* The small-signal ac analysis begins by removing the dc effects of V_{CC} and replacing the dc blocking capacitors C_1 and C_2 by short-circuit equivalents, resulting the network of Fig (5-20).

Z_i

$$Z_i = R_B \,//\, \beta r_e \quad \text{Ohms}$$
$$\cong \beta r_e \quad \text{as } R_B \text{ is greater than } \beta r_e \text{ by more than a factor of } 10$$

Z_o when $V_i = 0$, $I_i = I_b = 0$, O.C the current source

$$Z_o = R_C \,//\, r_o \cong R_C \quad \text{if } r_o \geq 10 R_C$$

A_V

$$V_o = -\beta I_b (R_C // r_o)$$
$$I_b = \frac{V_i}{\beta r_e}$$
$$V_o = -\beta \left(\frac{V_i}{\beta r_e}\right)(R_C // r_o)$$
$$A_V = \frac{V_o}{V_i} = -\frac{(R_C // r_o)}{r_e}$$
$$A_V = \frac{V_o}{V_i} = -\frac{R_C}{r_e} \quad \text{if } r_o \geq 10 R_C$$

$$A_i = \frac{I_o}{I_{in}} = \frac{\frac{V_o}{R_L}}{\frac{V_{in}}{Z_{in}}} = \frac{V_o}{V_{in}} \times \frac{Z_{in}}{R_L} = A_V \times \frac{Z_{in}}{R_L}$$

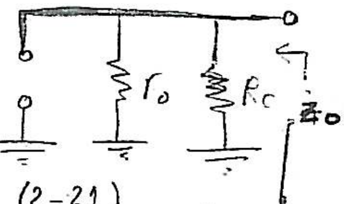
Fig (2-21) Determining Z_o for the network of Fig (5-20)

The negative sign reveals that a 180° phase shift occurs between the input and output signals.

7) VOLTAGE-DIVIDER BIAS: (By-pass CE)

* The r_e model used to voltage-divider bias network.

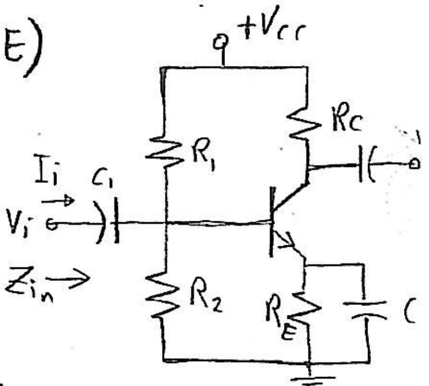
Fig (5-22) Voltage-divider bias configuration

* Note the absence of R_E due to the low-impedance shorting effect of the bypass capacitor, C_E.

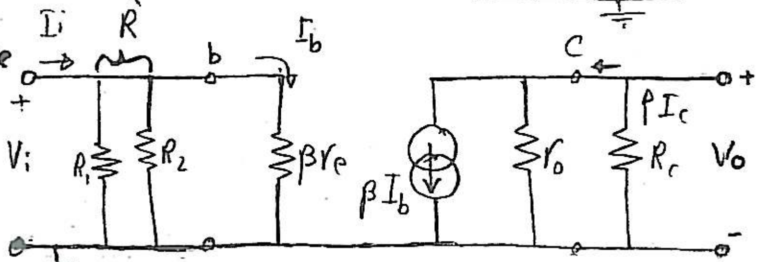
Fig (5-23)

$$\acute{R} = R_1 /\!/ R_2 = \frac{R_1 R_2}{R_1 + R_2}$$

Z_i $\quad Z_i = \acute{R} /\!/ \beta r_e$

Z_o with $V_i = 0$, $I_b = 0\,\mu A$ and $\beta I_b = 0\, mA$

$$Z_o = R_C /\!/ r_o$$

$$Z_o \cong R_C \qquad \text{if } r_o \geqslant 10 R_C$$

A_V $\quad V_o = -(\beta I_b)(R_C /\!/ r_o)$

$$I_b = \frac{V_i}{\beta r_e}$$

$$V_o = -\beta\left(\frac{V_i}{\beta r_e}\right)(R_C /\!/ r_o)$$

$$A_V = \frac{V_o}{V_i} = \frac{-R_C /\!/ r_o}{r_e}$$

$$A_V \cong \frac{V_o}{V_i} \cong -\frac{R_C}{r_e} \qquad \text{if } r_o \geqslant 10 R_C$$

8) CE EMITTER-BIAS CONFIGURATION :

* The r_e equivalent model is substituted in Fig (5-25), but note the absence of the resistance r_o. The effect of r_o is to make the analysis agreat deal more complicated, and considering the fact that in most situations its effect can be ignored.

