Tema 10:
CUADRIPOLOS

Cuadripolos

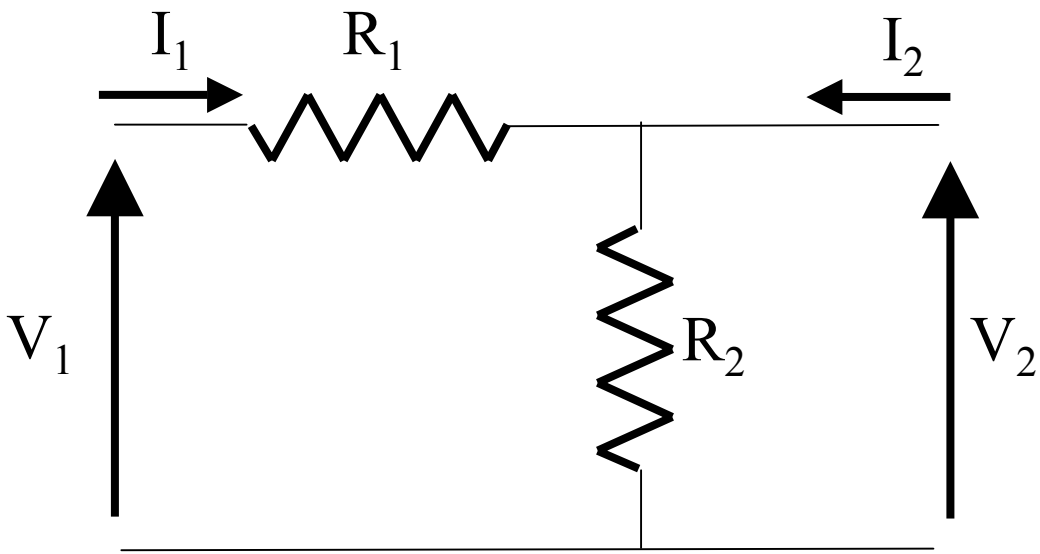
- **Descripción general**
- **Parámetros de cuadripolos**
- **Asociación de cuadripolos**

Cuadripolos

- **Relación de una red con los circuitos exteriores**
- **Red = caja negra con puertas de acceso**
- **Aplicaciones:**
  - **Modelo de componentes electrónicos**
  - **Circuitos equivalentes de la red inicial**

Cuadripolos

- **Puertas de acceso con V e I asociados**
- **Sistemas de ecuaciones relacionan las V e I de las puertas**

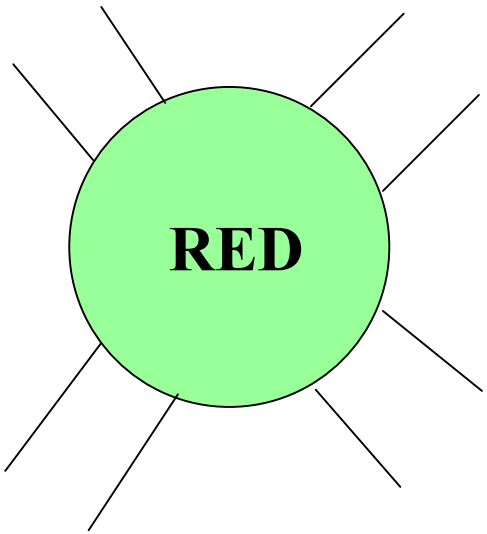


$$V_1=(R_1+R_2)I_1 + R_2I_2$$
$$V_2=R_2I_1+ R_2I_2$$

Cuadripolos

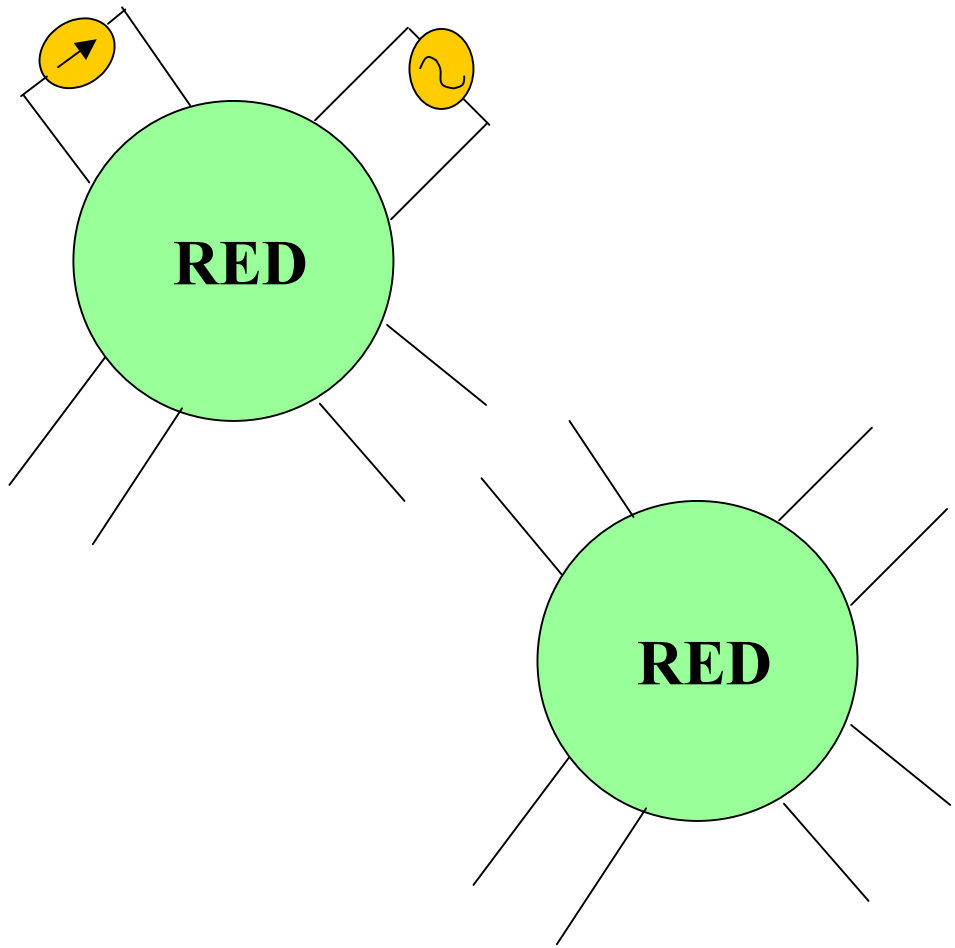
- **Se describe el circuito a partir de las relaciones entre las V e I de las puertas**
- **Circuitos lineales => ecuaciones lineales**
  - **Coeficientes= parámetros de la red**
  - **Permiten conocer V e I cualquier puerta conocidas las otras**
  - **Red sin generadores independientes**

Cuadripolos



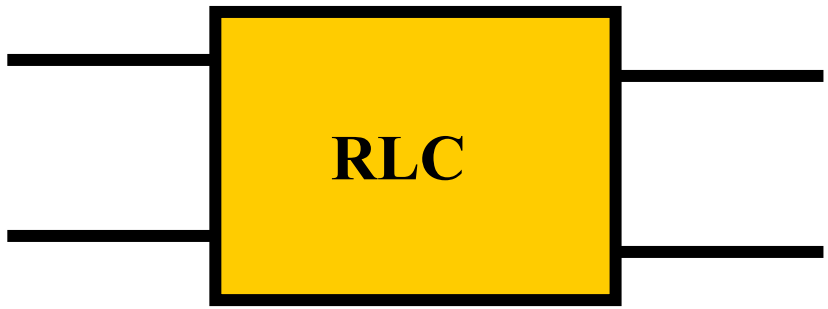
$$Y_1 = P_{11}\, X_1 + \ldots + P_{1N}\, X_N$$
$$Y_2 = P_{21}\, X_1 + \ldots + P_{2N}\, X_N$$
$$\ldots.$$
$$Y_N = P_{N1}\, X_1 + \ldots + P_{NN}\, X_N$$

Red Multipuerta



Extracción de fuentes

Cuadripolos



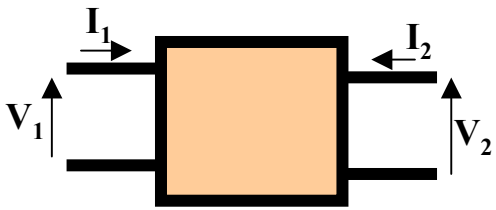
Red bipuerta o cuadripolo

- **Definido por dos ecuaciones**
- **Parámetros dependen de variables controladas y controladoras**

$$\begin{pmatrix} Y_1 \\ Y_2 \end{pmatrix} = \begin{pmatrix} P_{11} & P_{12} \\ P_{21} & P_{22} \end{pmatrix} \begin{pmatrix} X_1 \\ X_2 \end{pmatrix}$$

Y: variables controladas
X: variables controladoras

Parámetros de Impedancia Z



- Variables controladas V
- Variables controladoras I

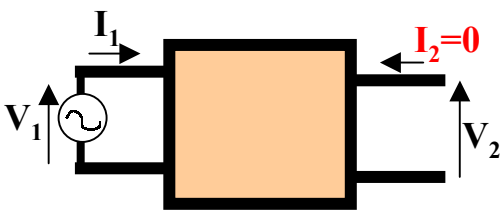
$$\left.\begin{aligned} V_1 &= Z_{11}I_1 + Z_{12}I_2 \\ V_2 &= Z_{21}I_1 + Z_{22}I_2 \end{aligned}\right\} \quad \begin{pmatrix} V_1 \\ V_2 \end{pmatrix} = \begin{pmatrix} Z_{11} & Z_{12} \\ Z_{21} & Z_{22} \end{pmatrix} \begin{pmatrix} I_1 \\ I_2 \end{pmatrix}$$

