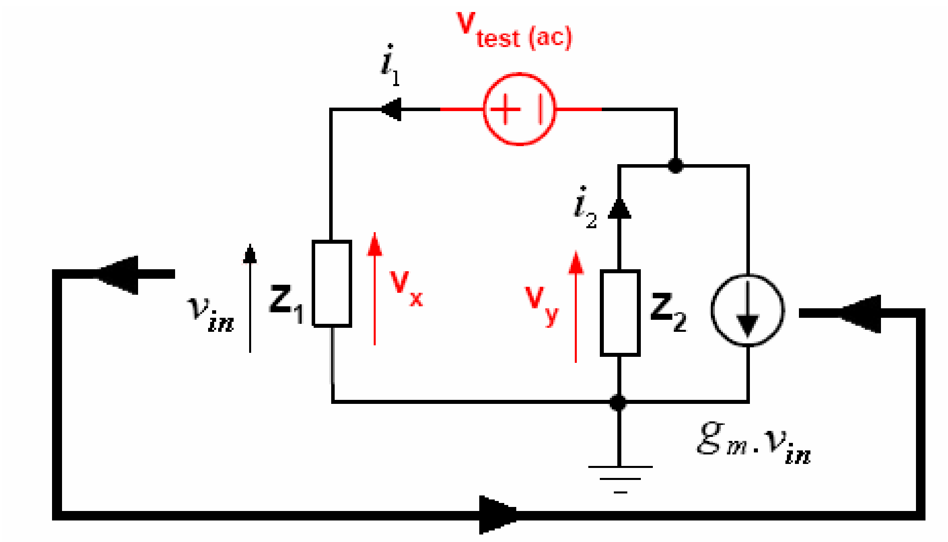

Figure 1. Voltage injection.

The loop transmission path above is arbitrarily represented as a non-ideal voltage controlled current source (VCCS). Identical results would be obtained from a non-ideal VCVS, CCCS, or CCVS.

True loop gain (in the absence of v_{test}) is obtained by inspection:

$$T = g_m \cdot \frac{Z_1 Z_2}{Z_1 + Z_2} \quad (1)$$

From fig. 1:

$$v_{in} = v_x \quad (3)$$

and:

$$v_y = -i_2 \cdot Z_2 \quad (4)$$

But,

$$i_2 - g_m \cdot v_{in} - i_1 = 0$$

$\Rightarrow$

$$i_2 = g_m \cdot v_x + \frac{v_x}{Z_1} \quad (5)$$

(5) into (4):

$$v_y = -v_x \cdot \left(g_m \cdot Z_2 + \frac{Z_2}{Z_1} \right) \quad (6)$$

The voltage return ratio T_v is defined as:

$$T_v = \frac{v_y}{v_x}$$

$\Rightarrow$

$$T_v = -\left(g_m \cdot Z_2 + \frac{Z_2}{Z_1}\right) (7)$$

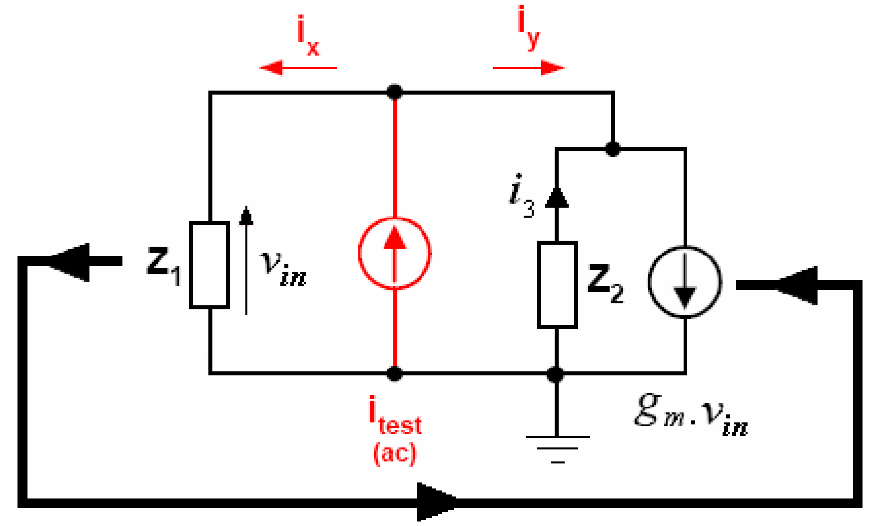

Figure 2. Current injection.

From fig. 2:

$$i_y + i_3 - g_m \cdot v_{in} = 0$$

$\Rightarrow$

$$i_y = g_m \cdot v_{in} - i_3$$

$\Rightarrow$

$$i_y = g_m \cdot v_{in} - \frac{v_{in}}{Z_2}$$

$\Rightarrow$

$$i_y = g_m \cdot i_x \cdot Z_1 - \frac{i_x \cdot Z_1}{Z_2}$$

$\Rightarrow$

$$i_y = -i_x\left(\frac{Z_1}{Z_2} + g_m \cdot Z_1\right)$$

The current return ratio T_v is defined as:

$$T_i = \frac{i_y}{i_x}$$

$\Rightarrow$

$$\boldsymbol{T}_y = -\left(\frac{\boldsymbol{Z}_1}{\boldsymbol{Z}_2} + \boldsymbol{g}_m \cdot \boldsymbol{Z}_1\right) \quad (8)$$

Express $\boldsymbol{T}_v$ in (7) in terms of $\boldsymbol{T}$ in (1):

$$\boldsymbol{T}_v = -\left[\boldsymbol{T} \cdot \left(1 + \frac{\boldsymbol{Z}_2}{\boldsymbol{Z}_1}\right) + \frac{\boldsymbol{Z}_2}{\boldsymbol{Z}_1}\right] \quad (9)$$