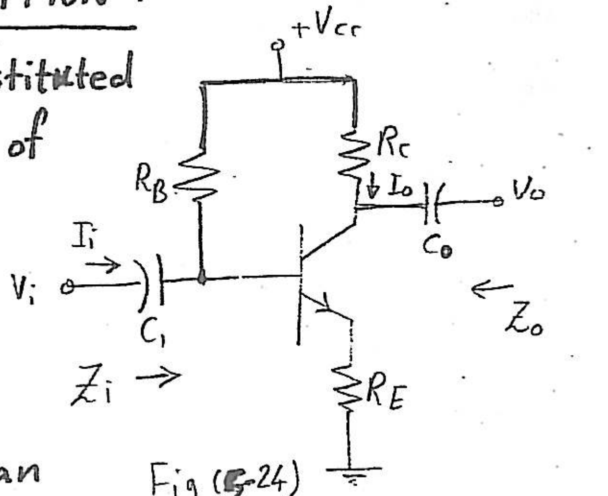

Fig (5-24)

CE emitter-bias Configuration

$$V_i = I_b \beta r_e + I_e R_E$$
$$= I_b \beta r_e + (\beta+1) I_b R_E$$

$$Z_b = \frac{V_i}{I_b} = \beta r_e + (\beta+1) R_E$$

$$Z_b \cong \beta (r_e + R_E) \qquad \text{since } \beta \gg 1$$

$$Z_b \cong \beta R_E \qquad \text{since } R_E \gg r_e$$

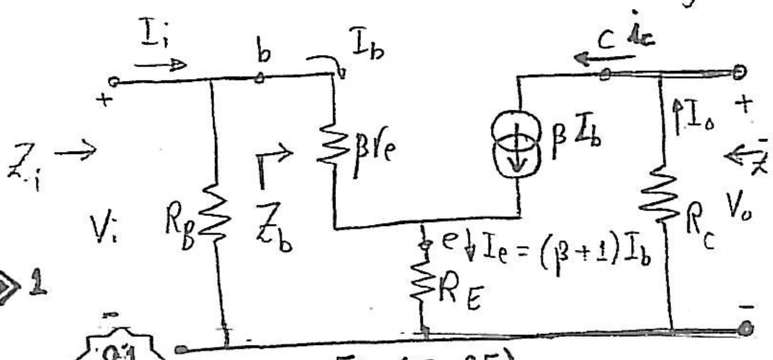

Fig (5-25)

Z_i // $Z_i = R_B \parallel Z_b$

Z_o // set $V_i = 0$, $I_b = 0$, $\therefore \beta I_b = 0$

$$Z_o = R_C$$

A_V // $I_b = \dfrac{V_i}{Z_b}$

$$V_o = -I_o R_C = -\beta I_b R_C = -\beta\left(\frac{V_i}{Z_b}\right) R_C$$

$$A_V = \frac{V_o}{V_i} = -\frac{\beta R_C}{Z_b} = -\frac{-\beta R_C}{\beta(R_E + r_e)} = -\frac{R_C}{R_E + r_e}$$

$$A_V = \frac{V_o}{V_i} \cong -\frac{R_C}{R_E}$$ as for approximation $Z_b \cong \beta R_E$

Effect of r_o

After derivation using KVL, KCL, source conversion and Thévenin's theorem.

Z_i //

$$Z_b = \beta r_e + \left[\frac{(\beta+1) + \frac{R_C}{r_o}}{1 + (R_C + R_E)/r_o}\right] R_E$$

since $\dfrac{R_C}{r_o} \ll (\beta+1)$

$$Z_b \cong \beta r_e + \frac{(\beta+1) R_E}{1 + (R_C + R_E)/r_o}$$

For $r_o \geq 10(R_C + R_E)$, $(\beta+1) \cong \beta$

$$Z_b \cong \beta r_e + (\beta+1) R_E \cong \beta(r_e + R_E)$$

Z_o //

$$Z_o = R_C \parallel \left[r_o + \frac{\beta(r_o + r_e)}{1 + \frac{\beta r_e}{R_E}}\right]$$