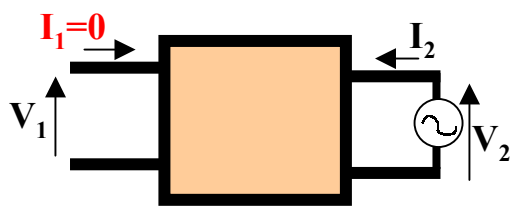
$Z_{11} = V_1 / I_1 \,|\, I_2 = 0$ Z entrada circ. abierto a la salida

$Z_{21} = V_2 / I_1 \,|\, I_2 = 0$ Z transf. sal.-entr. circ. abierto a la salida

$Z_{12} = V_1 / I_2 \,|\, I_1 = 0$ Z transf. entr.-sal. circ. abierto a la entrada

$Z_{22} = V_2 / I_2 \,|\, I_1 = 0$ Z salida circ. abierto a la entrada

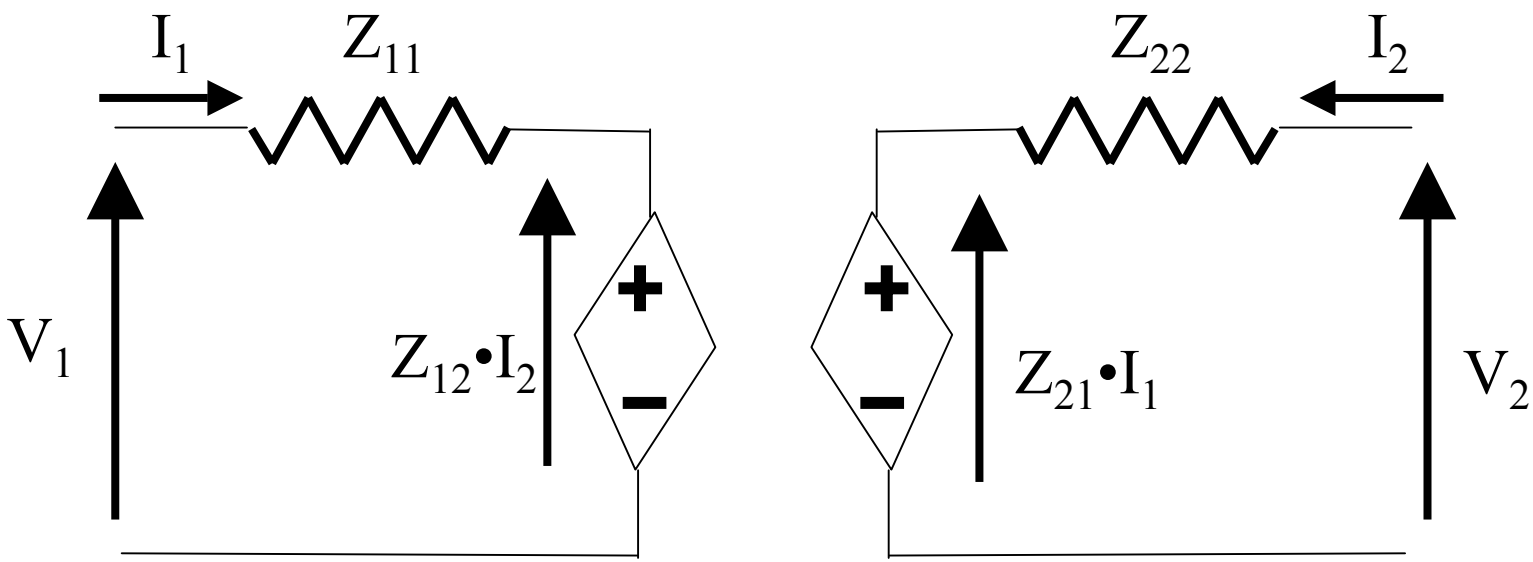




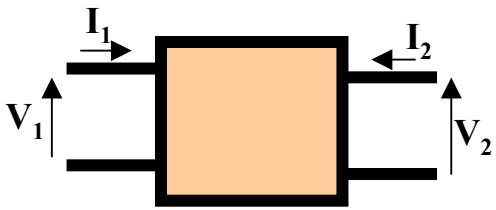
PARAMETROS DE IMPEDANCIA EN CIRC. ABIERTO

Parámetros de Impedancia Z

Circuito equivalente



Parámetros de admitancia Y

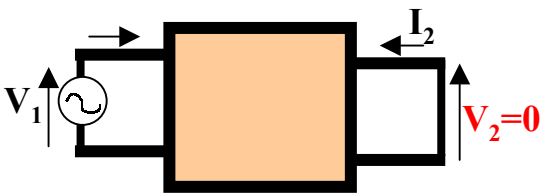


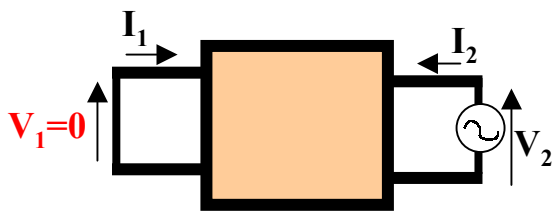
- Variables controladas I
- Variables controladoras V

$$I_1 = Y_{11}V_1 + Y_{12}V_2$$
$$I_2 = Y_{21}V_1 + Y_{22}V_2$$

$$\begin{pmatrix} I_1 \\ I_2 \end{pmatrix} = \begin{pmatrix} Y_{11} & Y_{12} \\ Y_{21} & Y_{22} \end{pmatrix} \begin{pmatrix} V_1 \\ V_2 \end{pmatrix}$$

$Y_{11} = I_1 / V_1 |\ V_2 = 0$ Y entrada cortocirc. a la salida
$Y_{21} = I_2 / V_1 |\ V_2 = 0$ Y transf. sal.-entr. cortocirc. a la salida
$Y_{12} = I_1 / V_2 |\ V_1 = 0$ Y transf. entr.-sal. cortocirc. a la entrada
$Y_{22} = I_2 / V_2 |\ V_1 = 0$ Y salida cortocirc. a la entrada

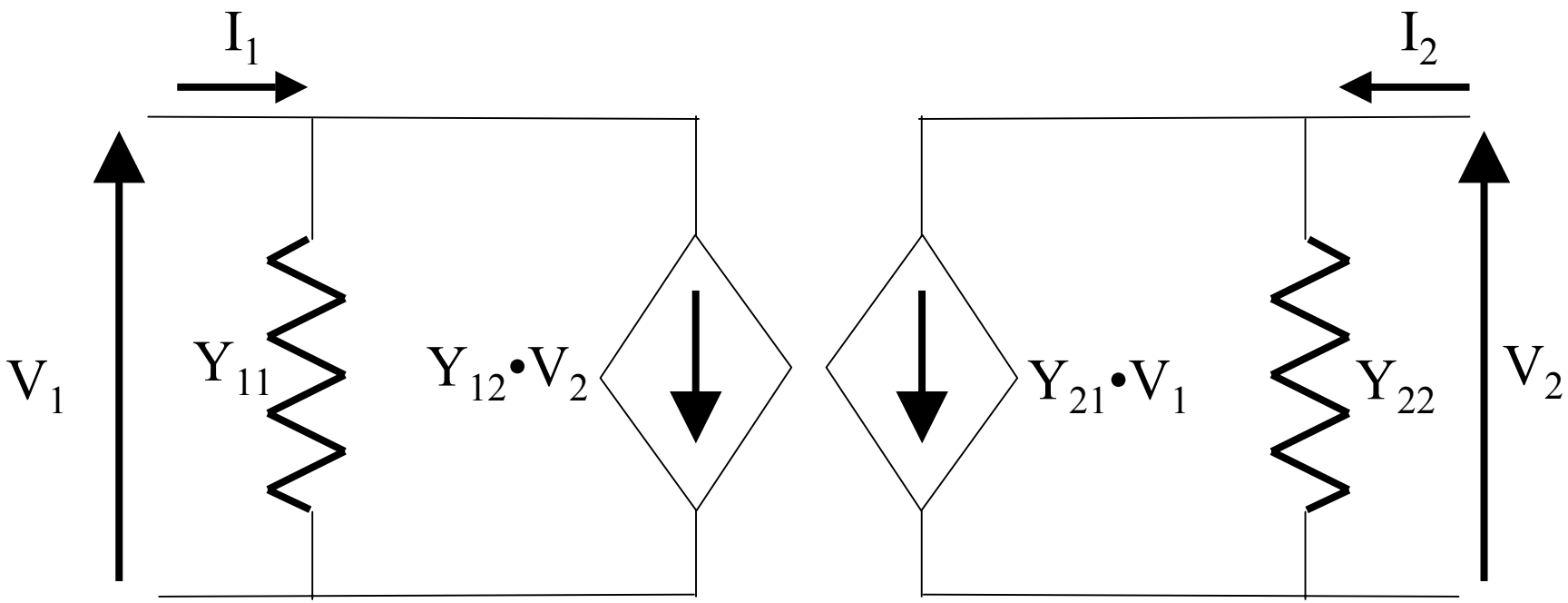




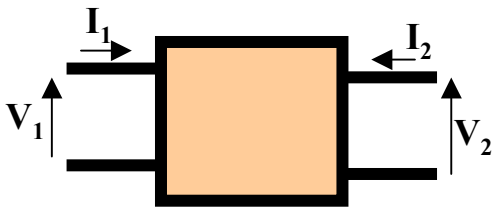
PARAMETROS DE ADMITANCIA EN CORTOCIRC.

