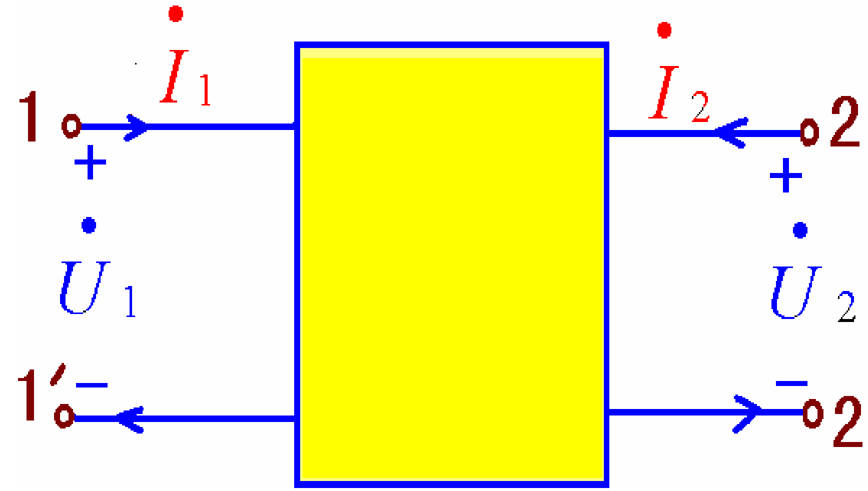
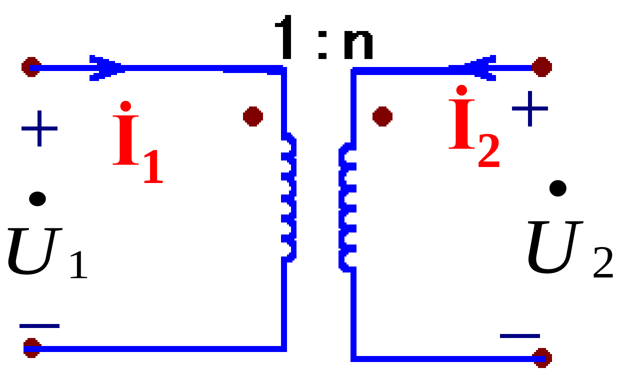
第十一章 二端口网络

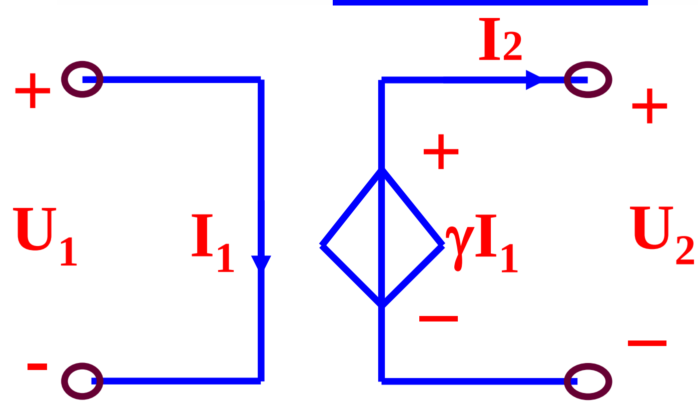
11-1 二端口网络



1、定义:

具有四个引出端纽，且每两个端纽流过同一电流的网络。

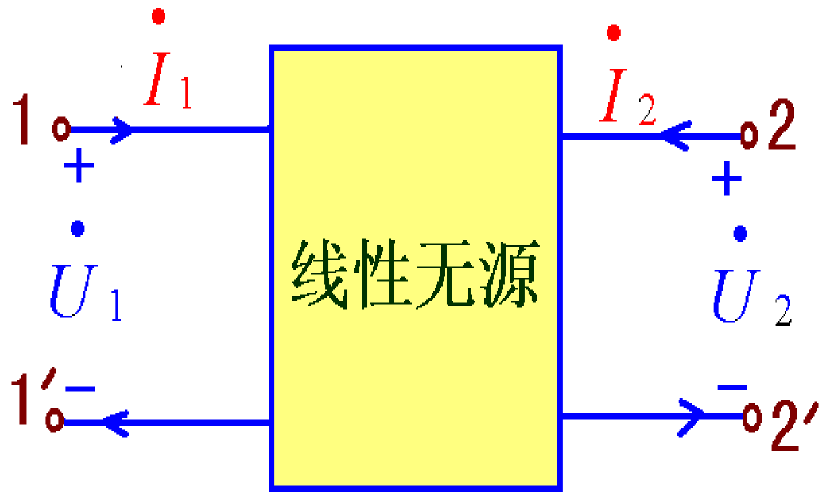




2、分类:

线　性	对　称	互　易	无　源
非线性	非对称	非互易	有　源

11-2 二端口网络方程与参数



二端口网络端口变量:

$\dot{U}_1$、$\dot{I}_1$、$\dot{U}_2$、$\dot{I}_2$

网络方程:

描述网络输入、输出端口电压、电流关系的方程。

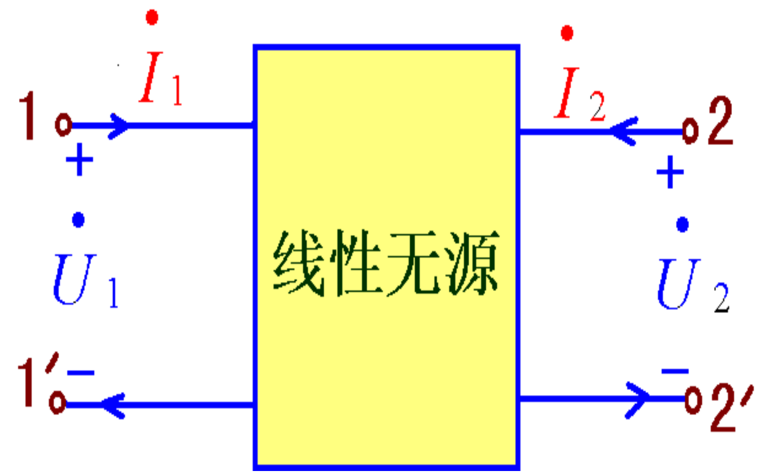
网络参数:

网络方程中的各个系数。

二端口网络方程与参数:

6种。

一、Z方程与参数（已知电流求电压）



1、方程:

$$\dot{U}_1 = z_{11}\dot{I}_1 + z_{12}\dot{I}_2$$

$$\dot{U}_2 = z_{21}\dot{I}_1 + z_{22}\dot{I}_2$$

2、参数:（开路阻抗参数）

$$z_{11} = \left.\frac{\dot{U}_1}{\dot{I}_1}\right|_{\dot{I}_2=0} \qquad z_{12} = \left.\frac{\dot{U}_1}{\dot{I}_2}\right|_{\dot{I}_1=0}$$

$$z_{21} = \left.\frac{\dot{U}_2}{\dot{I}_1}\right|_{\dot{I}_2=0} \qquad z_{22} = \left.\frac{\dot{U}_2}{\dot{I}_2}\right|_{\dot{I}_1=0}$$

3、网络的互易条件:

$$z_{12} = z_{21}$$

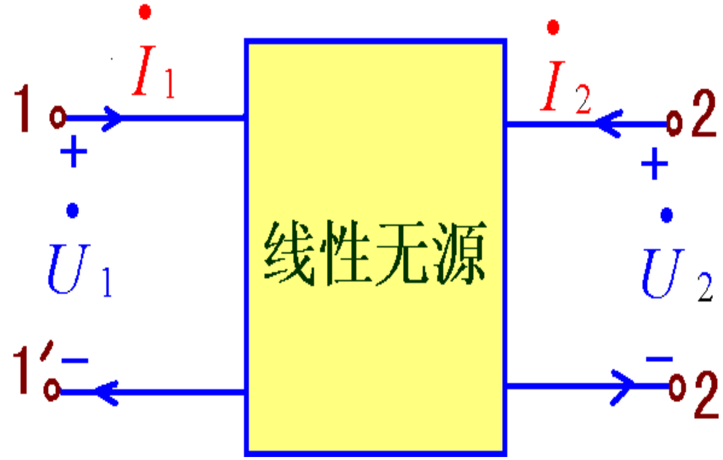
4、网络的对称条件:

$$z_{12} = z_{21} \qquad z_{11} = z_{22}$$

5、矩阵形式的Z方程

$$\begin{bmatrix} \dot{U}_1 \\ \dot{U}_2 \end{bmatrix} = \begin{bmatrix} z_{11} & z_{12} \\ z_{21} & z_{22} \end{bmatrix} \begin{bmatrix} \dot{I}_1 \\ \dot{I}_2 \end{bmatrix}$$

