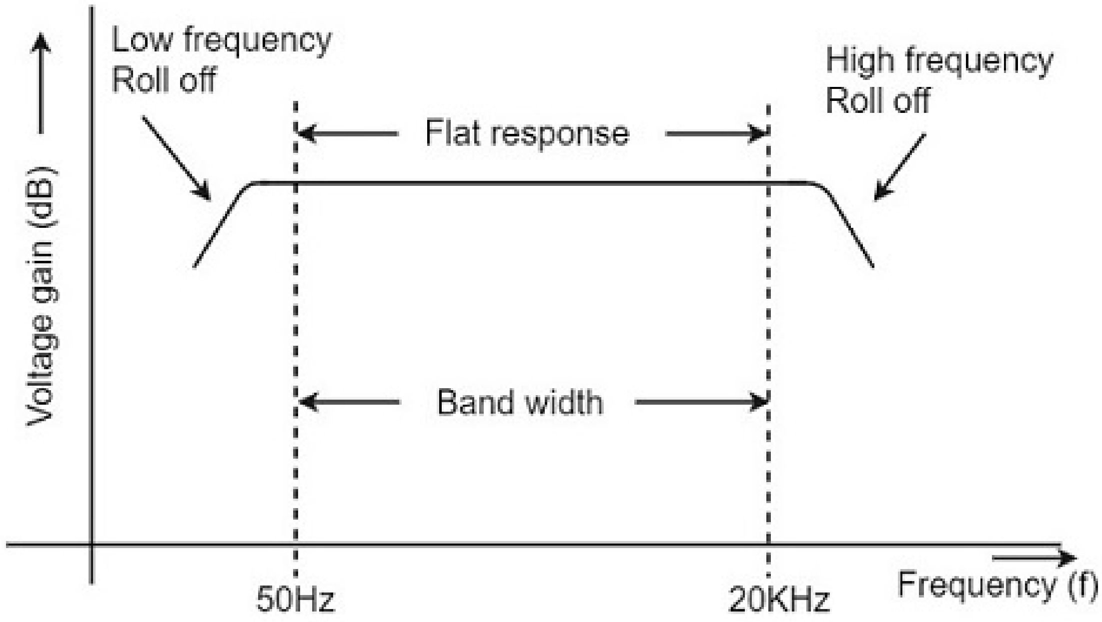


Two stage RC coupled amplifier



When an AC input signal is applied to the base of first transistor, it gets amplified and appears at the collector load R_L which is then passed through the coupling capacitor C_C to the next stage. This becomes the input of the next stage, whose amplified output again appears across its collector load.

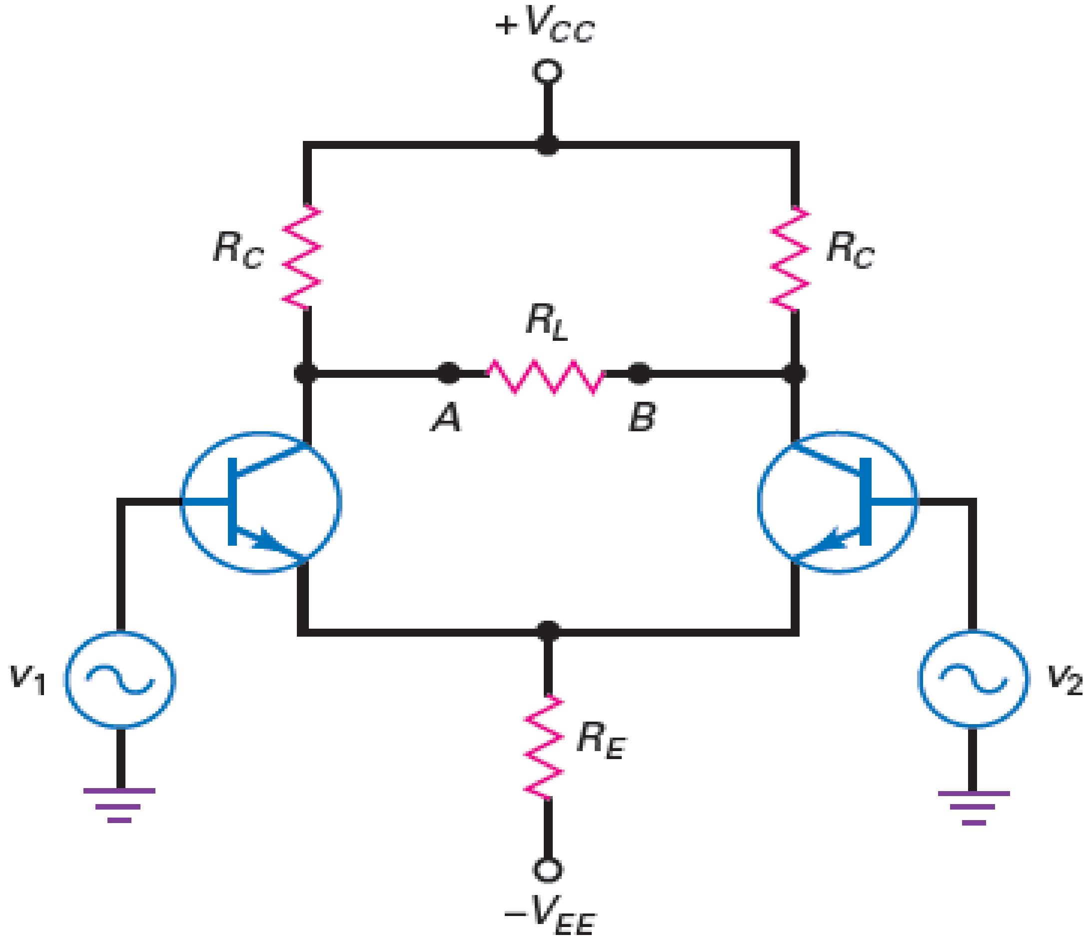
Frequency Response of RC Coupled Amplifier