Parámetros de admitancia Y

Circuito equivalente



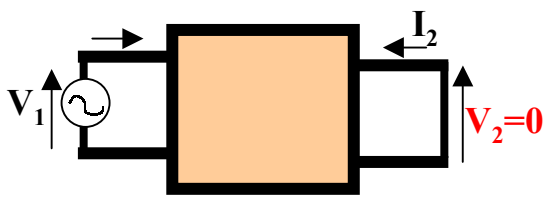
Parámetros Híbridos h

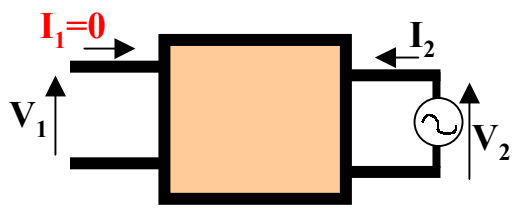


- Variables controladas V_1 I_2
- Variables controladoras V_2 I_1

$$\left.\begin{aligned} V_1 &= h_{11}I_1 + h_{12}V_2 \\ I_2 &= h_{21}I_1 + h_{22}V_2 \end{aligned}\right\} \quad \begin{pmatrix} V_1 \\ I_2 \end{pmatrix} = \begin{pmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{pmatrix} \begin{pmatrix} I_1 \\ V_2 \end{pmatrix}$$

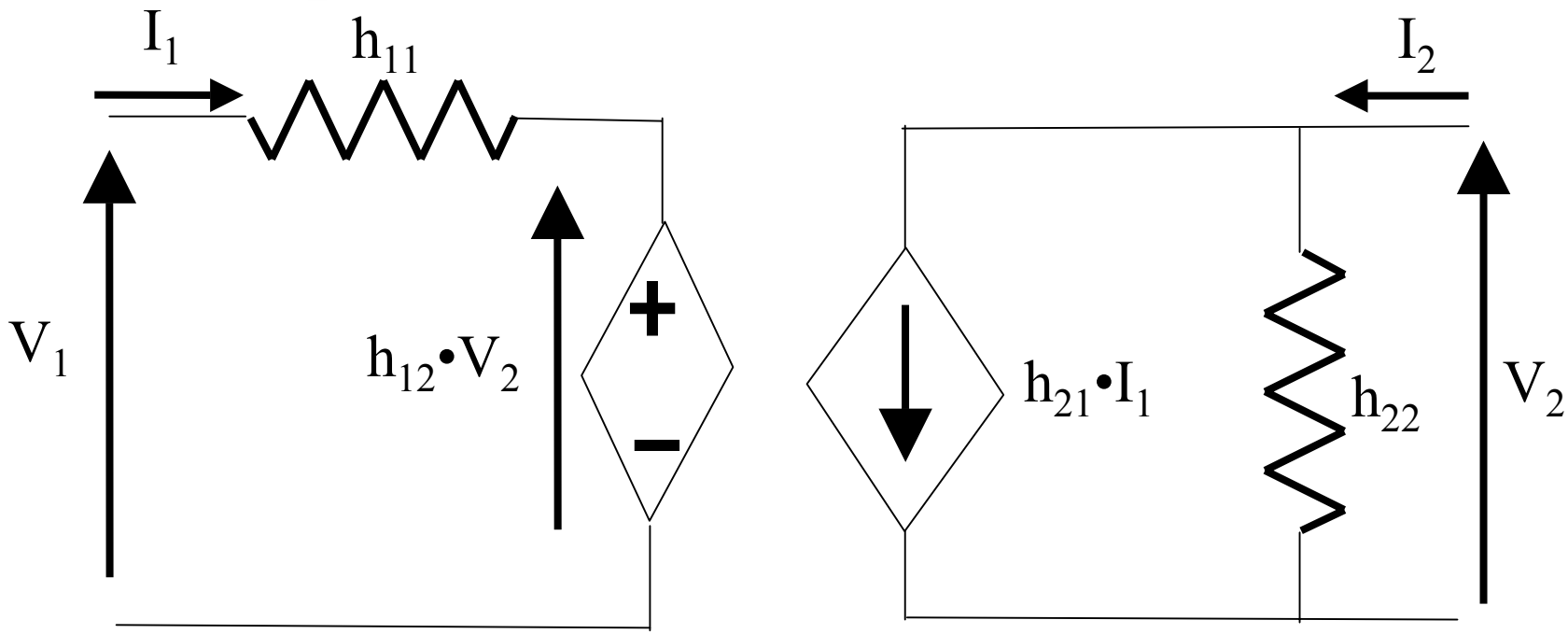
$h_{11} = V_1 / I_1 \,|\, V_2 = 0$ Z entrada cortocirc. a la salida
$h_{21} = I_2 / I_1 \,|\, V_2 = 0$ G corriente cortocirc. a la salida
$h_{12} = V_1 / V_2 \,|\, I_1 = 0$ G tensión circ. abierto a la entrada
$h_{22} = I_2 / V_2 \,|\, I_1 = 0$ Y salida circ. abierto a la entrada

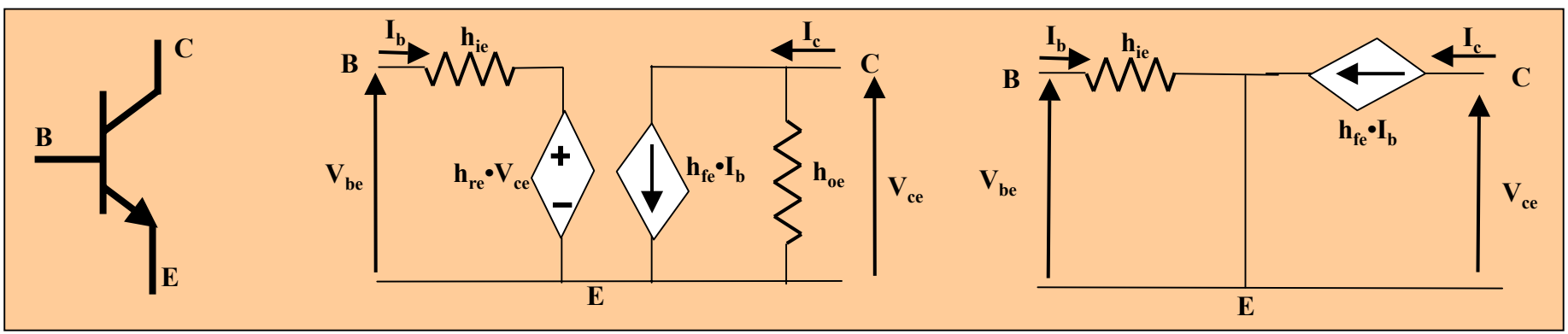




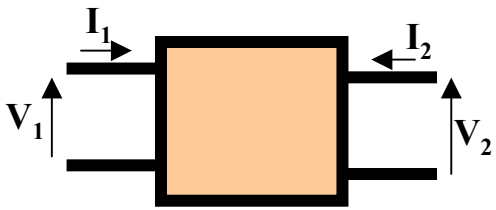
Parámetros Híbridos h

Circuito equivalente





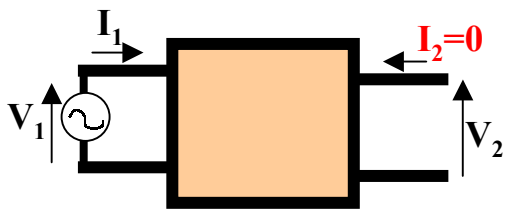
Parámetros Híbridos g

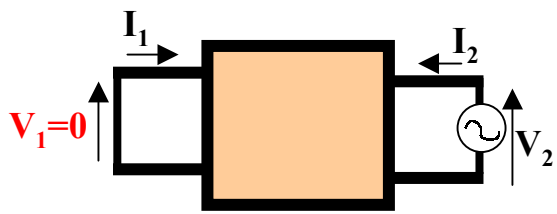


- Variables controladas I_1 V_2
- Variables controladoras I_2 V_1

$$\left.\begin{aligned} I_1 &= g_{11}V_1 + g_{12}I_2 \\ V_2 &= g_{21}V_1 + g_{22}I_2 \end{aligned}\right\} \quad \begin{pmatrix} I_1 \\ V_2 \end{pmatrix} = \begin{pmatrix} g_{11} & g_{12} \\ g_{21} & g_{22} \end{pmatrix} \begin{pmatrix} V_1 \\ I_2 \end{pmatrix}$$