二、Y方程与参数（已知电压求电流）



1、方程:

$$\dot{I}_1 = y_{11}\dot{U}_1 + y_{12}\dot{U}_2$$

$$\dot{I}_2 = y_{21}\dot{U}_1 + y_{22}\dot{U}_2$$

2、参数:（短路导纳参数）

$$y_{11} = \left.\frac{\dot{I}_1}{\dot{U}_1}\right|_{\dot{U}_2=0} \qquad y_{12} = \left.\frac{\dot{I}_1}{\dot{U}_2}\right|_{\dot{U}_1=0}$$

$$y_{21} = \left.\frac{\dot{I}_2}{\dot{U}_1}\right|_{\dot{U}_2=0} \qquad y_{22} = \left.\frac{\dot{I}_2}{\dot{U}_2}\right|_{\dot{U}_1=0}$$

3、网络的互易条件: $y_{12} = y_{21}$

4、网络的对称条件:

$y_{12} = y_{21}$ $y_{11} = y_{22}$

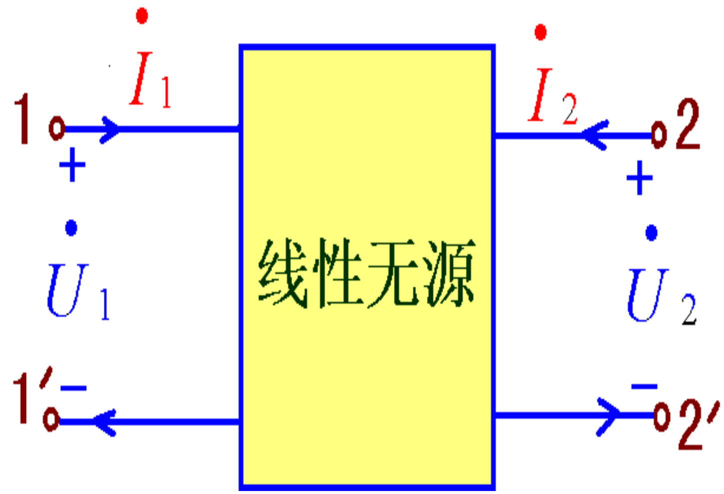
5、矩阵形式的Y方程

$$\begin{bmatrix} \dot{I}_1 \\ \dot{I}_2 \end{bmatrix} = \begin{bmatrix} y_{11} & y_{12} \\ y_{21} & y_{22} \end{bmatrix} \begin{bmatrix} \dot{U}_1 \\ \dot{U}_2 \end{bmatrix}$$

6、Z与Y关系

$$[Y] = [Z]^{-1}$$

三、A方程与参数（已知2端口求1端口）



1、方程:

$$\dot{U}_1 = a_{11}\dot{U}_2 + a_{12}(-\dot{I}_2)$$

$$\dot{I}_1 = a_{21}\dot{U}_2 + a_{22}(-\dot{I}_2)$$

2、参数:（混合参数）

$$a_{11} = \left.\frac{\dot{U}_1}{\dot{U}_2}\right|_{\dot{I}_2=0} \qquad a_{12} = \left.\frac{\dot{U}_1}{-\dot{I}_2}\right|_{\dot{U}_2=0}$$

$$a_{21} = \left.\frac{\dot{I}_1}{\dot{U}_2}\right|_{\dot{I}_2=0} \qquad a_{22} = \left.\frac{\dot{I}_1}{-\dot{I}_2}\right|_{\dot{U}_2=0}$$

3、网络的互易条件:

$$a_{11}a_{22} - a_{12}a_{21} = 1$$

即, $|\mathbf{A}| = 1$

4、网络的对称条件:

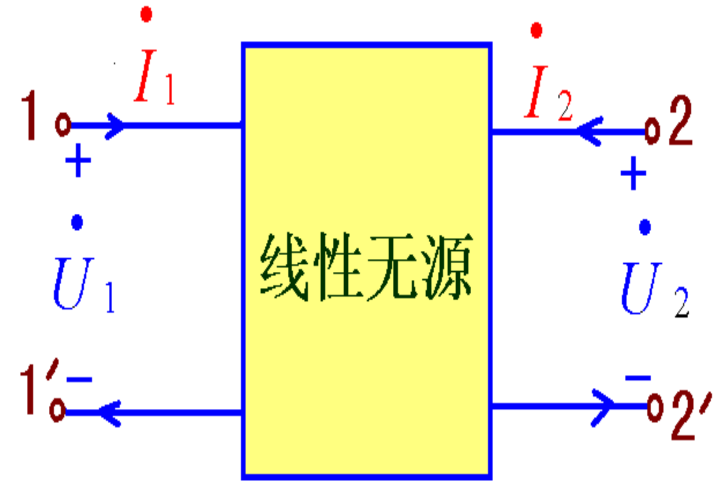
$$a_{11}a_{22} - a_{12}a_{21} = 1$$

且， $a_{11} = a_{22}$

5、矩阵形式的A方程

$$\begin{bmatrix} \dot{U}_1 \\ \dot{I}_1 \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} \begin{bmatrix} \dot{U}_2 \\ -\dot{I}_2 \end{bmatrix}$$

四、B方程与参数(已知1端口求2端口)



1、方程:

$$\dot{U}_2 = b_{11}\dot{U}_1 + b_{12}(-\dot{I}_1)$$

$$\dot{I}_2 = b_{21}\dot{U}_1 + b_{22}(-\dot{I}_1)$$

2、参数:(混合参数)

$$b_{11} = \frac{\dot{U}_2}{\dot{U}_1}\Big|_{\dot{I}_1=0} \qquad b_{12} = \frac{\dot{U}_2}{-\dot{I}_1}\Big|_{\dot{U}_1=0}$$

$$b_{21} = \frac{\dot{I}_2}{\dot{U}_1}\Big|_{\dot{I}_1=0} \qquad b_{22} = \frac{\dot{I}_2}{-\dot{I}_1}\Big|_{\dot{U}_1=0}$$

3、网络的互易条件:

$$b_{11}b_{22} - b_{12}b_{21} = 1$$

或,$|\mathbf{B}| = 1$

4、网络的对称条件:

$$b_{11}b_{22} - b_{12}b_{21} = 1$$

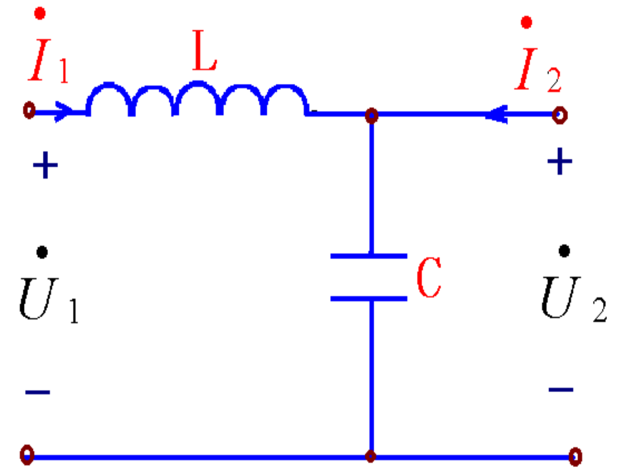
且,$b_{11} = b_{22}$

5、矩阵形式的B方程

$$\begin{bmatrix} \dot{U}_2 \\ \dot{I}_2 \end{bmatrix} = \begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix} \begin{bmatrix} \dot{U}_1 \\ -\dot{I}_1 \end{bmatrix}$$

