第16章 二端口网络

本章重点

1. 二端口的参数和方程

2. 二端口的等效电路

3. 二端口的连接

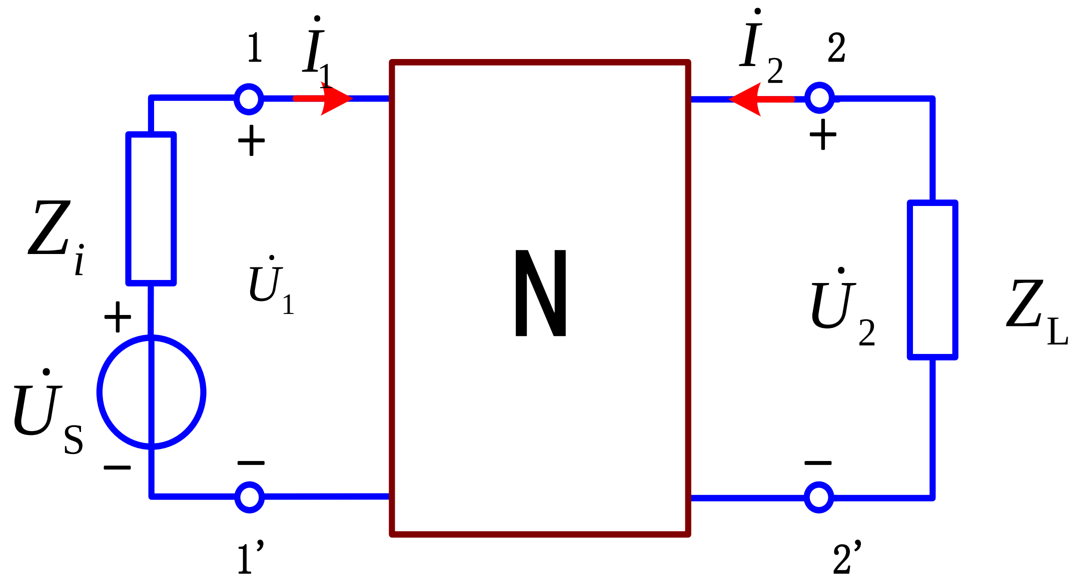
4. 二端口的转移函数

5. 回转器与负阻抗变换器

16.1 二端口网络

电源： $\dot{U}_1 = \dot{U}_S - Z_i\dot{I}_1$

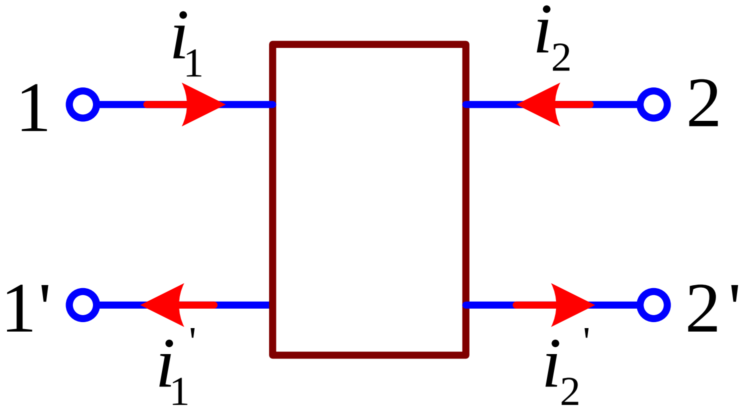
负载： $\dot{U}_2 = -Z_L\dot{I}_2$



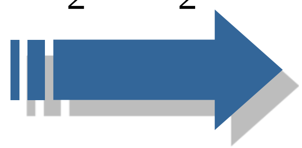
为了研究传输网络 N 的一般特性，将 N 从电路图中分离出来。

16.1 二端口网络

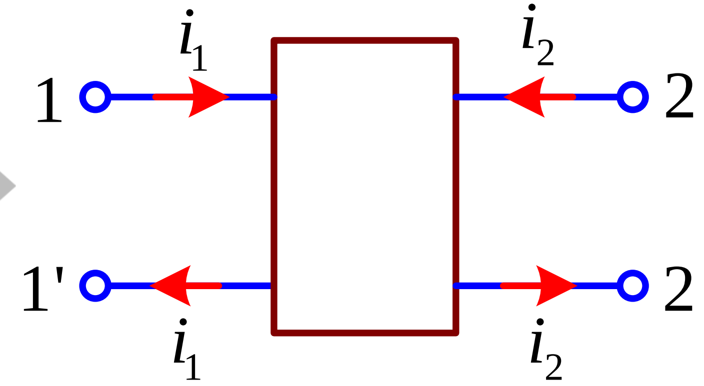
四端网络