Express $\boldsymbol{T}_i$ in (8) in terms of $\boldsymbol{T}$ in (1):

$$\boldsymbol{T}_i = -\left[\frac{\boldsymbol{Z}_1}{\boldsymbol{Z}_2} + \boldsymbol{T}\left(1 + \frac{\boldsymbol{Z}_1}{\boldsymbol{Z}_2}\right)\right] \quad (10)$$

From (9):

$$\frac{\boldsymbol{T}_v + \boldsymbol{T}}{\boldsymbol{T} + 1} = -\frac{\boldsymbol{Z}_2}{\boldsymbol{Z}_1} \quad (11)$$

From (10):

$$\frac{\boldsymbol{T}_i + \boldsymbol{T}}{\boldsymbol{T} + 1} = -\frac{\boldsymbol{Z}_1}{\boldsymbol{Z}_2} \quad (12)$$

$\Rightarrow$

$$\frac{\boldsymbol{T}_v + \boldsymbol{T}}{\boldsymbol{T} + 1} = \frac{\boldsymbol{T} + 1}{\boldsymbol{T}_i + \boldsymbol{T}}$$

$\Rightarrow$

$$\boldsymbol{T} = \frac{1 - \boldsymbol{T}_v \boldsymbol{T}_i}{\boldsymbol{T}_v + \boldsymbol{T}_i - 2} \quad (13)$$

With the form of equation (13), the measured ratios $(\boldsymbol{v}_y / \boldsymbol{v}_x)$, and $(\boldsymbol{i}_y / \boldsymbol{i}_x)$ MUST NOT be negated before substitution to obtain T.

However, if the conventions shown in figures 4 and 5 are used, then:

$$\boldsymbol{T} = \frac{\boldsymbol{T}_v \boldsymbol{T}_i - 1}{\boldsymbol{T}_v + \boldsymbol{T}_i + 2} \quad (14)$$

and each of the ratios $(\boldsymbol{v}_y / \boldsymbol{v}_x)$, and $(\boldsymbol{i}_y / \boldsymbol{i}_x)$ MUST BE negated to obtain T.

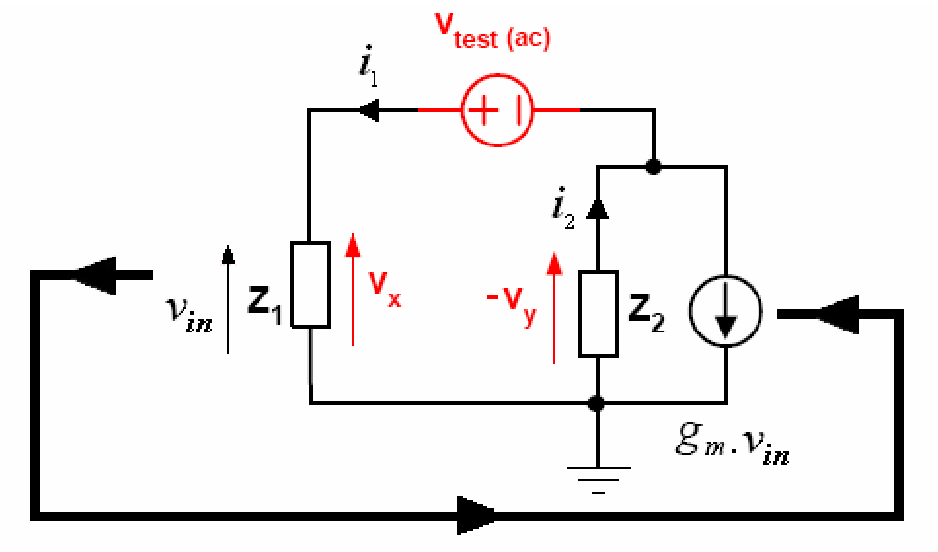

Figure 4.

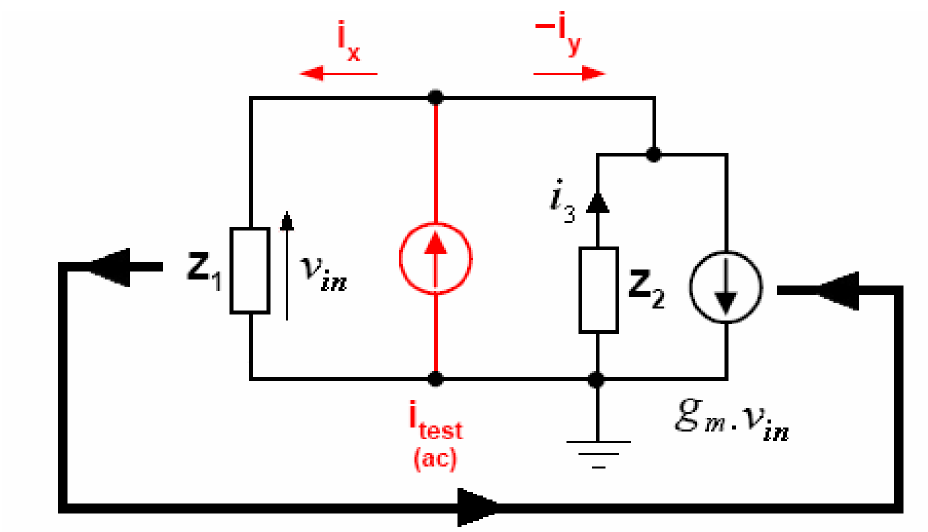

Figure 5.