6、注意: $[A] \neq [B]^{-1}$

例1: 图示二端口网络，求Z、Y、A参数。



方法有三:

1. 由物理意义求;
2. 写标准方程，由系数求得;
3. 由参数之间的关系求。

解:

$$\dot{U}_1=(j\omega L_1+\frac{1}{j\omega C})\dot{I}_1+\frac{1}{j\omega C}\dot{I}_2$$

$$\dot{U}_2=\frac{1}{j\omega C}\dot{I}_1+\frac{1}{j\omega C}\dot{I}_2$$

$$[Z]=\begin{bmatrix} j\omega L+\dfrac{1}{j\omega C} & \dfrac{1}{j\omega C} \\ \dfrac{1}{j\omega C} & \dfrac{1}{j\omega C} \end{bmatrix}$$

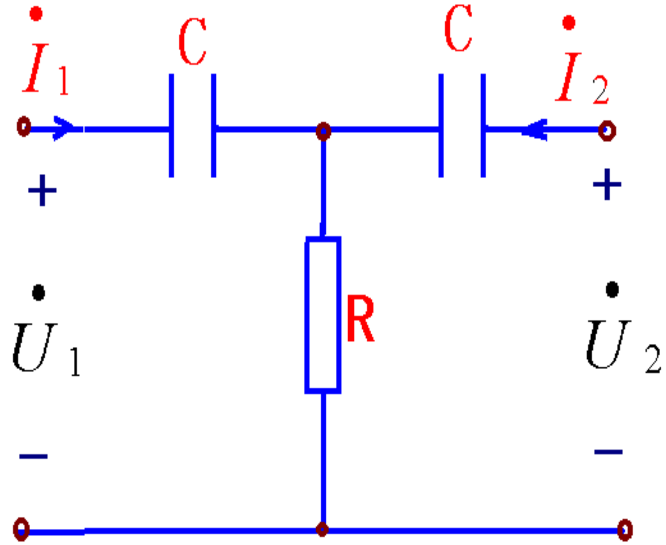
$$[Y]=\begin{bmatrix} \dfrac{1}{j\omega L} & -\dfrac{1}{j\omega L} \\ -\dfrac{1}{j\omega L} & j(\omega C-\dfrac{1}{\omega L}) \end{bmatrix}$$

$$\dot{U}_1=j\omega L(j\omega C\dot{U}_2-\dot{I}_2)+\dot{U}_2$$

$$\dot{I}_1=j\omega C\dot{U}_2-\dot{I}_2$$

$$[A]=\begin{bmatrix} (1-\omega^2LC) & j\omega L \\ j\omega C & 1 \end{bmatrix}$$

例2：图示二端口网络，求Z、Y、A参数。



解：$$z_{11}=\left.\frac{\dot{U}_1}{\dot{I}_1}\right|_{\dot{I}_2=0}=R+\frac{1}{j\omega C}=z_{22}$$

$$z_{12}=\left.\frac{\dot{U}_1}{\dot{I}_2}\right|_{\dot{I}_1=0}=\mathrm{R}=z_{21}$$

$$[Z]=\begin{bmatrix} R+\frac{1}{j\omega C} & R \\ R & R+\frac{1}{j\omega C} \end{bmatrix}$$

$$[\mathrm{Y}]=\begin{bmatrix} \frac{\mathrm{j}\omega\mathrm{C}-\omega^2\mathrm{C}^2\mathrm{R}}{1+\mathrm{j}2\omega\mathrm{CR}} & \frac{\mathrm{R}\omega^2\mathrm{C}^2}{1+\mathrm{j}2\omega\mathrm{CR}} \\ \frac{\mathrm{R}\omega^2\mathrm{C}^2}{1+\mathrm{j}2\omega\mathrm{CR}} & \frac{\mathrm{j}\omega\mathrm{C}-\omega^2\mathrm{C}^2\mathrm{R}}{1+\mathrm{j}2\omega\mathrm{CR}} \end{bmatrix}$$

$$\dot{U}_1=z_{11}\dot{I}_1+z_{12}\dot{I}_2$$
$$\dot{U}_2=z_{21}\dot{I}_1+z_{22}\dot{I}_2$$

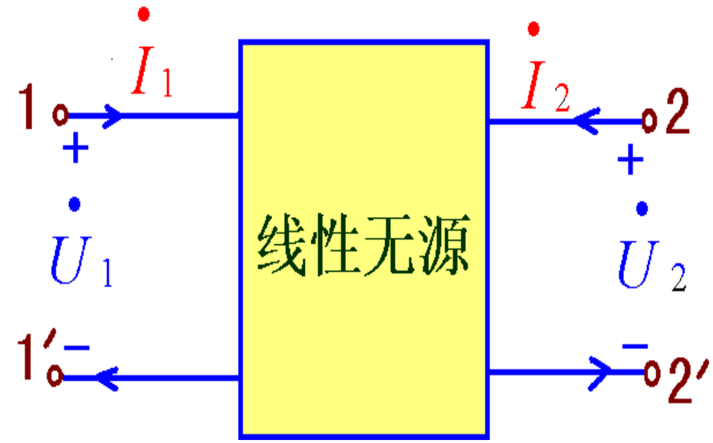
$$a_{11}=\left.\frac{\dot{U}_1}{\dot{U}_2}\right|_{\dot{I}_2=0}=\frac{1+\mathrm{j}\omega\mathrm{CR}}{\mathrm{j}\omega\mathrm{CR}}=a_{22}$$

$$a_{21}=\left.\frac{\dot{I}_1}{\dot{U}_2}\right|_{\dot{I}_2=0}=\frac{1}{\mathrm{R}}$$

$$a_{12}=\left.\frac{\dot{U}_1}{-\dot{I}_2}\right|_{\dot{U}_2=0}=\frac{1+\mathrm{j}2\omega\mathrm{CR}}{-\omega^2\mathrm{C}^2\mathrm{R}}$$

$$\dot{U}_1=a_{11}\dot{U}_2+a_{12}(-\dot{I}_2)$$
$$\dot{I}_1=a_{21}\dot{U}_2+a_{22}(-\dot{I}_2)$$

五、H方程与参数（已知$\dot{I}_1$、$\dot{U}_2$求$\dot{I}_2$、$\dot{U}_1$）



1、方程:

$$\dot{U}_1 = h_{11}\dot{I}_1 + h_{12}\dot{U}_2$$

$$\dot{I}_2 = h_{21}\dot{I}_1 + h_{22}\dot{U}_2$$

2、参数:（混合参数）

$$h_{11} = \frac{\dot{U}_1}{\dot{I}_1}\bigg|_{\dot{U}_2=0} \qquad h_{12} = \frac{\dot{U}_1}{\dot{U}_2}\bigg|_{\dot{I}_1=0}$$

$$h_{21} = \frac{\dot{I}_2}{\dot{I}_1}\bigg|_{\dot{U}_2=0} \qquad h_{22} = \frac{\dot{I}_2}{\dot{U}_2}\bigg|_{\dot{I}_1=0}$$

3、网络的互易条件: $h_{12} = -h_{21}$

4、网络的对称条件:

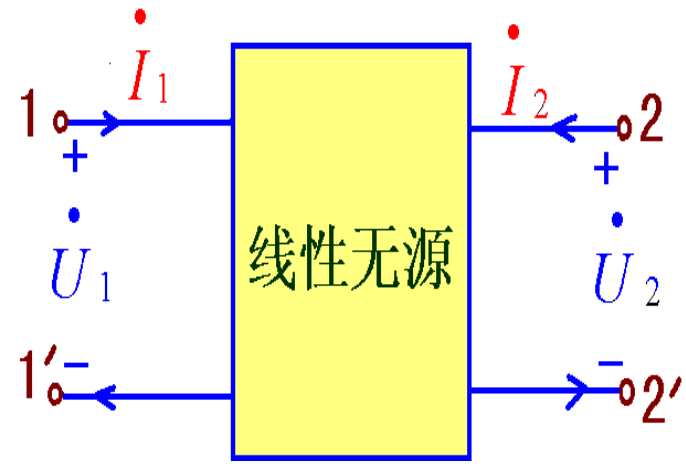
$$h_{12} = -h_{21}$$

且，$h_{11}h_{22} - h_{12}h_{21} = 1$

5、矩阵形式方程

$$\begin{bmatrix} \dot{U}_1 \\ \dot{I}_2 \end{bmatrix} = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix} \begin{bmatrix} \dot{I}_1 \\ \dot{U}_2 \end{bmatrix}$$