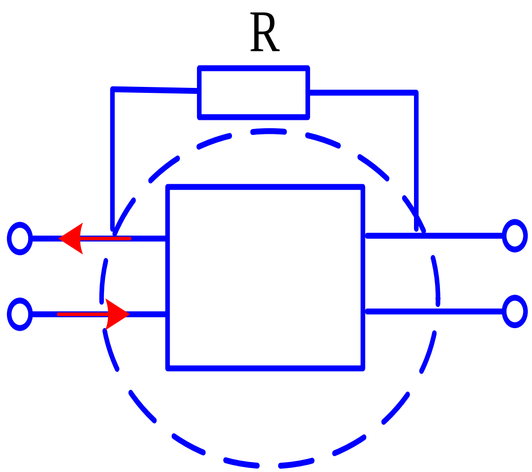


$$i_1 = i_1'$$
$$i_2 = i_2'$$



二端口网络
（双口网络)



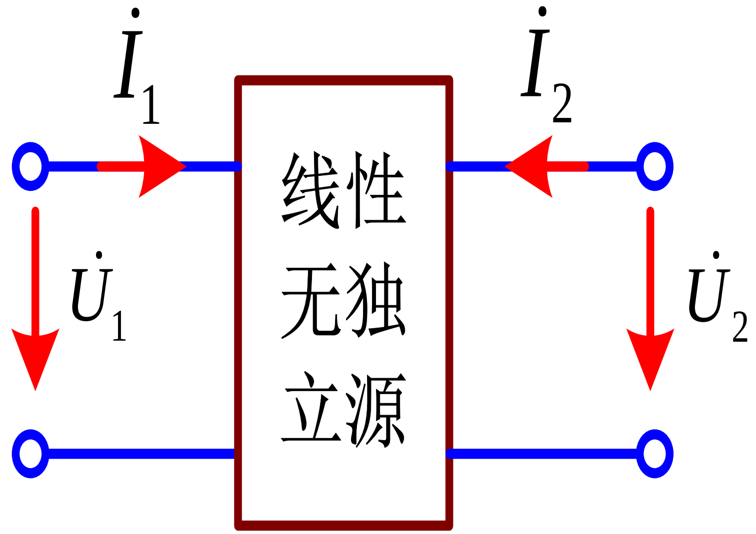


◆四端网络并不一定是二端口网络

? 二端口网络(双口网络)分析方法

联想一端口网络分析方法

- 列端口方程
- 等效电路

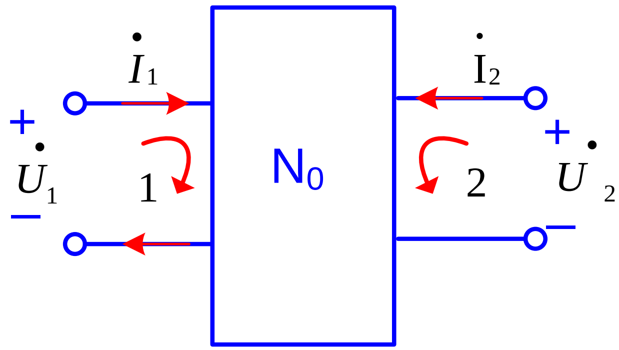


本章研究的二端口网络

- 线性无独立源；
- 用相量表示，但并非只适用于正弦激励；
- 规定的参考方向上得到的结论

16.2 二端口的方程和参数

1. 二端口网络的Y参数方程 Y参数（短路参数）



$$Z_{11}\dot{I}_1+Z_{12}\dot{I}_2+Z_{13}\dot{I}_3+\ldots Z_{1l}\dot{I}_l=\dot{U}_1$$