At low frequencies, the capacitive reactance is very high. The reactance of input capacitor C_{in} and the coupling capacitor C_C are so high that only small part of the input signal is allowed.

Capacitive reactance is low at high frequencies. So, a capacitor behaves as a short circuit, at high frequencies. As a result of this, the loading effect of the next stage increases, which reduces the voltage gain. Along with this, as the capacitance of emitter diode decreases, it increases the base current of the transistor due to which the current gain (β) reduces. Hence the voltage gain rolls off at high frequencies.

Differential Amplifier with load resistor (R_L)

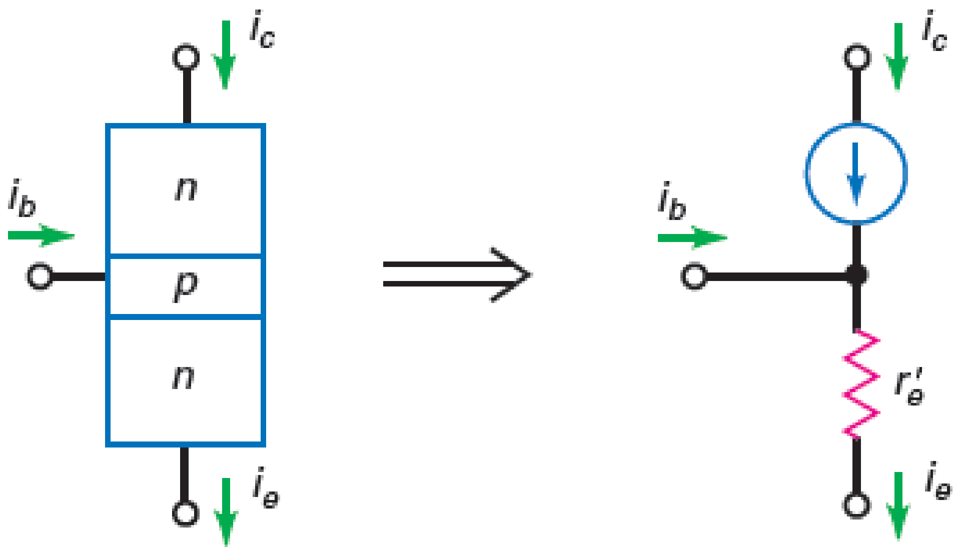


Two Transistor Models

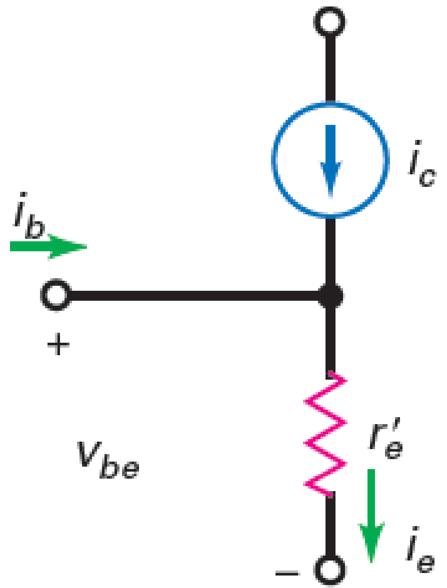
To analyze the ac operation of a transistor amplifier, we need an ac-equivalent circuit for a transistor.