六、G方程与参数（已知$\dot{I}_2$、$\dot{U}_1$求$\dot{I}_1$、$\dot{U}_2$）



1、方程:

$$\dot{I}_1 = g_{11}\dot{U}_1 + g_{12}\dot{I}_2$$
$$\dot{U}_2 = g_{21}\dot{U}_1 + g_{22}\dot{I}_2$$

2、参数:（混合参数）

$$g_{11} = \left.\frac{\dot{I}_1}{\dot{U}_1}\right|_{\dot{I}_2=0} \qquad g_{12} = \left.\frac{\dot{I}_1}{\dot{I}_2}\right|_{\dot{U}_1=0}$$

$$g_{21} = \left.\frac{\dot{U}_2}{\dot{U}_1}\right|_{\dot{I}_2=0} \qquad g_{22} = \left.\frac{\dot{U}_2}{\dot{I}_2}\right|_{\dot{U}_1=0}$$

3、网络的互易条件：$g_{12} = -g_{21}$

4、网络的对称条件:

$$g_{12} = -g_{21}$$

且，$g_{11}g_{22} - g_{12}g_{21} = 1$

5、矩阵形式方程

$$\begin{bmatrix} \dot{I}_1 \\ \dot{U}_2 \end{bmatrix} = \begin{bmatrix} g_{11} & g_{12} \\ g_{21} & g_{22} \end{bmatrix} \begin{bmatrix} \dot{U}_1 \\ \dot{I}_2 \end{bmatrix}$$

6、H与G关系 $[H] = [G]^{-1}$

网络方程与参数小结：

Z： 已知电流求电压

$$\begin{bmatrix} \dot{U}_1 \\ \dot{U}_2 \end{bmatrix} = \begin{bmatrix} z_{11} & z_{12} \\ z_{21} & z_{22} \end{bmatrix} \begin{bmatrix} \dot{I}_1 \\ \dot{I}_2 \end{bmatrix}$$

$$Y = Z^{-1}$$

Y： 已知电压求电流

$$\begin{bmatrix} \dot{I}_1 \\ \dot{I}_2 \end{bmatrix} = \begin{bmatrix} y_{11} & y_{12} \\ y_{21} & y_{22} \end{bmatrix} \begin{bmatrix} \dot{U}_1 \\ \dot{U}_2 \end{bmatrix}$$

A： 已知2端口求1端口

$$\begin{bmatrix} \dot{U}_1 \\ \dot{I}_1 \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} \begin{bmatrix} \dot{U}_2 \\ -\dot{I}_2 \end{bmatrix}$$

$$A \neq B^{-1}$$

B： 已知1端口求2端口

$$\begin{bmatrix} \dot{U}_2 \\ \dot{I}_2 \end{bmatrix} = \begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix} \begin{bmatrix} \dot{U}_1 \\ -\dot{I}_1 \end{bmatrix}$$

H： 已知I_1，U_2求I_2，U_1

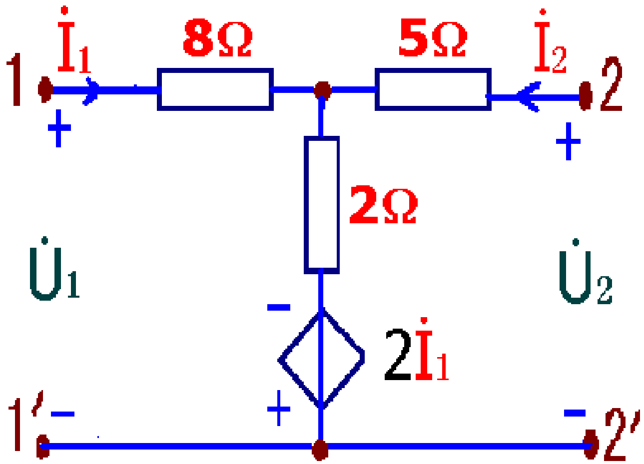
$$\begin{bmatrix} \dot{U}_1 \\ \dot{I}_2 \end{bmatrix} = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix} \begin{bmatrix} \dot{I}_1 \\ \dot{U}_2 \end{bmatrix}$$

$$\mathbf{G} = \mathbf{H}^{-1}$$

G： 已知U_1，I_2求U_2，I_1

$$\begin{bmatrix} \dot{I}_1 \\ \dot{U}_2 \end{bmatrix} = \begin{bmatrix} g_{11} & g_{12} \\ g_{21} & g_{22} \end{bmatrix} \begin{bmatrix} \dot{U}_1 \\ \dot{I}_2 \end{bmatrix}$$

例1: 图示二端口网络，求Z 、 Y 参数。



解:

$$\dot{U}_1 = 8\dot{I}_1 + 2(\dot{I}_1 + \dot{I}_2) - 2\dot{I}_1$$

$$= 8\dot{I}_1 + 2\dot{I}_2$$

$$\dot{U}_2 = 5\dot{I}_2 + 2(\dot{I}_1 + \dot{I}_2) - 2\dot{I}_1$$

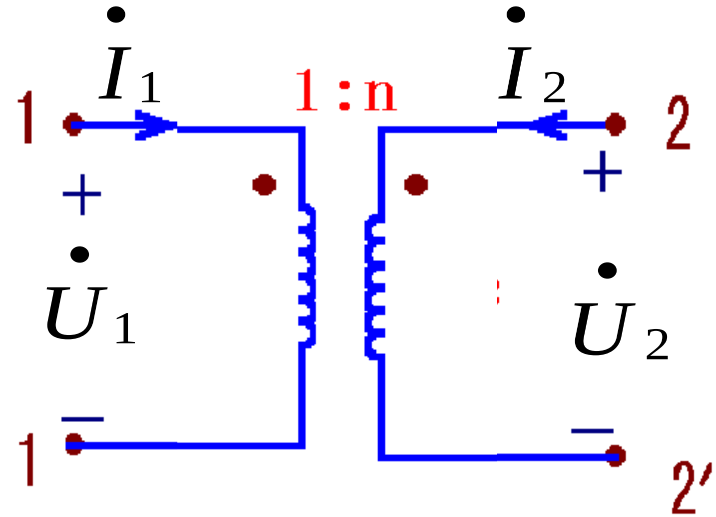
$$= 7\dot{I}_2$$

$$\begin{bmatrix} \dot{U}_1 \\ \dot{U}_2 \end{bmatrix} = \begin{bmatrix} 8 & 2 \\ 0 & 7 \end{bmatrix} \begin{bmatrix} \dot{I}_1 \\ \dot{I}_2 \end{bmatrix}$$

$$[Z] = \begin{bmatrix} 8 & 2 \\ 0 & 7 \end{bmatrix}$$

$$[Y] = [Z]^{-1} = \begin{bmatrix} 1/8 & -1/28 \\ 0 & 1/7 \end{bmatrix}$$

例2：图示二端口网络，求A参数。



解：（a）耦合电感，有

$$\dot{U}_1 = j\omega L_1 \dot{I}_1 + j\omega M \dot{I}_2 \qquad (1)$$

$$\dot{U}_2 = j\omega M \dot{I}_1 + j\omega L_2 \dot{I}_2 \qquad (2)$$

由（2）式，可有：

$$\dot{I}_1 = \frac{1}{j\omega M}\dot{U}_2 + \frac{j\omega L_2}{j\omega M}(-\dot{I}_2)$$