$r_o \gg r_e$

$$Z_o \cong R_C \parallel r_o \left[1 + \frac{1}{\frac{1}{\beta} + \frac{r_e}{R_E}}\right]$$

Typically $\dfrac{1}{\beta}$ and $\dfrac{r_e}{R_E}$ are less than one with a sum usually less than one. For $\beta = 100$, $r_e = 10\,\Omega$ and $R_E = 1\,k\Omega$

$$\frac{1}{\frac{1}{\beta} + \frac{r_e}{R_E}} = \frac{1}{\frac{1}{100} + \frac{10}{1000}} = \frac{1}{0.02} = 50$$

$$Z_o = R_C \parallel 51 r_o \approx R_C$$

Av

$$A_V = \frac{V_o}{V_i} = \frac{-\beta R_C / Z_b [1 + r_e/r_o] + R_C/r_o}{1 + \frac{R_C}{r_o}}$$

$$\frac{r_e}{r_o} \ll 1$$

$$A_V = \frac{V_o}{V_i} \cong \frac{-\frac{\beta R_C}{Z_b} + \frac{R_C}{r_o}}{1 + \frac{R_C}{r_o}}$$

For $r_o \geq 10 R_C$

$$A_V = \frac{V_o}{V_i} \cong -\frac{\beta R_C}{Z_b}$$

g) EMITTER – FOLLOWER CONFIGURATION:

* When the o/p is taken from the emitter terminal of the transistor as shown in Fig (5-26). The output voltage is always slightly less than the input signal due to the drop from base to emitter, but the approximation $A_V \cong 1$, The fact that V_o "follows" the magnitude of V_i with an in-phase relationship accounts for the terminology emitter-follower
* The collector is grounded for ac analysis, it is actually a common-Collector configuration, used for impedance matching.

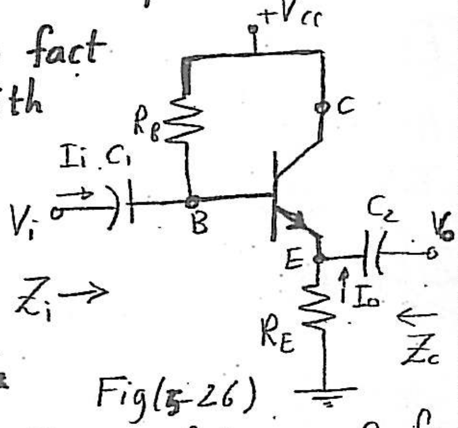

Fig (5-26)
Emitter-follower Config.

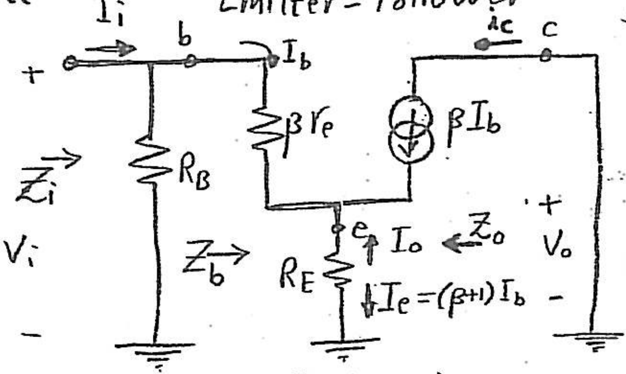

Fig (5-27)
re equ. cct. into the ac equivalent network of Fig (5-26)

Zi

$Z_i = R_B \,//\, Z_b$ (high)

$$Z_b = \beta r_e + (\beta + 1) R_E$$

$$\cong \beta (r_e + R_E)$$

$$Z_b \cong \beta R_E \quad \text{for } R_E \gg r_e$$

Zo

$$I_b = \frac{V_i}{Z_b}$$

multiplying by $(\beta+1)$ to establish I_e

$$I_e = (\beta+1) I_b = (\beta+1) \frac{V_i}{Z_b}$$

$$I_e = \frac{(\beta+1) V_i}{\beta r_e + (\beta+1) R_E} = \frac{V_i}{[\beta r_e/(\beta+1)] + R_E}$$

but $(\beta+1) \cong \beta$

$$\frac{\beta r_e}{\beta+1} \cong \frac{\beta r_e}{\beta} = r_e$$

$$I_e \cong \frac{V_i}{r_e + R_E}$$