substituting $I_b = V_i / \beta r_e$ gives

$$V_o = -I_o R_C = -\beta \frac{V_{in}}{\beta r_e} R_C$$

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

* Or we can use Miller's theorem which states:

if we have an impedance (Z) connected between two different potential points N_1, N_2 can be transferred in two impedance one into input the other into output side

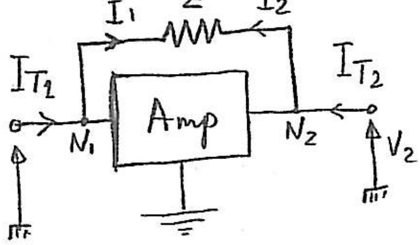

Fig (5-34)

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

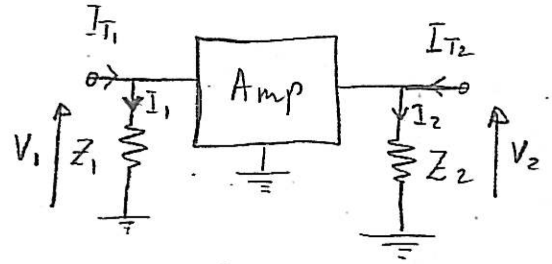

Fig (5-35)

so $I_1 = \frac{V_1 - V_2}{Z}$

$$I_1 = \frac{V_1(1-K)}{Z} \quad , \because I_1 = \frac{V_1}{Z_1}$$

$$\therefore \boxed{Z_1 = \frac{Z}{1-K}} \qquad (5-22)$$

$$I_2 = \frac{V_2 - V_1}{Z} = \frac{V_2 - \frac{V_2}{K}}{Z} = \frac{V_2}{Z}\left(1 - \frac{1}{K}\right)$$

$$\because I_2 = \frac{V_2}{Z_2}$$

$$\therefore \boxed{Z_2 = \frac{Z}{1 - \frac{1}{K}}} \qquad (5-23)$$

if $1 \gg \frac{1}{K} \Rightarrow Z_2 \cong Z$

second case:

if $\frac{I_2}{I_1} = A_I$

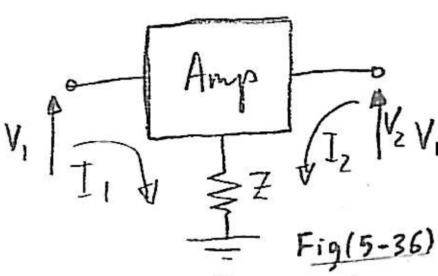

Fig (5-36)

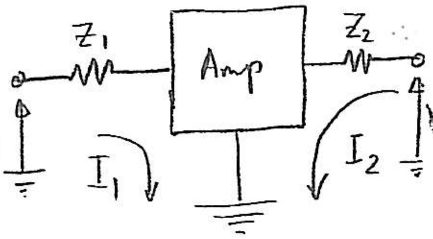

Fig (5-37)

For Fig (3-36)

$$V_1 = (I_1 - I_2) Z$$
$$= Z I_1 (1 - A_I)$$

$V_1 = I_1 Z_1$ Fig (5-37)

$$\therefore \boxed{Z_1 = Z(1 - A_i)} \quad \text{-------------- (5-24)}$$

also: $V_2 = Z(I_2 - I_1)$

$$= Z I_2 \left(1 - \frac{1}{A_i}\right)$$

$$V_2 = I_2 Z_2$$

$$\therefore \boxed{Z_2 = Z\left(1 - \frac{1}{A_i}\right)} \quad \text{---------- (5-25)}$$

if $A_i \gg 1 \Rightarrow Z_2 = Z$

Return to Fig (5-32) applying Miller theorem:

consider $\grave{I} = 0$ as $\ll \beta I_b$

so $A_V = -\dfrac{R_C}{r_e}$

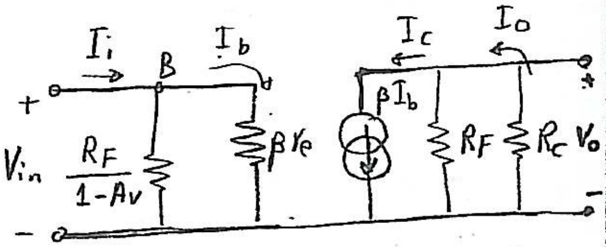

Fig (5-38)

$$Z_1 = \frac{R_F}{1 - \left(-\frac{R_C}{r_e}\right)} = \frac{R_F}{1 + \frac{R_C}{r_e}}$$

$$Z_2 = \frac{R_F}{1 + \frac{r_e}{R_C}} \approx R_F \quad \text{as } \frac{r_e}{R_C} \ll 1$$