$$Z_{21}\dot{I}_1+Z_{22}\dot{I}_2+Z_{23}\dot{I}_3+\ldots Z_{2l}\dot{I}_l=\dot{U}_2$$

$$Z_{31}\dot{I}_1+Z_{32}\dot{I}_2+Z_{33}\dot{I}_3+\ldots Z_{3l}\dot{I}_l=0$$

$$\vdots$$

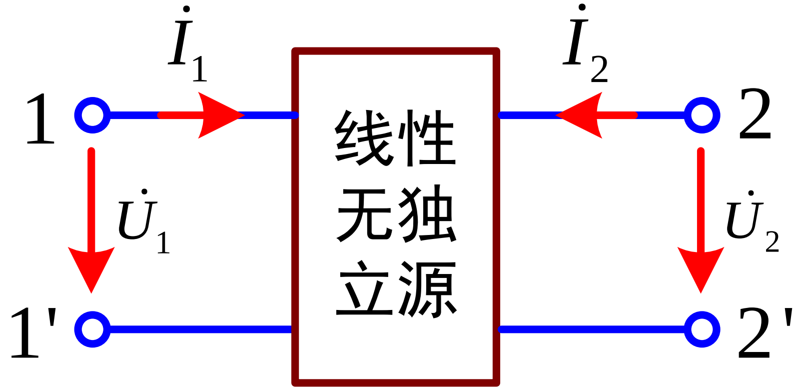
$$Z_{l1}\dot{I}_1+Z_{l2}\dot{I}_2+Z_{l3}\dot{I}_3+\ldots Z_{ll}\dot{I}_l=0$$

$$\dot{I}_1=\begin{vmatrix} U_1 & Z_{12} & \cdots & Z_{1l} \\ U_2 & Z_{22} & \cdots & Z_{2l} \\ \vdots & \vdots & \ddots & \vdots \\ 0 & Z_{l2} & \cdots & Z_{ll} \end{vmatrix} \Bigg/ \begin{vmatrix} Z_{11} & Z_{12} & \cdots & Z_{1l} \\ Z_{21} & Z_{22} & \cdots & Z_{2l} \\ \vdots & \vdots & \ddots & \vdots \\ Z_{l1} & Z_{l2} & \cdots & Z_{ll} \end{vmatrix}=\frac{\Delta_{11}}{\Delta}\dot{U}_1+\frac{\Delta_{21}}{\Delta}\dot{U}_2=Y_{11}\dot{U}_1+Y_{12}\dot{U}_2$$

$$\dot{I}_2=\begin{vmatrix} Z_{11} & U_1 & \cdots & Z_{1l} \\ Z_{21} & U_2 & \cdots & Z_{2l} \\ \vdots & \vdots & \ddots & \vdots \\ Z_{l2} & 0 & \cdots & Z_{ll} \end{vmatrix} \Bigg/ \begin{vmatrix} Z_{11} & Z_{12} & \cdots & Z_{1l} \\ Z_{21} & Z_{22} & \cdots & Z_{2l} \\ \vdots & \vdots & \ddots & \vdots \\ Z_{l1} & Z_{l2} & \cdots & Z_{ll} \end{vmatrix}=\frac{\Delta_{12}}{\Delta}\dot{U}_1+\frac{\Delta_{22}}{\Delta}\dot{U}_2=Y_{21}\dot{U}_1+Y_{22}\dot{U}_2$$

1. 二端口网络的Y参数方程 Y参数（短路参数）

替代定理＋叠加定理



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

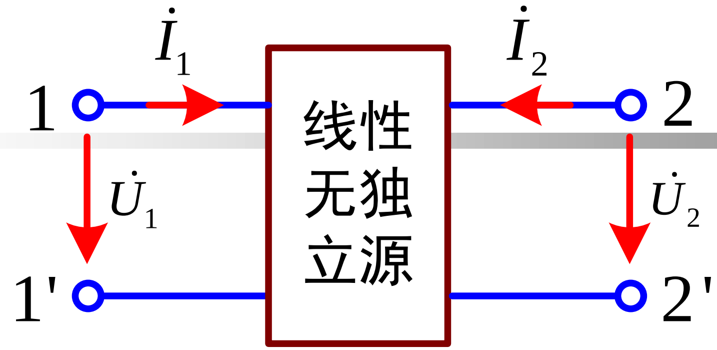
$$\dot{I}_2 = Y_{21}\dot{U}_1 + Y_{22}\dot{U}_2$$