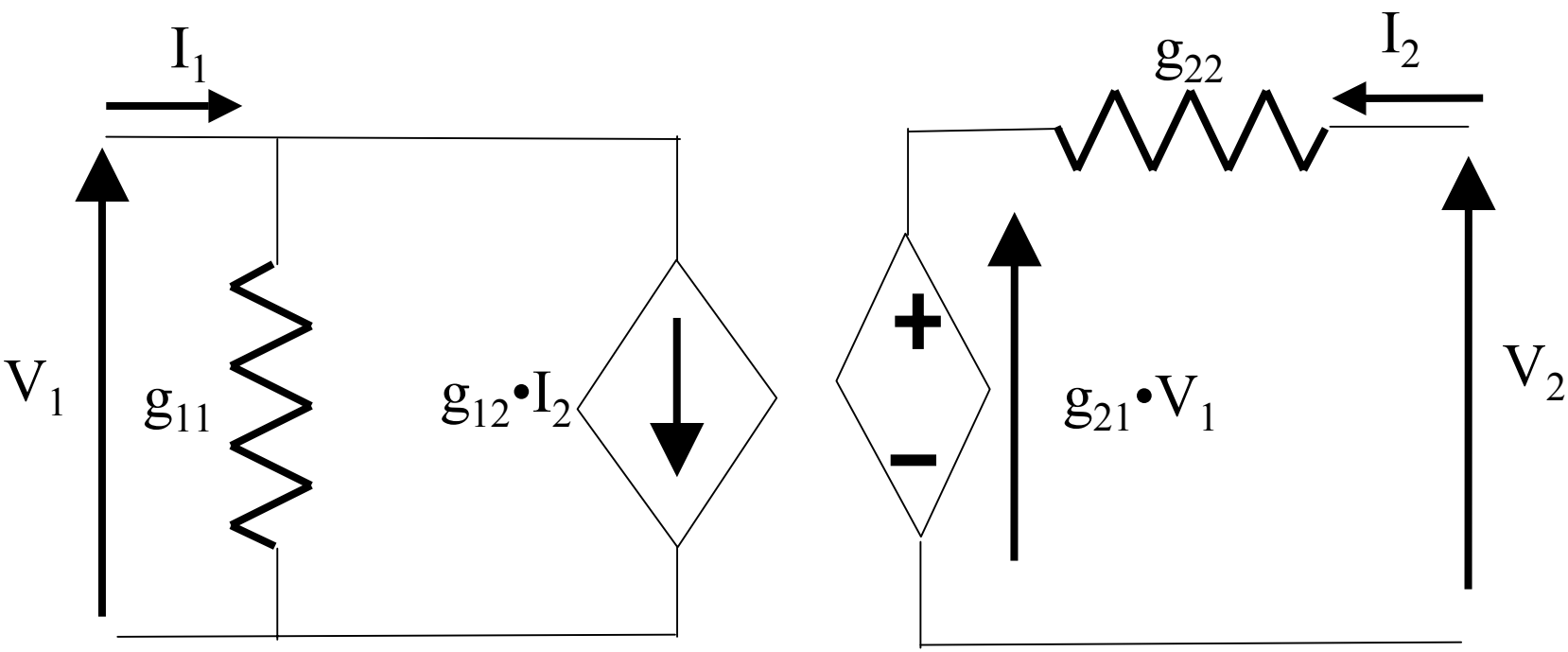
$g_{11} = I_1 / V_1 | I_2 = 0$ Y entrada circ. abierto a la salida
$g_{21} = V_2 / V_1 | I_2 = 0$ G tensión circ. abierto a la salida
$g_{12} = I_1 / I_2 | V_1 = 0$ G corriente cortocirc. a la entrada
$g_{22} = V_2 / I_2 | V_1 = 0$ Z salida cortocirc. a la entrada



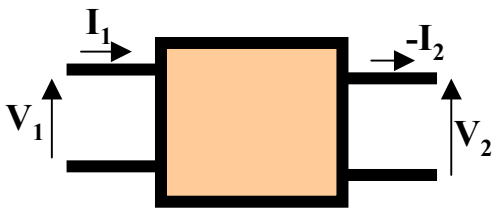


Parámetros Híbridos g

Circuito equivalente



Parámetros Transmisión ABCD

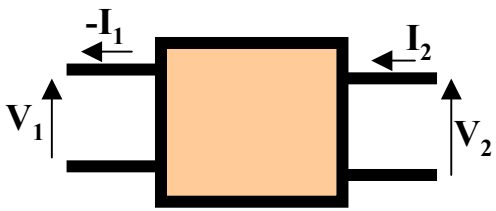


- Variables controladas I_1 V_1 (entrada)
- Variables controladoras I_2 V_2 (salida)

$$\left.\begin{aligned} V_1 &= AV_2 + BI_2 \\ I_1 &= CV_2 + DI_2 \end{aligned}\right\} \qquad \begin{pmatrix} V_1 \\ I_1 \end{pmatrix} = \begin{pmatrix} A & B \\ C & D \end{pmatrix} \begin{pmatrix} V_2 \\ -I_2 \end{pmatrix}$$

$A = V_1 / V_2 \,|\, I_2 = 0$ G inversa tensión circ. abierto a la salida
$C = I_1 / V_2 \,|\, I_2 = 0$ Y transf. entr.-salida circ. abierto a la salida
$B = V_1 / -I_2 \,|\, V_2 = 0$ Z transf. entr.-salida cortocirc. a la salida
$D = I_1 / -I_2 \,|\, V_2 = 0$ G inversa corriente cortocirc. a la salida

Parámetros Transmisión Inversa A'B'C'D'



- Variables controladas I_2 V_2 (salida)
- Variables controladoras I_1 V_1 (entrada)

$$\left.\begin{aligned} V_2 &= A'V_1 + B'I_1 \\ I_2 &= C'V_1 + D'I_1 \end{aligned}\right\} \qquad \begin{pmatrix} V_2 \\ I_2 \end{pmatrix} = \begin{pmatrix} A' & B' \\ C' & D' \end{pmatrix} \begin{pmatrix} V_1 \\ -I_1 \end{pmatrix}$$

$A' = V_2 / V_1 \,|\, I_1 = 0$ G inversa tensión circ. abierto a la entrada
$C' = I_2 / V_1 \,|\, I_1 = 0$ Y transf. salida-entr. circ. abierto a la entrada
$B' = V_2 / -I_1 \,|\, V_1 = 0$ Z transf. salida-entr. cortocirc. a la entrada
$D' = I_2 / -I_1 \,|\, V_2 = 0$ G inversa corriente cortocirc. a la entrada

Relación entre parámetros

- **Distintos parámetros => distintas combinaciones mismas variables**
- **Relaciones entre las matrices de parámetros**
- **Simplificaciones:**
  - **Pasivo (RLC):**

    $Z_{12}=Z_{21}$; $Y_{12}=Y_{21}$; AD-BC=1; $h_{12}=-h_{21}$; $g_{12}=-g_{21}$

  - **Pasivo y eléctricamente simétrico:**

    $Z_{11}=Z_{22}$; $Y_{11}=Y_{22}$; A=D ; |h|=1; |g|=1

Relación entre parámetros

$$Z = \begin{bmatrix} z_{11} & z_{12} \\ z_{21} & z_{22} \end{bmatrix}$$

Y	H	G	F
$\frac{z_{22}}{\lvert z\rvert}$ $-\frac{z_{12}}{\lvert z\rvert}$	$\frac{\lvert z\rvert}{z_{22}}$ $\frac{z_{12}}{z_{22}}$	$\frac{1}{z_{11}}$ $-\frac{z_{12}}{z_{11}}$	$\frac{z_{11}}{z_{21}}$ $\frac{\lvert z\rvert}{z_{21}}$
$-\frac{z_{21}}{\lvert z\rvert}$ $\frac{z_{11}}{\lvert z\rvert}$	$-\frac{z_{21}}{z_{22}}$ $\frac{1}{z_{22}}$	$\frac{z_{21}}{z_{11}}$ $\frac{\lvert z\rvert}{z_{11}}$	$\frac{1}{z_{21}}$ $\frac{z_{22}}{z_{21}}$

$$Y = \begin{bmatrix} y_{11} & y_{12} \\ y_{21} & y_{22} \end{bmatrix}$$

Z	H	G	F
$\frac{y_{22}}{\lvert y\rvert}$ $-\frac{y_{12}}{\lvert y\rvert}$	$\frac{1}{y_{11}}$ $-\frac{y_{12}}{y_{11}}$	$\frac{\lvert y\rvert}{y_{22}}$ $\frac{y_{12}}{y_{22}}$	$-\frac{y_{22}}{y_{21}}$ $-\frac{1}{y_{21}}$
$-\frac{y_{21}}{\lvert y\rvert}$ $\frac{y_{11}}{\lvert y\rvert}$	$\frac{y_{21}}{y_{11}}$ $\frac{\lvert y\rvert}{y_{11}}$	$-\frac{y_{21}}{y_{22}}$ $\frac{1}{y_{22}}$	$-\frac{\lvert y\rvert}{y_{21}}$ $-\frac{y_{11}}{y_{21}}$

$$H = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix}$$

Z	Y	G	F
$\frac{\lvert h\rvert}{h_{22}}$ $\frac{h_{12}}{h_{22}}$	$\frac{1}{h_{11}}$ $-\frac{h_{12}}{h_{11}}$	$\frac{h_{22}}{\lvert h\rvert}$ $-\frac{h_{12}}{\lvert h\rvert}$	$-\frac{\lvert h\rvert}{h_{21}}$ $-\frac{h_{11}}{h_{21}}$
$-\frac{h_{21}}{h_{22}}$ $\frac{1}{h_{22}}$	$\frac{h_{21}}{h_{11}}$ $\frac{\lvert h\rvert}{h_{11}}$	$-\frac{h_{21}}{\lvert h\rvert}$ $\frac{h_{11}}{\lvert h\rvert}$	$-\frac{h_{22}}{h_{21}}$ $-\frac{1}{h_{21}}$

$$G = \begin{bmatrix} g_{11} & g_{12} \\ g_{21} & g_{22} \end{bmatrix}$$

Z	Y	H	F
$\frac{1}{g_{11}}$ $-\frac{g_{12}}{g_{11}}$	$\frac{\lvert g\rvert}{g_{22}}$ $-\frac{g_{12}}{g_{22}}$	$\frac{g_{22}}{\lvert g\rvert}$ $-\frac{g_{12}}{\lvert g\rvert}$	$\frac{1}{g_{21}}$ $\frac{g_{22}}{g_{21}}$
$\frac{g_{21}}{g_{11}}$ $\frac{\lvert g\rvert}{g_{11}}$	$-\frac{g_{21}}{g_{22}}$ $\frac{1}{g_{22}}$	$-\frac{g_{21}}{\lvert g\rvert}$ $\frac{g_{11}}{\lvert g\rvert}$	$\frac{g_{11}}{g_{21}}$ $\frac{\lvert g\rvert}{g_{21}}$

$$F = \begin{bmatrix} A & B \\ C & D \end{bmatrix}$$

Z	Y	H	G
$\frac{A}{C}$ $\frac{\lvert F\rvert}{C}$	$\frac{D}{B}$ $-\frac{\lvert F\rvert}{B}$	$\frac{B}{D}$ $\frac{\lvert F\rvert}{D}$	$\frac{C}{A}$ $-\frac{\lvert F\rvert}{A}$
$\frac{1}{C}$ $\frac{D}{C}$	$-\frac{1}{B}$ $\frac{A}{B}$	$-\frac{1}{D}$ $\frac{C}{D}$	$\frac{1}{A}$ $\frac{B}{A}$