代入（1）式，有：

$$\dot{U}_1 = j\omega L_1\left[\frac{1}{j\omega M}\dot{U}_2 + \frac{j\omega L_2}{j\omega M}(-\dot{I}_2)\right] + j\omega M \dot{I}_2$$

$$= \frac{L_1}{M}\dot{U}_2 + j\omega\frac{L_1 L_2 - M^2}{M}(-\dot{I}_2)$$

$$[A] = \begin{bmatrix} \dfrac{L_1}{M} & j\omega\dfrac{L_1 L_2 - M^2}{M} \\ \dfrac{1}{j\omega M} & \dfrac{L_2}{M} \end{bmatrix}$$

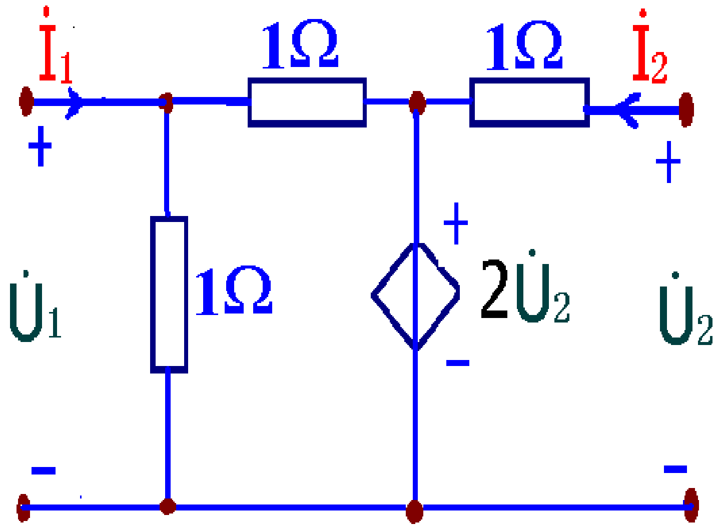
(b)理想变压器，有：

$$\dot{U}_1 = \frac{1}{n}\dot{U}_2$$

$$\dot{I}_1 = -n\dot{I}_2$$

$$[A] = \begin{bmatrix} \dfrac{1}{n} & 0 \\ 0 & n \end{bmatrix}$$

例3: 图示二端口网络，求H、Z参数。



解：

$$\dot{U}_1 = (\dot{I}_1 + \frac{2\dot{U}_2 - \dot{U}_1}{1}) \times 1$$

$$= \dot{I}_1 + 2\dot{U}_2 - \dot{U}_1$$

$$\therefore \quad \dot{U}_1 = \frac{1}{2}\dot{I}_1 + \dot{U}_2$$

$$\dot{I}_2 = \frac{\dot{U}_2 - 2\dot{U}_2}{1} = -\dot{U}_2$$

$$\begin{bmatrix} \dot{U}_1 \\ \dot{I}_2 \end{bmatrix} = \begin{bmatrix} \frac{1}{2} & 1 \\ 0 & -1 \end{bmatrix} \begin{bmatrix} \dot{I}_1 \\ \dot{U}_2 \end{bmatrix}$$

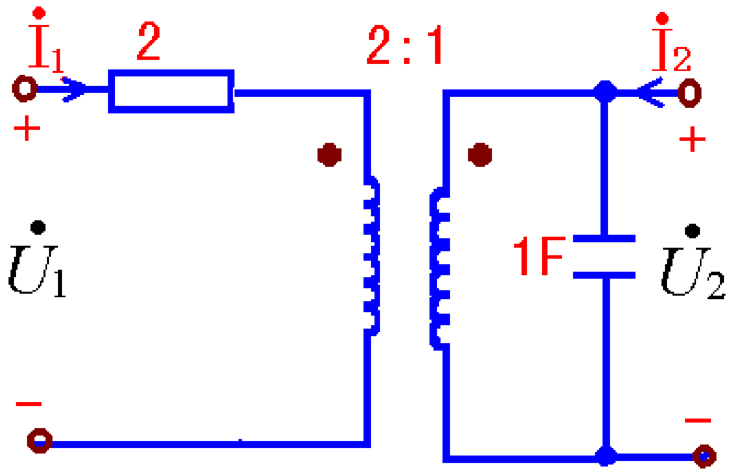
$$[H] = \begin{bmatrix} \frac{1}{2} & 1 \\ 0 & -1 \end{bmatrix}$$

$$\dot{U}_1 = \frac{1}{2}\dot{I}_1 + \dot{U}_2 = \frac{1}{2}\dot{I}_1 - \dot{I}_2$$

$$\dot{U}_2 = -\dot{I}_2$$

$$[Z] = \begin{bmatrix} \frac{1}{2} & -1 \\ 0 & -1 \end{bmatrix}$$

例4: 图4所示二端口网络，求Z 、 H、 A 参数。



解: $\dot{U}_1 = 2\dot{I}_1 + 2\dot{U}_2$

$$\dot{I}_2 = -2\dot{I}_1 + j\omega\dot{U}_2$$

$$[H] = \begin{bmatrix} 2 & 2 \\ -2 & j\omega \end{bmatrix}$$

$$\dot{U}_1 = 2\dot{I}_1 + 2\left(\frac{2}{j\omega}\dot{I}_1 + \frac{1}{j\omega}\dot{I}_2\right)$$

$$= \left(2 + \frac{4}{j\omega}\right)\dot{I}_1 + \frac{2}{j\omega}\dot{I}_2$$

$$\dot{U}_2 = \frac{2}{j\omega}\dot{I}_1 + \frac{1}{j\omega}\dot{I}_2$$

$$[Z] = \begin{bmatrix} 2 + \frac{4}{j\omega} & \frac{2}{j\omega} \\ \frac{2}{j\omega} & \frac{1}{j\omega} \end{bmatrix}$$

$$\dot{U}_1 = 2\left(\frac{j\omega}{2}\dot{U}_2 - \frac{1}{2}\dot{I}_2\right) + 2\dot{U}_2$$

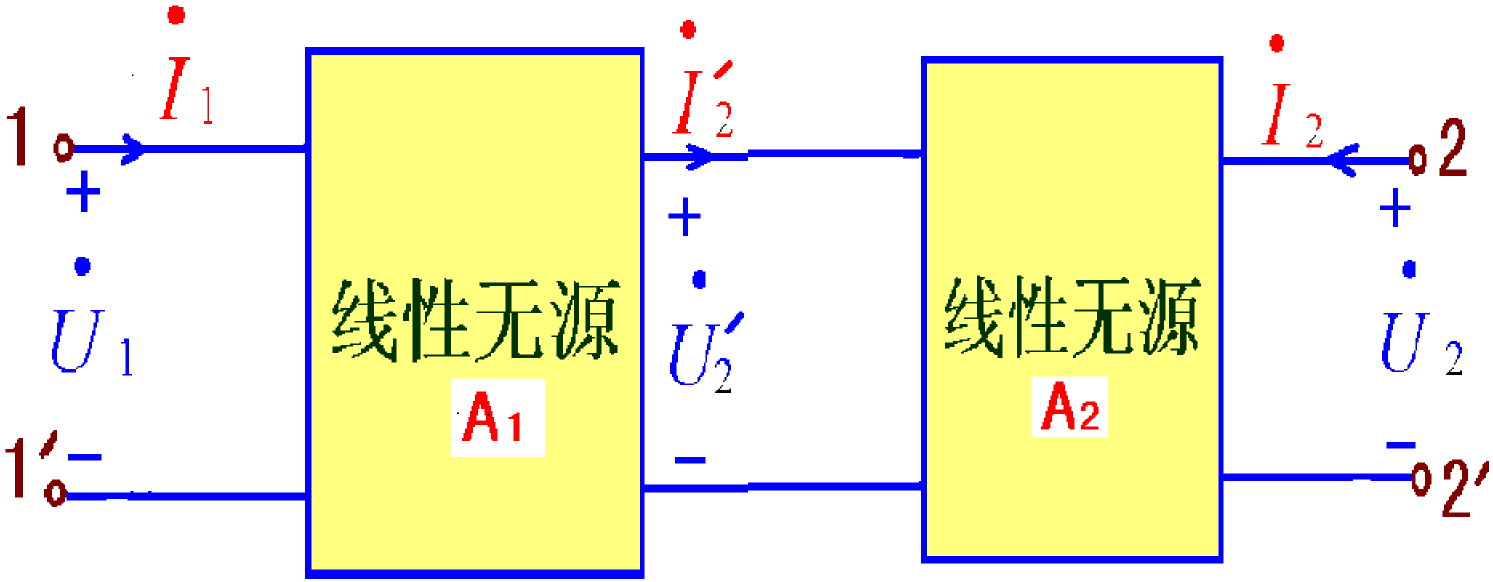
$$= (2 + j\omega)\dot{U}_2 - \dot{I}_2$$

$$\dot{I}_1 = \frac{j\omega}{2}\dot{U}_2 - \frac{1}{2}\dot{I}_2$$

$$[A] = \begin{bmatrix} 2 + j\omega & 1 \\ \frac{j\omega}{2} & \frac{1}{2} \end{bmatrix}$$