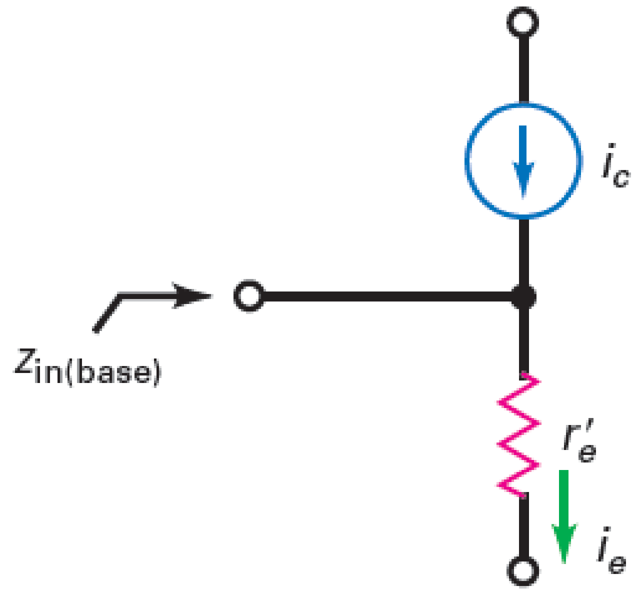
T Model - Ebers-Moll model

Replacing transistor by a T-model – looks like 'T'



For small ac signal, the emitter diode of a transistor acts like an ac resistance r_e' and the collector diode acts like a current source i_c.





Looking into the base of the transistor, the ac voltage source sees an input impedance $z_{\text{in(base)}}$. At low frequencies, this impedance is purely resistive and defined as: $z_{\text{in(base)}}=v_{be}/i_b$

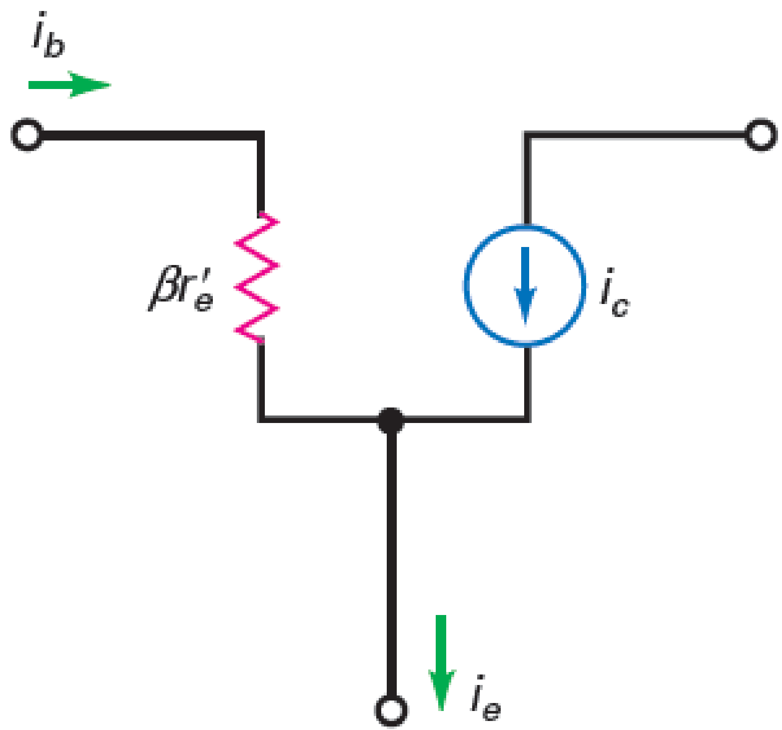
Applying Ohm's law to the emitter diode, we can write:

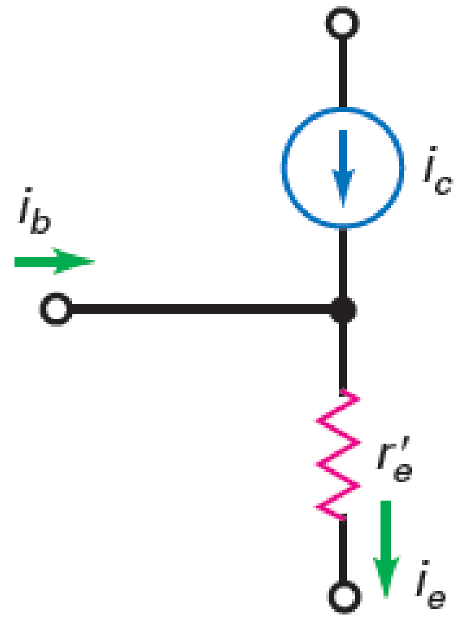
$v_{be}=i_e r_e'$.

So, $z_{\text{in(base)}}=v_{be}/i_b = i_e r_e'/i_b$

As $i_e \approx i_c$, $z_{\text{in(base)}}=\beta r_e'$

The π Model

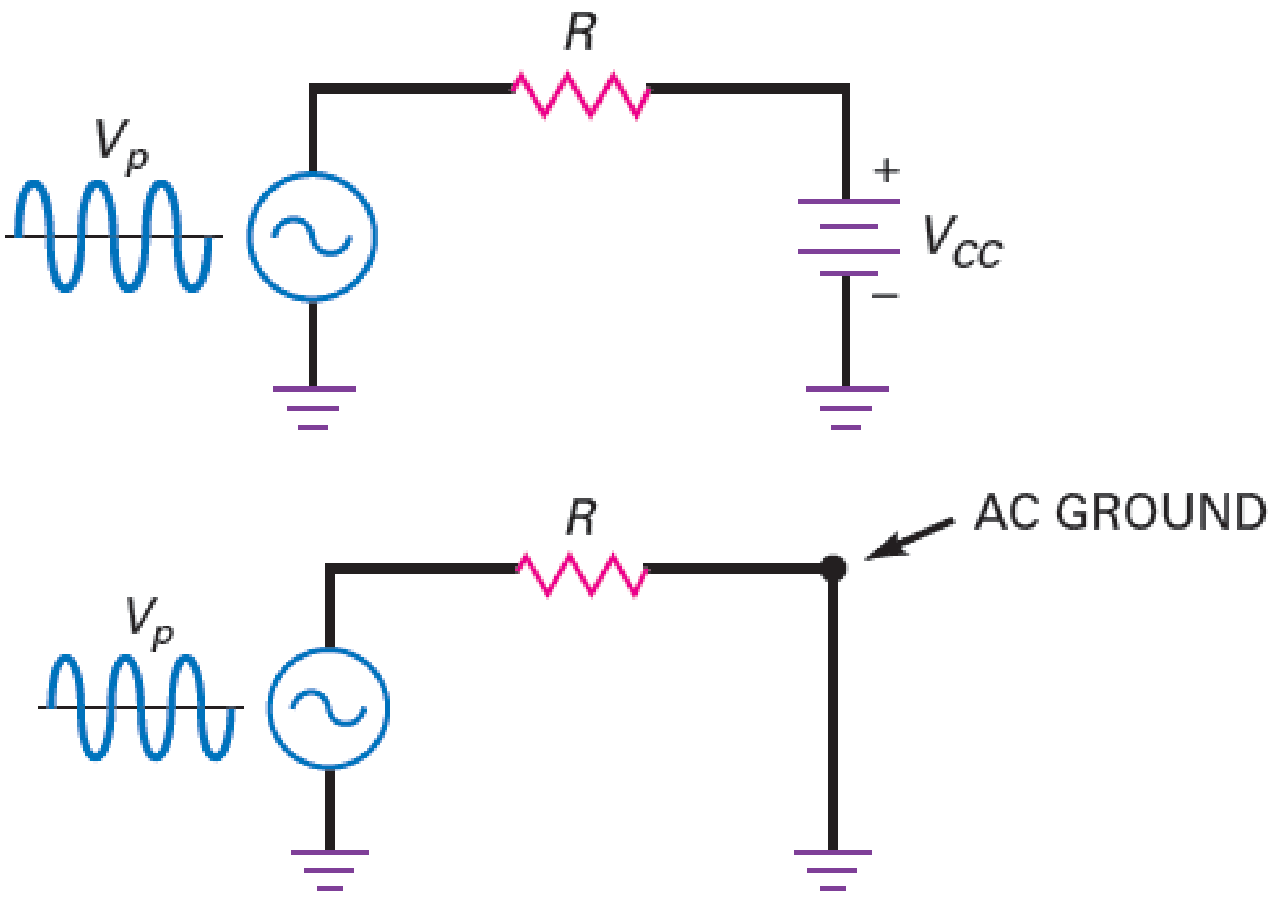




It's the visual representation of the equation derived earlier ($z_{in(base)}=\beta r_e'$).