Asociación de Cuadripolos

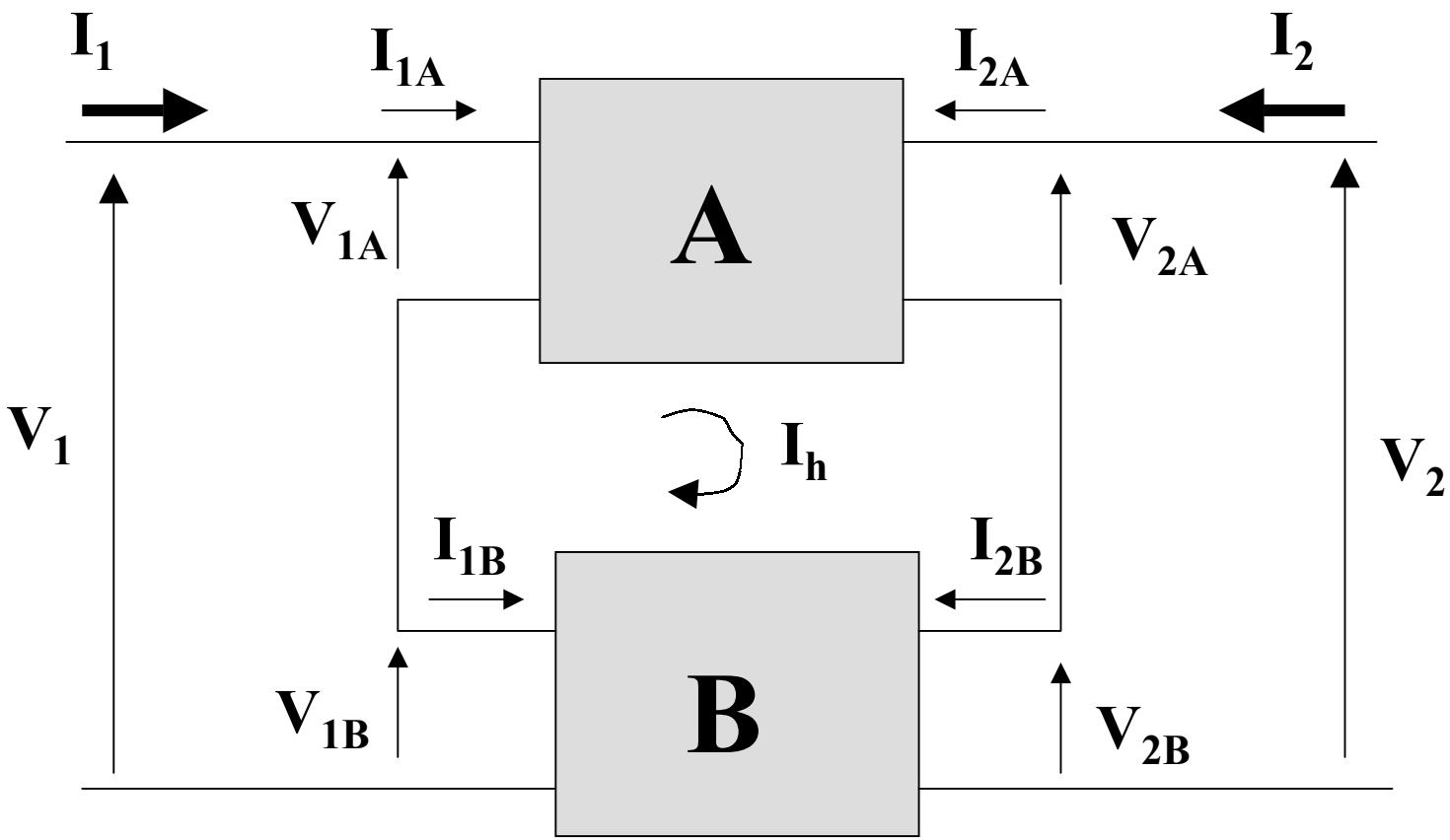
- **Asociando cuadripolos se obtiene un nuevo cuadripolo**
- **Los parámetros del nuevo cuadripolo se pueden obtener de los parámetros de los cuadripolos componentes**
- **Cuadripolos complejos se descomponen en otros sencillos asociados para obtener los parámetros globales**

Asociación de Cuadripolos

- **Asociaciones y parámetros que facilitan el cálculo de los parámetros totales:**
  - **Serie-serie => Z**
  - **Paralelo-paralelo => Y**
  - **Serie-paralelo => h**
  - **Paralelo-serie => g**
  - **Cascada => Transmisión**
- **Serie**
  - **Variable controlada V**
  - **Variable controladora I**
- **Paralelo**
  - **Variable controlada V**
  - **Variable controladora I**

Asociación Serie-Serie

Entradas y salidas en serie



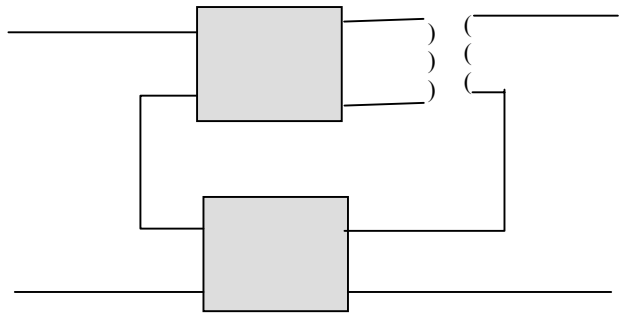
Asociación Serie-Serie

$$\mathbf{V_1=V_{1A}+V_{1B}} \qquad V_{1A}=I_{1A}\,Z_{11A}+I_{2A}\,Z_{12A}$$
$$V_{2A}=I_{1A}\,Z_{21A}+I_{2A}\,Z_{22A}$$

$$\mathbf{V_2=V_{2A}+V_{2B}}$$

$$\mathbf{I_1=I_{1A}=I_{1B}} \qquad V_{1B}=I_{1B}\,Z_{11B}+I_{2B}\,Z_{12B}$$
$$V_{2B}=I_{1B}\,Z_{21B}+I_{2B}\,Z_{22B}$$

$$\mathbf{I_2=I_{2A}=I_{2B}}$$



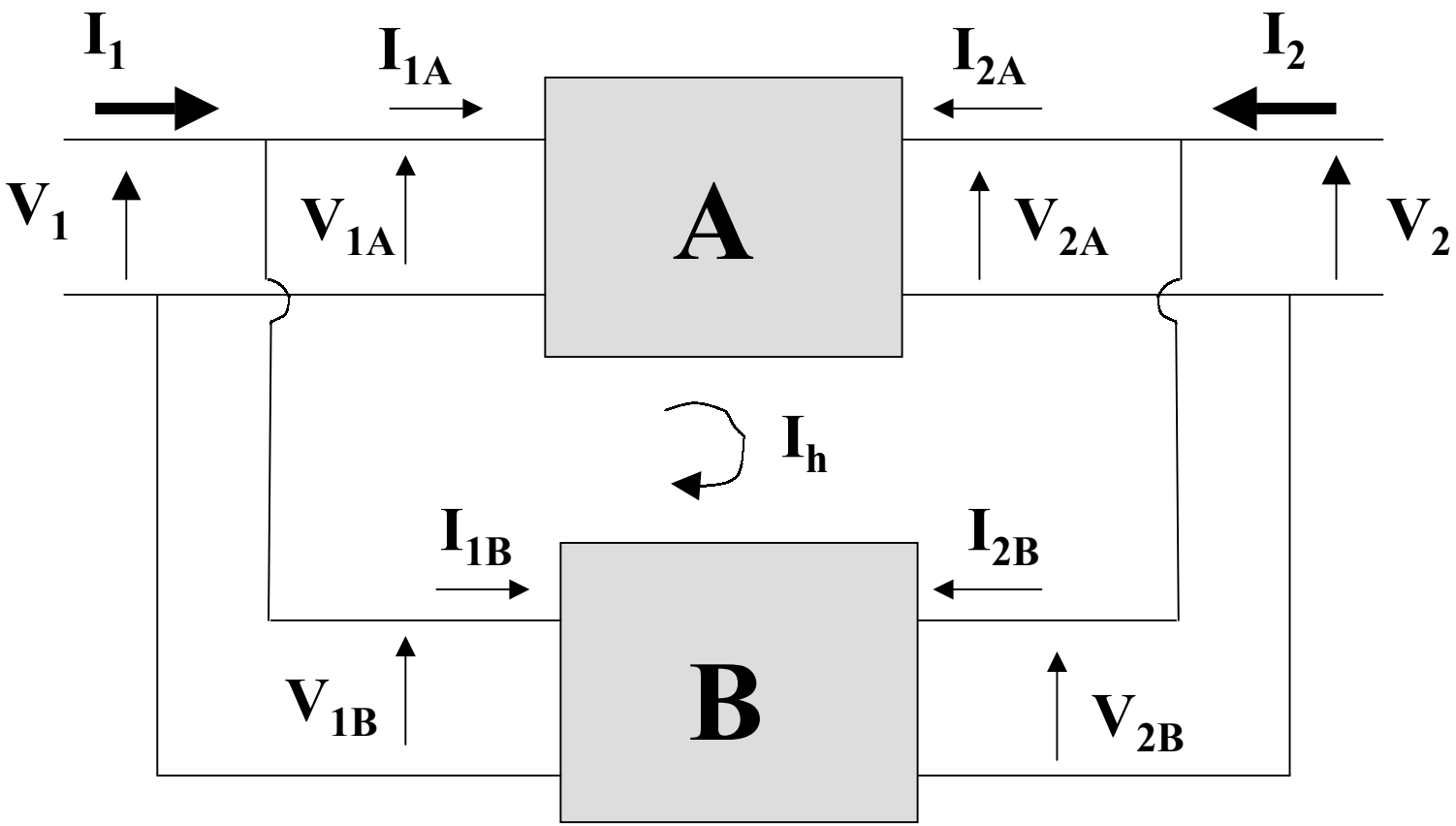
$$V_1=V_{1A}+V_{1A}=I_1\,(Z_{11A}+Z_{11B})+I_2\,(Z_{12A}+Z_{12B}) \qquad V_1=I_1\,Z_{11}+I_2\,Z_{12}$$
$$V_2=V_{2A}+V_{2A}=I_1\,(Z_{21A}+Z_{21B})+I_2\,(Z_{22A}+Z_{22B}) \qquad V_2=I_1\,Z_{21}+I_2\,Z_{22}$$