11-5 二端口网络的连接

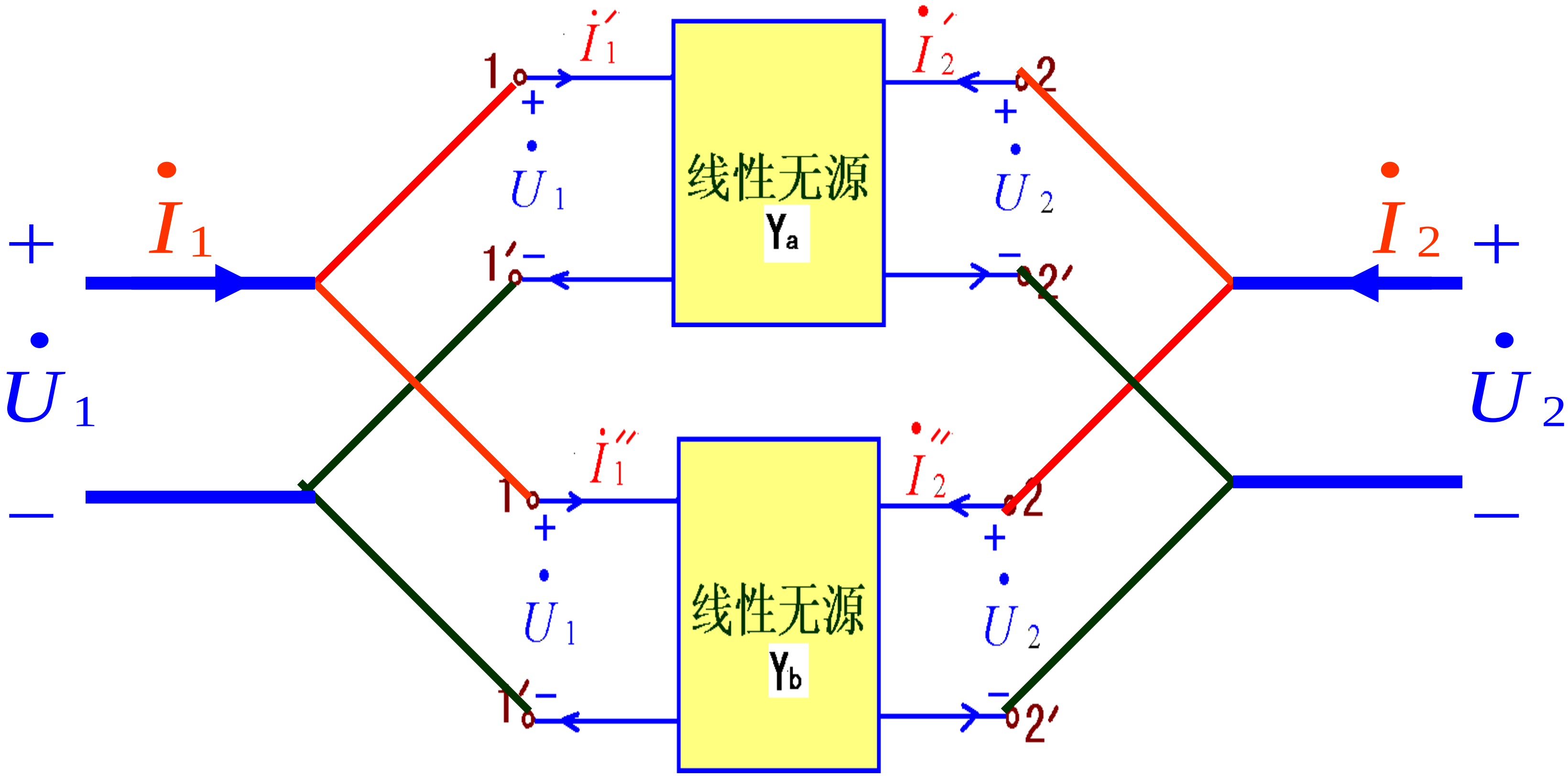
一、级联（网络A2的输入端口与网络A1的输出端口相联接）



$$\begin{bmatrix}\dot{U}_1\\ \dot{I}_1\end{bmatrix}=A_1\begin{bmatrix}\dot{U}_2'\\ \dot{I}_2'\end{bmatrix}\qquad \begin{bmatrix}\dot{U}_2'\\ \dot{I}_2'\end{bmatrix}=A_2\begin{bmatrix}\dot{U}_2\\ -\dot{I}_2\end{bmatrix}\Rightarrow\begin{bmatrix}\dot{U}_1\\ \dot{I}_1\end{bmatrix}=A_1A_2\begin{bmatrix}\dot{U}_2\\ -\dot{I}_2\end{bmatrix}$$

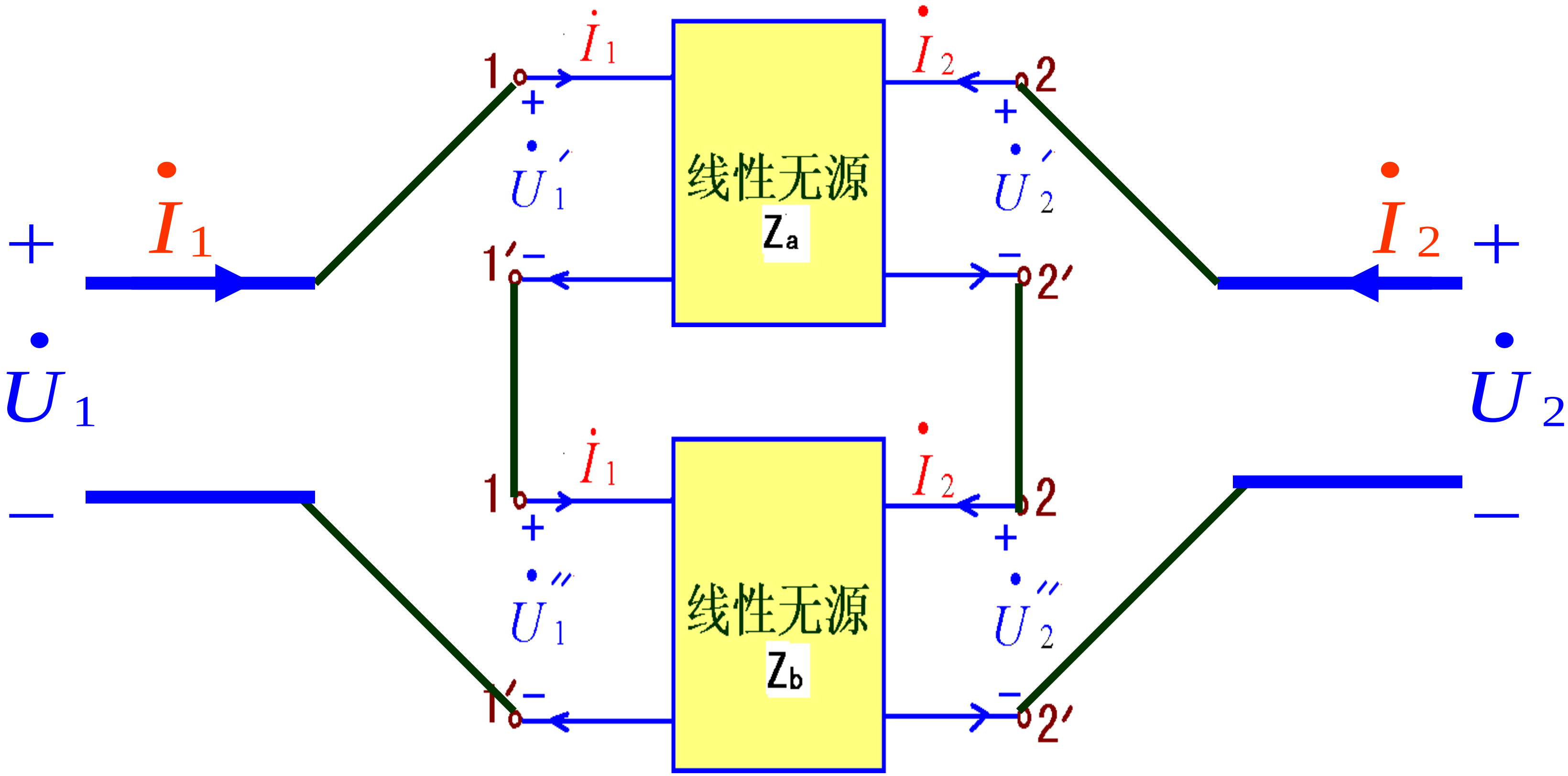
N个子网络级联时，总网络的A参数矩阵等于各子网络的A参数矩阵相乘，即，$A=A_1A_2\cdots\cdots A_N$