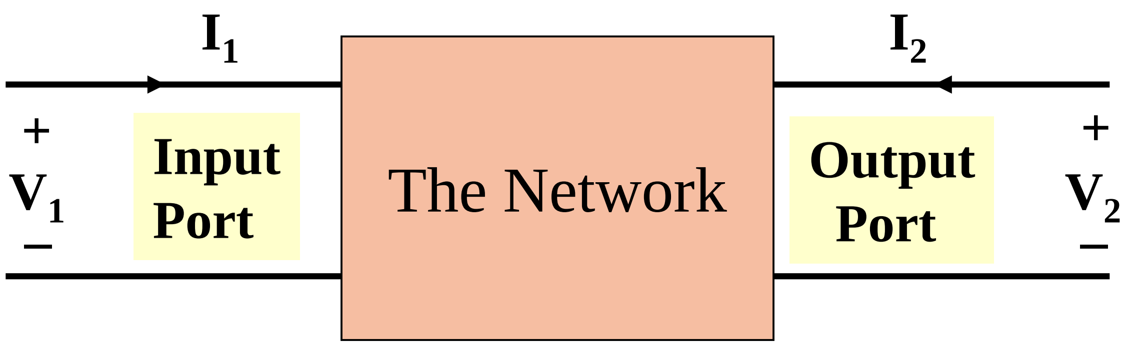
The model is easier to use than the T model because the input impedance is not obvious when we look at the T model. On the other hand, the π model clearly shows that an input impedance of $\beta r_e'$ will load the ac voltage source driving the base.

<u>**AC effect of a DC Voltage Source**</u>



DC voltage source is an AC short - Because a dc voltage source has a constant voltage across it. Therefore, any ac current flowing through it cannot produce an ac voltage across it.

Hybrid (h) parameters



Of these four variables V_1, V_2, i_1 and i_2, two can be selected as independent variables and the remaining two can be expressed in terms of these independent variables.

If the input current i_1 and output Voltage V_2 are takes as independent variables,
Then input voltage V_1 and output current i_2 can be written as:

$$V_1 = h_{11}\, i_1 + h_{12}\, V_2$$
$$i_2 = h_{21}\, i_1 + h_{22}\, V_2$$

The four hybrid parameters : h_{11}, h_{12}, h_{21} and h_{22} are defined as follows.

- $h_{11} = [V_1 / i_1]$ with $V_2 = 0$, : Input resistance with output port short circuited.
- $h_{12} = [V_1 / V_2]$ with $i_1 = 0$, : reverse voltage gain with i/p port open circuited.
- $h_{21} = [i_2 / i_1]$ with $V_2 = 0$, : Forward current gain with output part short circuited.
- $h_{22} = [i_2 / V_2]$ with $i_1 = 0$, : Output admittance with input part open circuited.

h_{11} - Ω, **h_{12} – dimension less,**
h_{21} – dimension less, **h_{22} – siemens**

h parameters of CET

$$h_{ie} = \frac{\partial v_i}{\partial i_i} = \frac{\partial v_{be}}{\partial i_b} \cong \left.\frac{\Delta v_{be}}{\Delta i_b}\right|_{V_{CE}=\text{constant}} \quad \text{(ohms)}$$

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

$$h_{fe} = \frac{\partial i_o}{\partial i_i} = \frac{\partial i_c}{\partial i_b} \cong \left.\frac{\Delta i_c}{\Delta i_b}\right|_{V_{CE}=\text{constant}} \quad \text{(unitless)}$$

$$h_{oe} = \frac{\partial i_o}{\partial v_o} = \frac{\partial i_c}{\partial v_{ce}} \cong \left.\frac{\Delta i_c}{\Delta v_{ce}}\right|_{I_B=\text{constant}} \quad \text{(siemens)}$$