$$Z_{11}=Z_{11A}+Z_{11B} \qquad Z_{21}=Z_{21A}+Z_{21B}$$
$$Z_{12}=Z_{12A}+Z_{12B} \qquad Z_{22}=Z_{22A}+Z_{22B}$$

$$\mathbf{(Z)=(Z_A)+(Z_B)}$$

Asociación Paralelo-Paralelo

Entradas y salidas en paralelo



Asociación Paralelo-Paralelo

$$\mathbf{V_1=V_{1A}=V_{1B}}$$

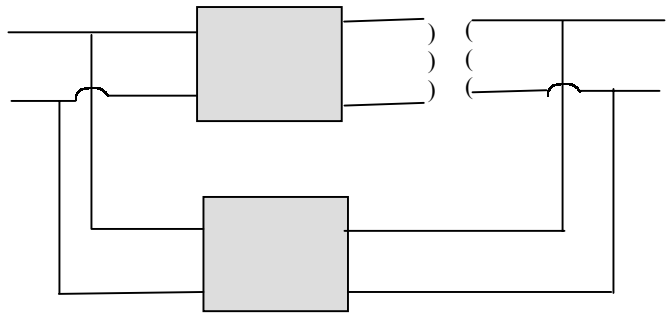
$$\mathbf{V_2=V_{2A}=V_{2B}}$$

$$\mathbf{I_1=I_{1A}+ I_{1B}}$$

$$\mathbf{I_2=I_{2A}+ I_{2B}}$$

$$\left.\begin{aligned} I_{1A}&=V_{1A}\ Y_{11A}+V_{2A}\ Y_{12A}\\ I_{2A}&=V_{1A}\ Z_{21A}+V_{2A}\ Y_{22A}\end{aligned}\right\}$$

$$\left.\begin{aligned} I_{1B}&=V_{1B}\ Y_{11B}+V_{2B}\ Y_{12B}\\ I_{2B}&=V_{1B}\ Y_{21B}+V_{2B}\ Y_{22B}\end{aligned}\right\}$$



$$I_h=0$$

$$\left.\begin{aligned} I_1&=I_{1A}+I_{1A}= V_1\ (Y_{11A}+ Y_{11B})+V_2\ (Y_{12A}+ Y_{12B})\\ I_2&=I_{2A}+I_{2A}= V_1\ (Y_{21A}+ Y_{21B})+V_2\ (Y_{22A}+ Y_{22B})\end{aligned}\right\} \quad \left.\begin{aligned} I_1&=V_1\ Y_{11}+V_2\ Y_{12}\\ I_2&=V_1\ Y_{21}+V_2\ Y_{22}\end{aligned}\right\}$$

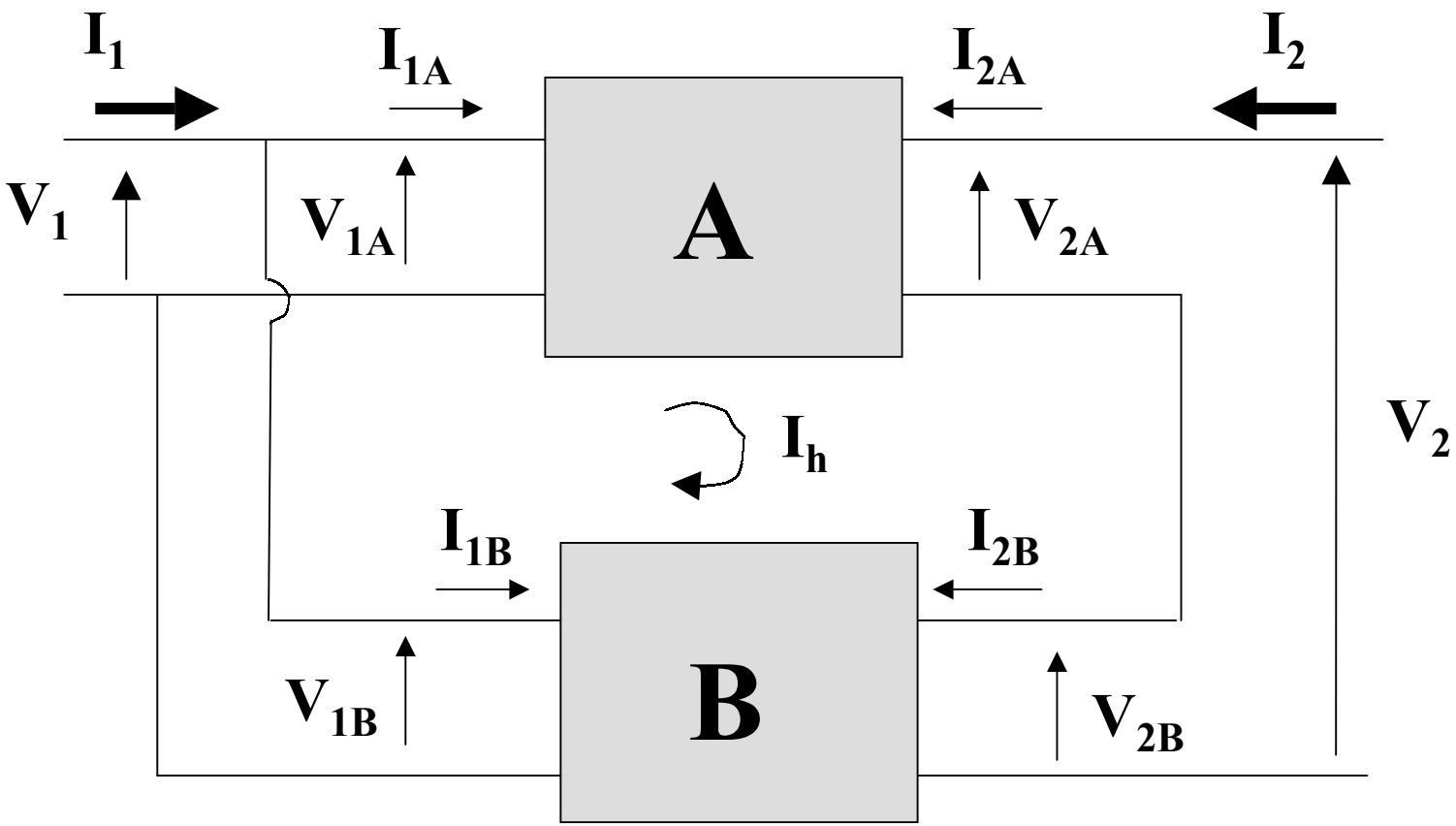
$$Y_{11}=Y_{11A}+ Y_{11B} \qquad Y_{21}=Y_{21A}+ Y_{21B}$$

$$Y_{12}=Y_{12A}+ Y_{12B} \qquad Y_{22}=Y_{22A}+ Y_{22B}$$

$$\mathbf{(Y)=(Y_A)+(Y_B)}$$

Asociación Paralelo-Serie

Entradas paralelo y salida en serie



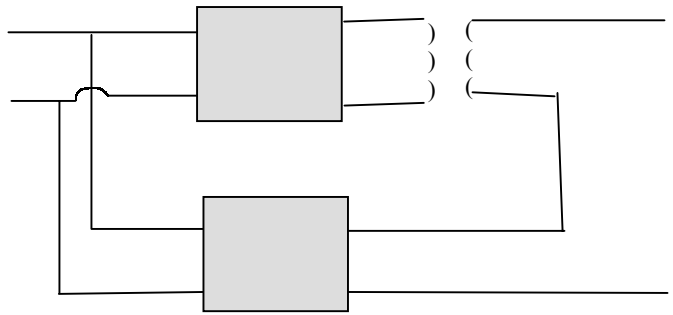
Asociación Paralelo-Serie

$$\mathbf{V_1=V_{1A}=V_{1B}} \qquad I_{1A}=V_{1A}\,g_{11A}+I_{2A}\,g_{12A}$$
$$V_{2A}=V_{1A}\,g_{21A}+I_{2A}\,g_{22A}$$