二、并联



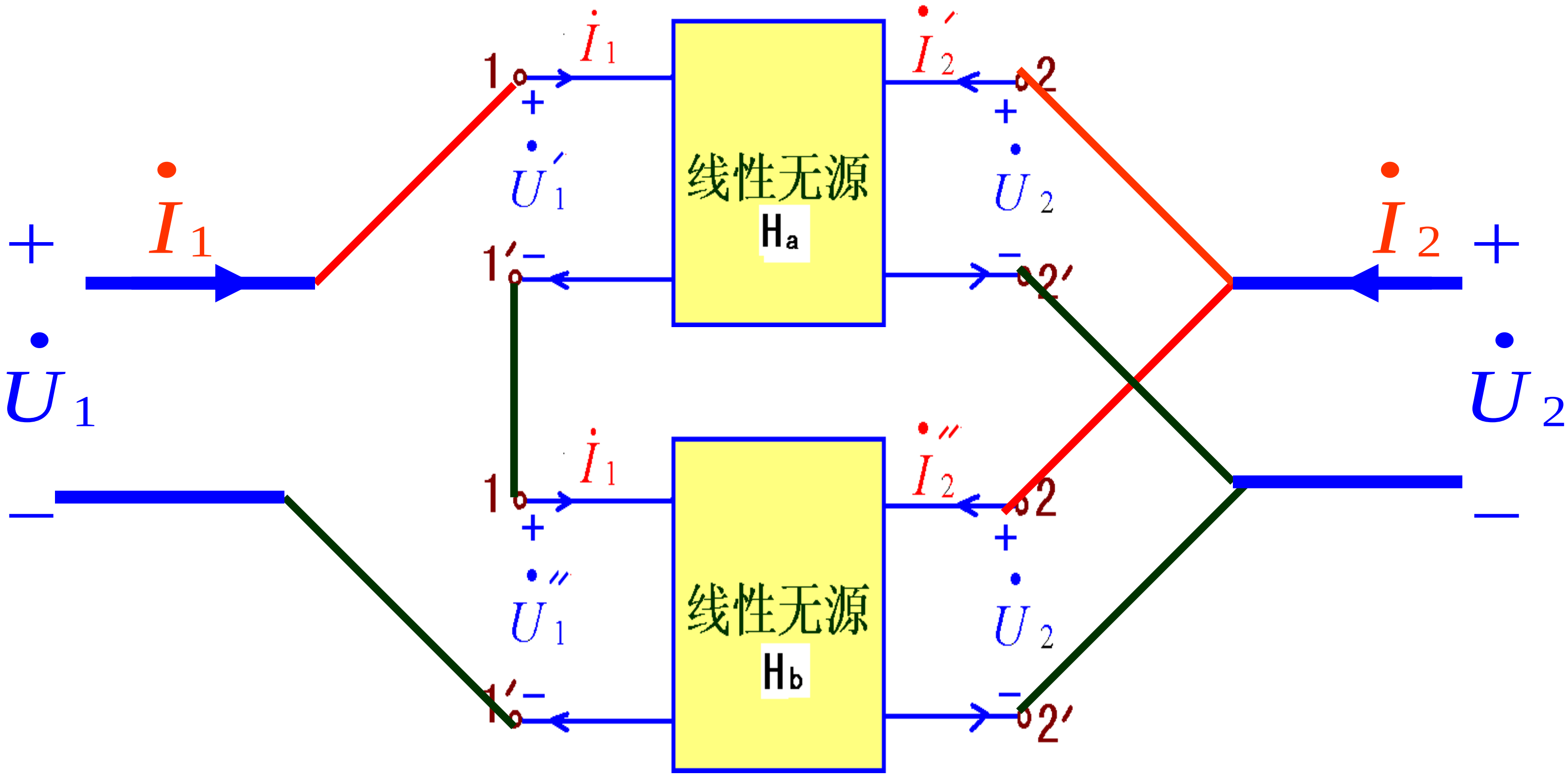
N个网络并联时，总网络的Y参数矩阵等于各子网络Y参数矩阵相加，即：$Y=Y_1+Y_2+\cdots\cdots+Y_N$