$$Z_i = \frac{\beta r_e \left(\frac{R_F}{1 + R_C/r_e}\right)}{\beta r_e + \frac{R_F}{1 + \frac{R_C}{r_e}}} = \frac{\beta r_e R_F}{\beta r_e \left(1 + \frac{R_C}{r_e}\right) + R_F} = \frac{\beta r_e}{1 + \frac{\beta r_e}{R_F}\left(1 + \frac{R_C}{r_e}\right)}$$

$$Z_i = \frac{\beta r_e}{1 + \frac{\beta R_C}{R_F}} \cong \frac{r_e}{\frac{1}{\beta} + \frac{R_C}{R_F}}$$

$$Z_o \cong R_C \,//\, R_F$$

* To calculate current gain in general (A_i)

$$A_i = \frac{I_o}{I_i} = \frac{\frac{V_o}{R_L}}{\frac{V_i}{Z_i}} = \frac{V_o}{V_i} \cdot \frac{Z_i}{R_L}$$

$$\boxed{A_i = A_V \frac{Z_i}{R_L}} \quad \text{-------------- (5-26)}$$

12) Effects of R_L and R_S :

* $A_V = \dfrac{V_o}{V_i}$ with R_L.

$$A_{VS} = \frac{V_o}{V_s} = \frac{V_o}{V_i} * \frac{V_i}{V_s} = A_V * \frac{V_i}{V_s}$$

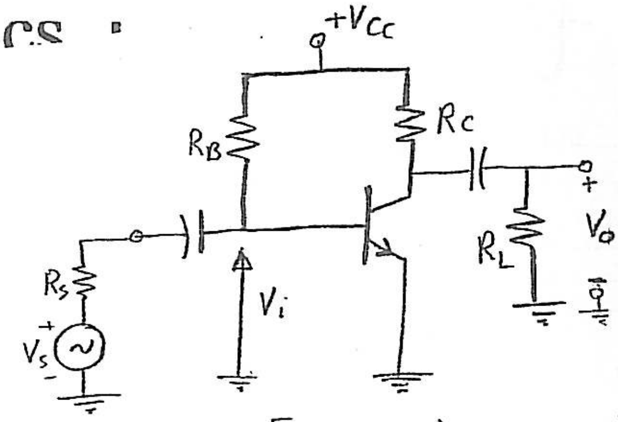

Fig (5-39)

* For a particular amplifier, the larger the level of R_L, and the smaller the internal resistance of the signal source, the greater is the overall gain.

13) CASCADED SYSTEMS :

The two-port systems is particularly useful for cascaded systems such as that appearing in Fig (5-40), where A_{V_1}, A_{V_2}, A_{V_3} and so on, are the voltage gain of each stage under loaded

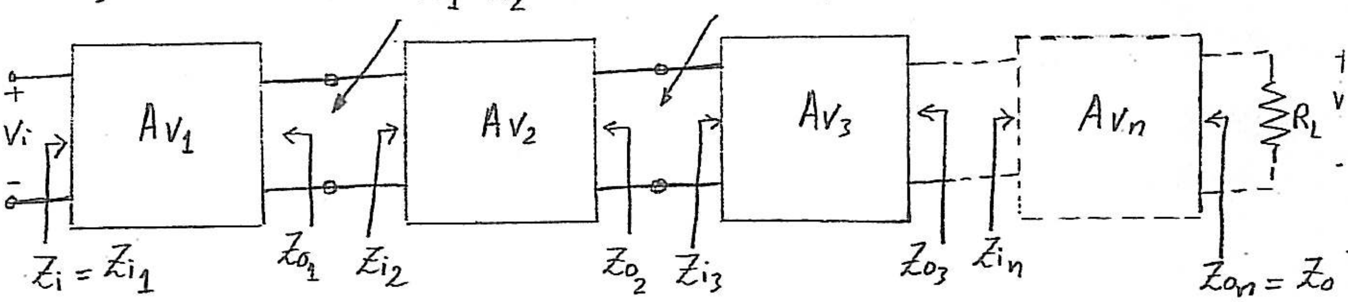

Fig (5-40)
Cascaded System

The total gain of the system is then determined by the produ of the individual gains:

$$\boxed{A_{V_T} = A_{V_1} \cdot A_{V_2} \cdot A_{V_3} \cdots} \quad \text{-------- (5-27)}$$

and the total current gain is given by

$$\boxed{A_{i_T} = - A_{V_T} \frac{Z_{i_1}}{R_L}}$$

* One popular connection of amplifier stages is the RC-coupled in Fig (5-41)