$$\mathbf{V_2=V_{2A}+V_{2B}}$$

$$\mathbf{I_1=I_{1A}+I_{1B}} \qquad I_{1B}=V_{1B}\,g_{11B}+I_{2B}\,g_{12B}$$
$$V_{2B}=V_{1B}\,g_{21B}+I_{2B}\,g_{22B}$$

$$\mathbf{I_2=I_{2A}=I_{2B}}$$



$I_h=0$

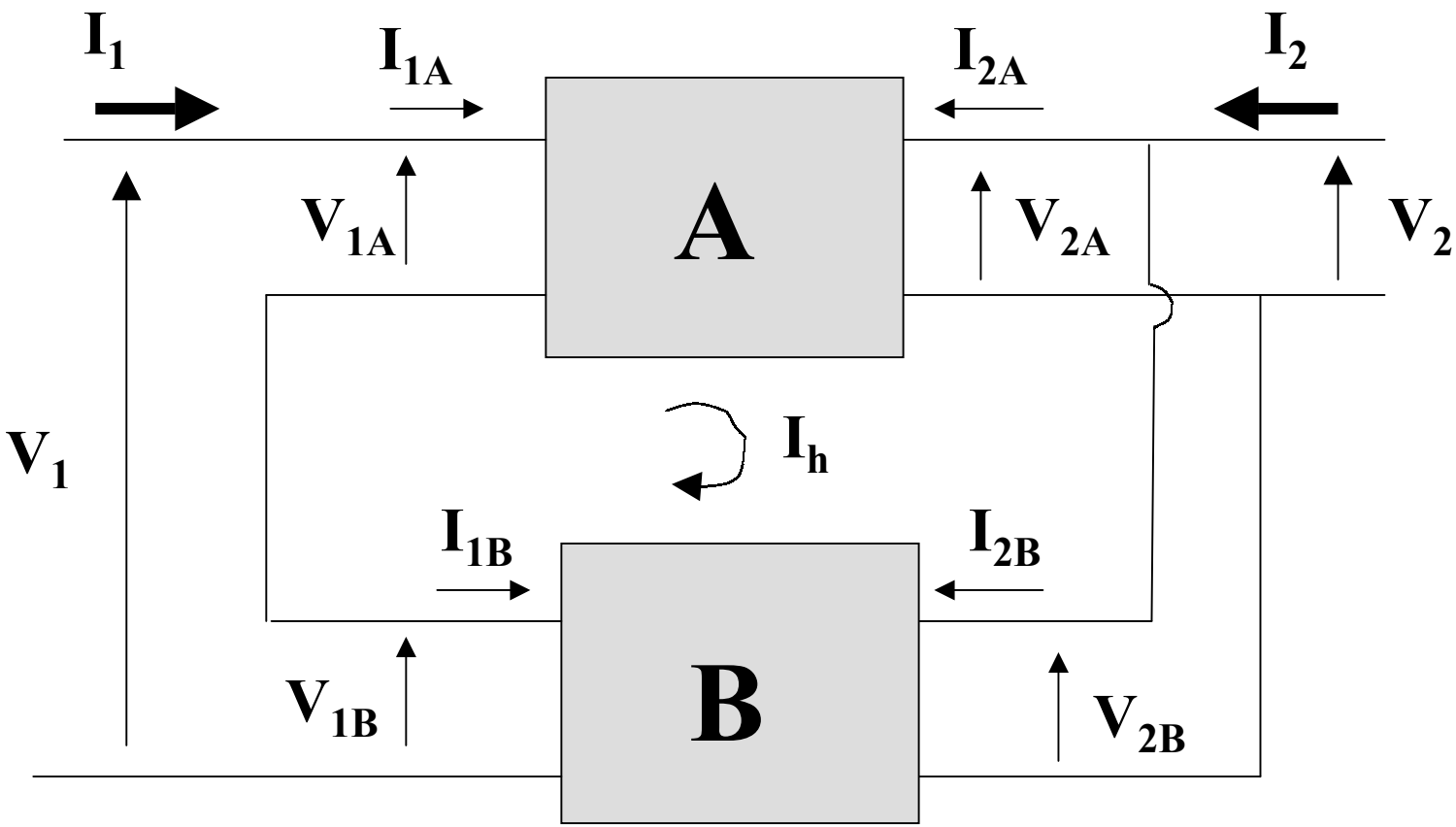
$$I_1=I_{1A}+I_{1A}=V_1\,(g_{11A}+g_{11B})+I_2\,(g_{12A}+g_{12B}) \qquad I_1=V_1\,g_{11}+I_2\,g_{12}$$
$$V_2=V_{2A}+V_{2A}=V_1\,(g_{21A}+g_{21B})+I_2\,(g_{22A}+g_{22B}) \qquad V_2=V_1\,g_{21}+I_2\,g_{22}$$

$$g_{11}=g_{11A}+g_{11B} \qquad g_{21}=g_{21A}+g_{21B}$$
$$g_{12}=g_{12A}+g_{12B} \qquad g_{22}=g_{22A}+g_{22B}$$

$$\mathbf{(g)=(g_A)+(g_B)}$$

Asociación Serie-Paralelo

Entradas serie y salida en paralelo



Asociación Serie- Paralelo

$\mathbf{V_1=V_{1A}+V_{1B}}$

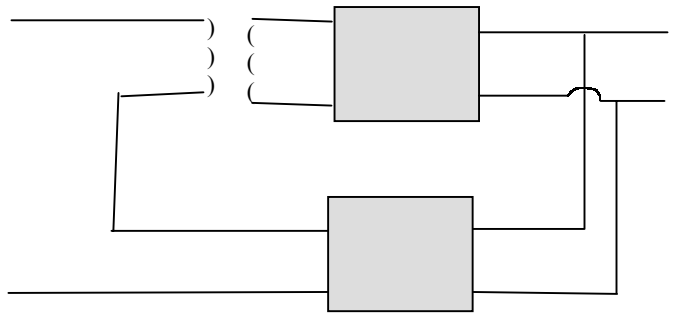
$\mathbf{V_2=V_{2A}=V_{2B}}$

$\mathbf{I_1=I_{1A}= I_{1B}}$

$\mathbf{I_2=I_{2A}+ I_{2B}}$

$$V_{1A}=I_{1A}\, h_{11A}+V_{2A}\, h_{12A}$$
$$I_{2A}=I_{1A}\, h_{21A}+V_{2A}\, h_{22A}$$

$$V_{1B}=I_{1B}\, h_{11B}+V_{2B}\, h_{12B}$$
$$I_{2B}=I_{1B}\, h_{21B}+V_{2B}\, h_{22B}$$



$I_h=0$

$$V_1=V_{1A}+V_{1A}= I_1\,(h_{11A}+ h_{11B})+V_2\,(h_{12A}+ h_{12B})$$
$$I_2=I_{2A}+I_{2A}= I_1\,(h_{21A}+ h_{21B})+V_2\,(h_{22A}+ h_{22B})$$

$$V_1=I_1\, h_{11}+V_2\, h_{12}$$
$$I_2=I_1\, h_{21}+V_2\, h_{22}$$

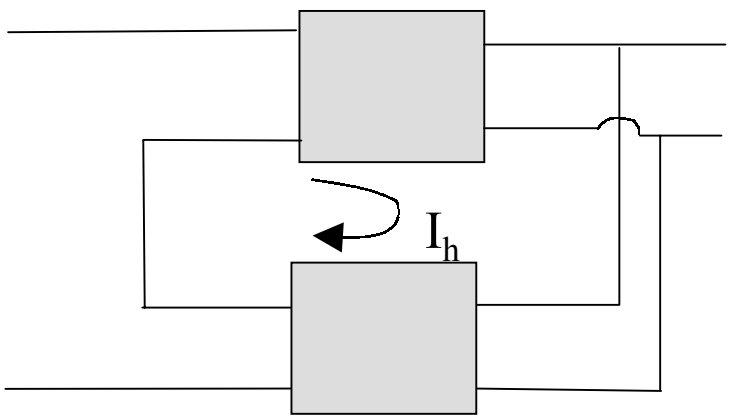
$h_{11}=h_{11A}+ h_{11B}$ $\quad$ $h_{21}=h_{21A}+ h_{21B}$

$h_{12}=h_{12A}+ h_{12B}$ $\quad$ $h_{22}=h_{22A}+ h_{22B}$

$$\mathbf{(h)=(h_A)+(h_B)}$$

Test de Brune

- **Permite comprobar si $I_h = 0$**
- **Calcula la contribución de las variables independientes a I_h por superposición si ambas dan 0 $I_h = 0$**
- **$I_h = 0$ => los cuadripolos no interaccionan entre si y no hace falta poner un transformador**