三、串联



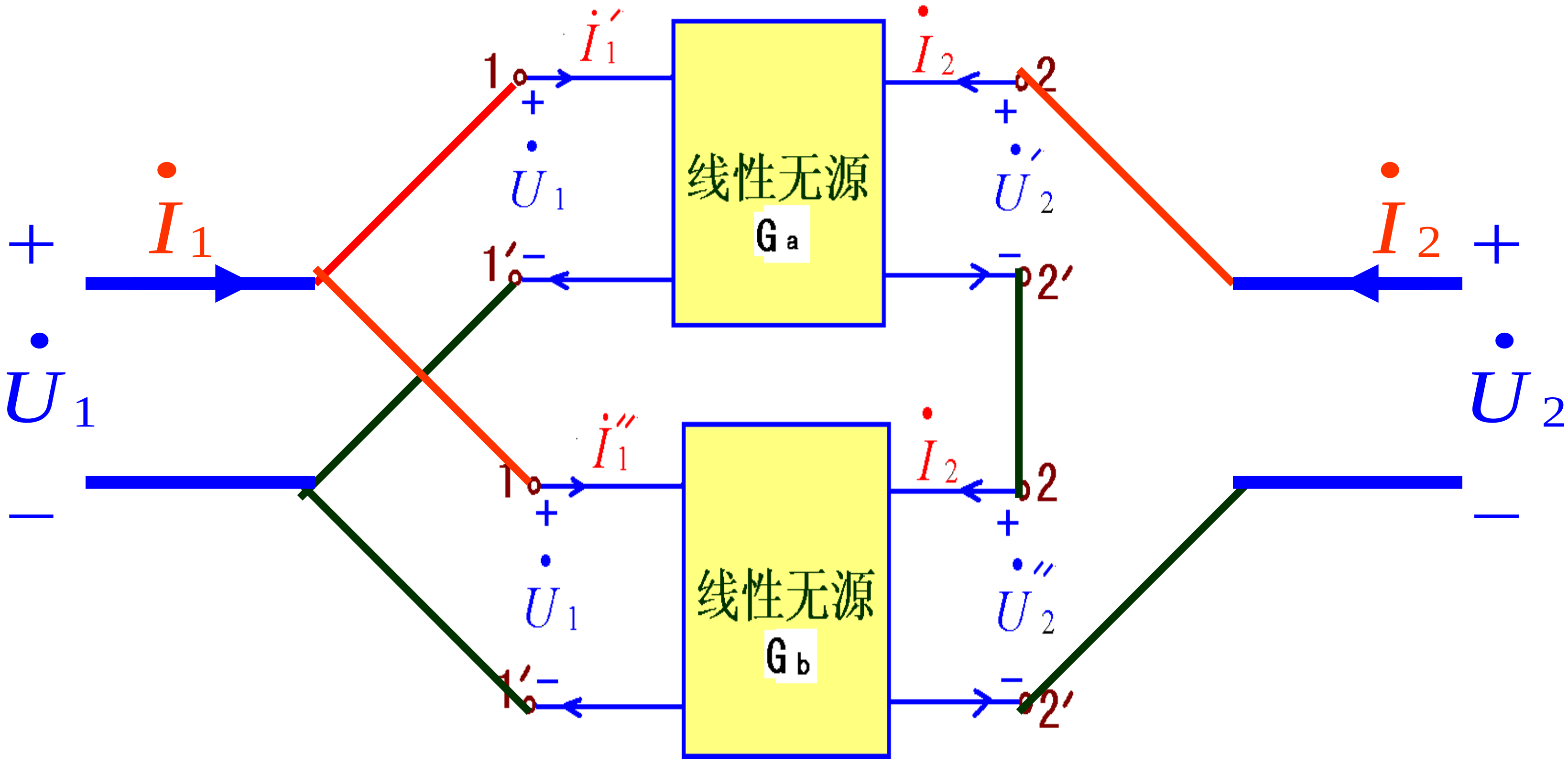
N个网络串联时，总网络的Z参数矩阵等于各子网络的Z参数矩阵相加，即： $Z=Z_1+Z_2+\cdots\cdots+Z_N$

四、串并联



N个网络串并联时，总网络的H参数矩阵等于各子网络的H参数矩阵相加，即：$H=H_1+H_2+\cdots\cdots+H_N$

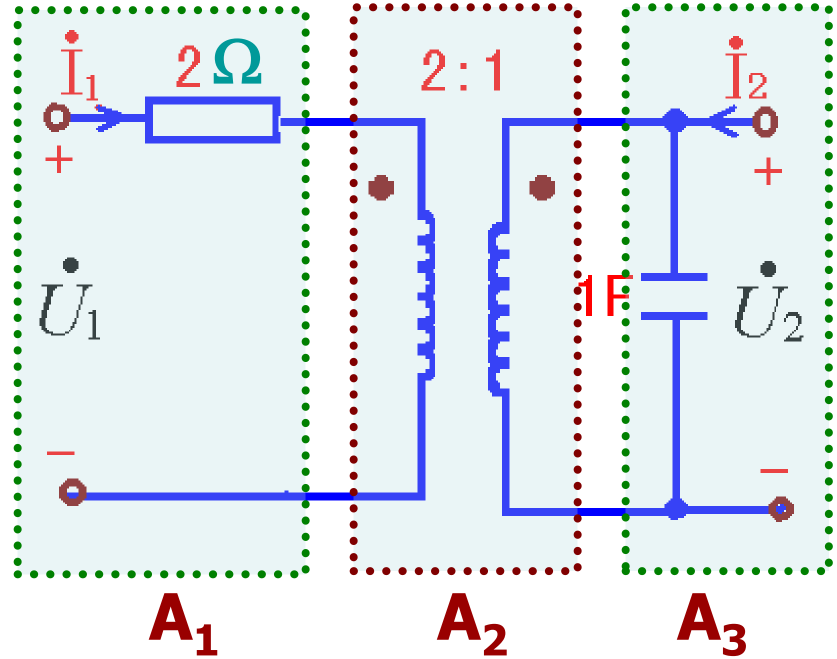
五、并串联



N个网络并串联时，总网络的G参数矩阵等于各子网络的G参数矩阵相加，即：$G=G_1+G_2+\cdots\cdots+G_N$

例1: 图示二端口网络，求A 参数。

解：将所示网络可分解为三个子网络A_1、A_2、A_3的级联。



对于网络A_1，有 $[A_1]=\begin{bmatrix}1 & 2\\0 & 1\end{bmatrix}$

对于网络A_2，有 $[A_2]=\begin{bmatrix}2 & 0\\0 & 0.5\end{bmatrix}$

对于网络A_3，有 $[A_3]=\begin{bmatrix}1 & 0\\j\omega & 1\end{bmatrix}$

对于整个网络A，有

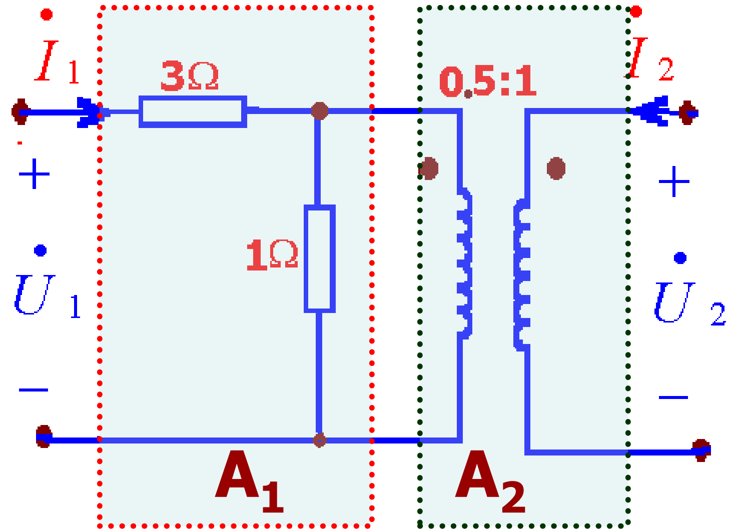
$$[A]=[A_1][A_2][A_3]$$

$$[A]=\begin{bmatrix}1 & 2\\0 & 1\end{bmatrix}\begin{bmatrix}2 & 0\\0 & 0.5\end{bmatrix}\begin{bmatrix}1 & 0\\j\omega & 1\end{bmatrix}$$

$$=\begin{bmatrix}2+j\omega & 1\\ \frac{1}{2}j\omega & \frac{1}{2}\end{bmatrix}$$

例2:　图示二端口网络是否具有互易性和对称性。

解：将所示网络可分解为两个网络A_1、A_2的级联。



对于网络A_1，有

$$\begin{cases} \dot{U}_1 = \dot{U}_2' + 3(\dot{U}_2' - \dot{I}_2') \\ \dot{I}_1 = \dot{U}_2' - \dot{I}_2' \end{cases}$$

$$[A_1] = \begin{bmatrix} 4 & 3 \\ 1 & 1 \end{bmatrix}$$

$$[A] = [A_1][A_2]$$

对于网络A_2，有

$$\begin{cases} \dot{U}_1' = 0.5\dot{U}_2 \\ \dot{I}_1' = -2\dot{I}_2 \end{cases}$$

$$[A_2] = \begin{bmatrix} 0.5 & 0 \\ 0 & 2 \end{bmatrix}$$

$$= \begin{bmatrix} 4 & 3 \\ 1 & 1 \end{bmatrix} \begin{bmatrix} 0.5 & 0 \\ 0 & 2 \end{bmatrix} = \begin{bmatrix} 2 & 6 \\ 0.5 & 2 \end{bmatrix}$$

因　$|A| = 1$，且$A_{11} = A_{22}$　故，网络具有互易性和对称性

注意：不含受控源的二端口网络都是互易网络，
含有受控源的二端口网络可能不互易。

本章小结

1、二端口网络方程与参数

Z、Y、A、H、B、G 方程与参数

2、二端口网络的连接

级联、串联、并联、串并联、
并串联