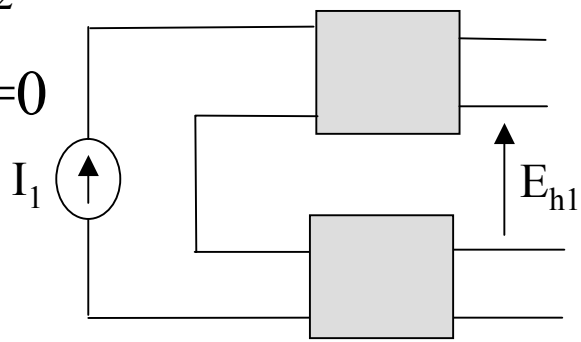
Test de Brune

Serie-Serie

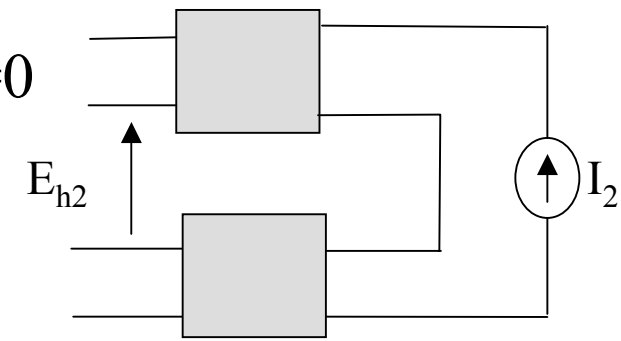
Variables independientes

I_1 e I_2

a) $I_2=0$



b) $I_1=0$



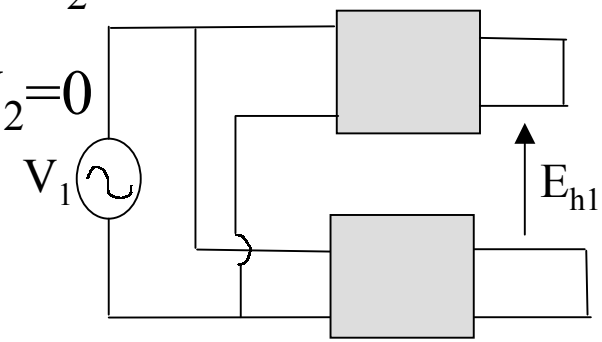
$E_{h1}=0$ y $E_{h2}=0$ => $I_h=0$

Paralelo-Paralelo

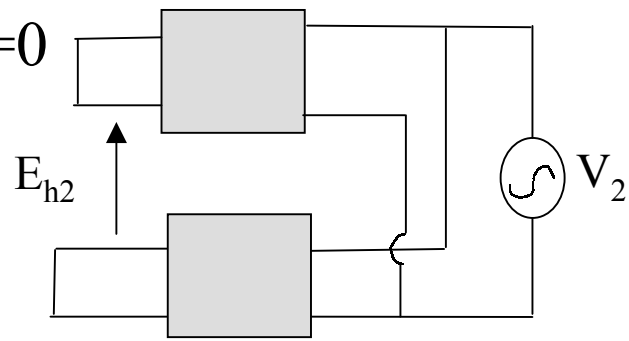
Variables independientes

V_1 y V_2

a) $V_2=0$



b) $V_1=0$



$E_{h1}=0$ y $E_{h2}=0$ => $I_h=0$

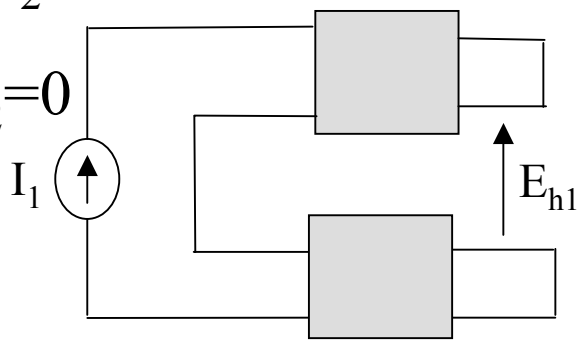
Test de Brune

Serie-Paralelo

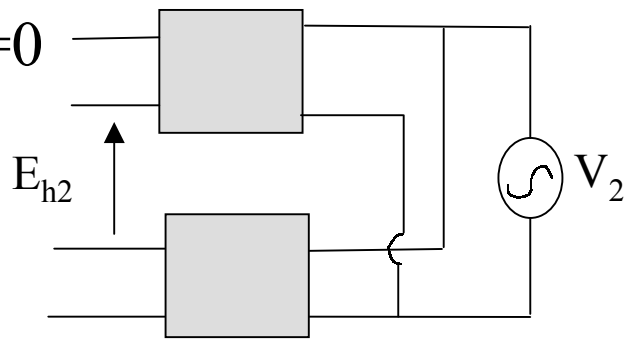
Variables independientes

I_1 y V_2

a) $V_2=0$



b) $I_1=0$



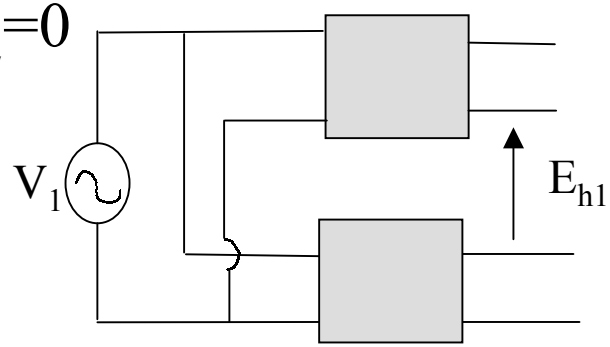
$E_{h1}=0$ y $E_{h2}=0$ => $I_h=0$

Paralelo-Serie

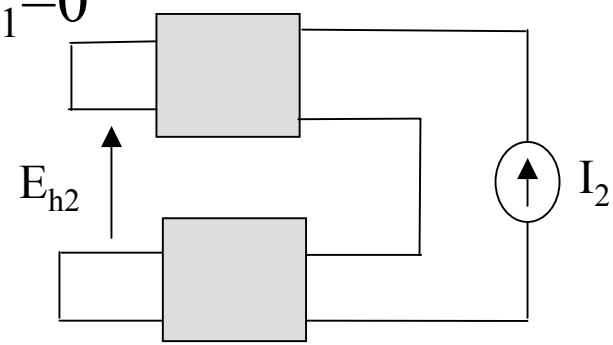
Variables independientes

V_1 e I_2

a) $I_2=0$

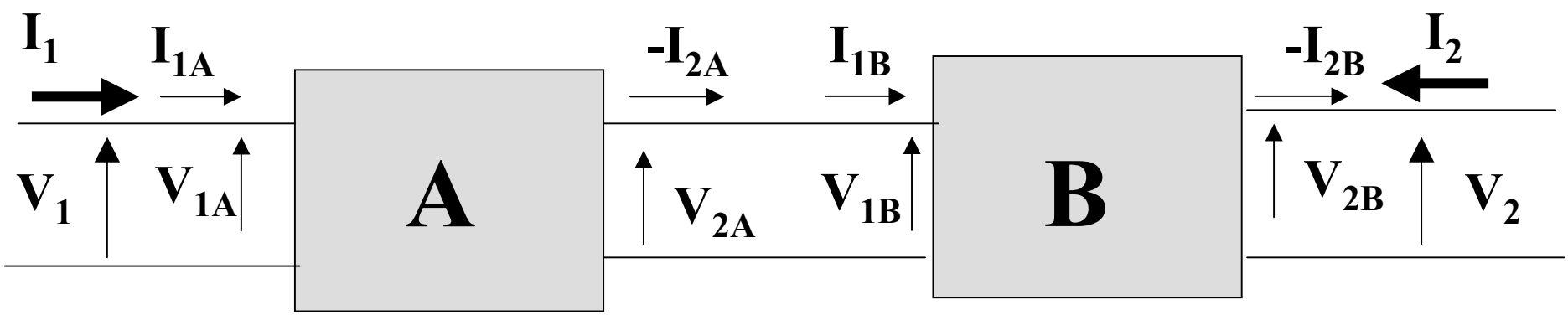


b) $V_1=0$



$E_{h1}=0$ y $E_{h2}=0$ => $I_h=0$

Asociación en Cascada



Asociación en Cascada

$V_1=V_{1A}$

$V_2=V_{2B}$

$I_1=I_{1A}$

$I_2=I_{2B}$

$I_{1B}=-I_{2A}$

$V_{1B}=V_{2A}$

$$\left.\begin{aligned} V_{1A}&=V_{2A}A_A-I_{2A}\,B_A \\ I_{1A}&=V_{2A}\,C_A-I_{2A}\,D_A \end{aligned}\right\} \qquad \left.\begin{aligned} V_{1B}&=V_{2B}A_B-I_{2B}\,B_B \\ I_{1B}&=V_{2B}\,C_B-I_{2B}\,D_B \end{aligned}\right\}$$

$$\begin{pmatrix} V_1 \\ I_1 \end{pmatrix} = \begin{pmatrix} V_{1A} \\ I_{1A} \end{pmatrix} = \begin{pmatrix} A_A & B_A \\ C_A & D_A \end{pmatrix} \begin{pmatrix} V_{2A} \\ -I_{2A} \end{pmatrix} = \begin{pmatrix} V_{1B} \\ I_{1B} \end{pmatrix}$$

$$\begin{pmatrix} V_{1B} \\ I_{1B} \end{pmatrix} = \begin{pmatrix} A_B & B_B \\ C_B & D_B \end{pmatrix} \begin{pmatrix} V_{2B} \\ -I_{2B} \end{pmatrix} = \begin{pmatrix} V_2 \\ -I_2 \end{pmatrix}$$

$$\begin{pmatrix} V_1 \\ I_1 \end{pmatrix} = \begin{pmatrix} A_A & B_A \\ C_A & D_A \end{pmatrix} \begin{pmatrix} A_B & B_B \\ C_B & D_B \end{pmatrix} \begin{pmatrix} V_2 \\ -I_2 \end{pmatrix} \qquad (F)=(F_A)*(F_B)$$