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

线性无源(无独立源, 无受控源)：$Y_{12} = Y_{21}$

对　称：$Y_{11} = Y_{22}$

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



$$Y_{11} = \frac{\dot{I}_1}{\dot{U}_1}\bigg|_{\dot{U}_2=0}$$ 端口2–2’短路, 端口1–1’处输入导纳

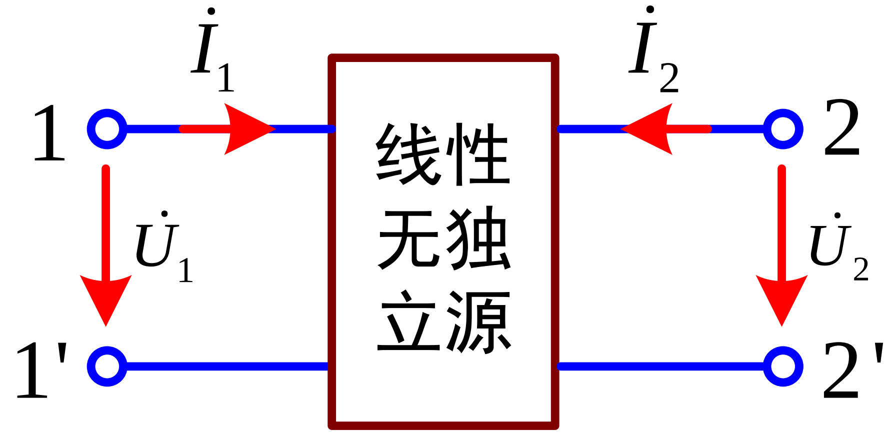
$$Y_{21} = \frac{\dot{I}_2}{\dot{U}_1}\bigg|_{\dot{U}_2=0}$$ 端口2–2’短路时的转移导纳

$$Y_{12} = \frac{\dot{I}_1}{\dot{U}_2}\bigg|_{\dot{U}_1=0}$$ 端口1–1’短路时的转移导纳

$$Y_{22} = \frac{\dot{I}_2}{\dot{U}_2}\bigg|_{\dot{U}_1=0}$$ 端口1–1’短路, 端口2–2’处输入导纳

2. 二端口网络的Z参数方程Z参数（开路参数）

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

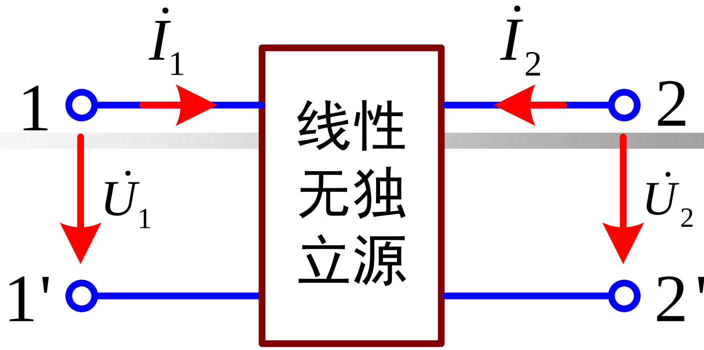


$$\begin{bmatrix} \dot{U}_1 \\ \dot{U}_2 \end{bmatrix} = \begin{bmatrix} Z_{11} & Z_{12} \\ Z_{21} & Z_{22} \end{bmatrix} \begin{bmatrix} \dot{I}_1 \\ \dot{I}_2 \end{bmatrix} = \mathbf{Z} \begin{bmatrix} \dot{I}_1 \\ \dot{I}_2 \end{bmatrix}$$

线性无源(无独立源，无受控源)： $Z_{12} = Z_{21}$

对 称： $Z_{11} = Z_{22}$

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



$$Z_{11} = \frac{\dot{U}_1}{\dot{I}_1}\bigg|_{\dot{I}_2=0}$$ 端口2-2’开路, 端口1-1’处输入阻抗

$$Z_{21} = \frac{\dot{U}_2}{\dot{I}_1}\bigg|_{\dot{I}_2=0}$$ 端口2-2’开路时的转移阻抗

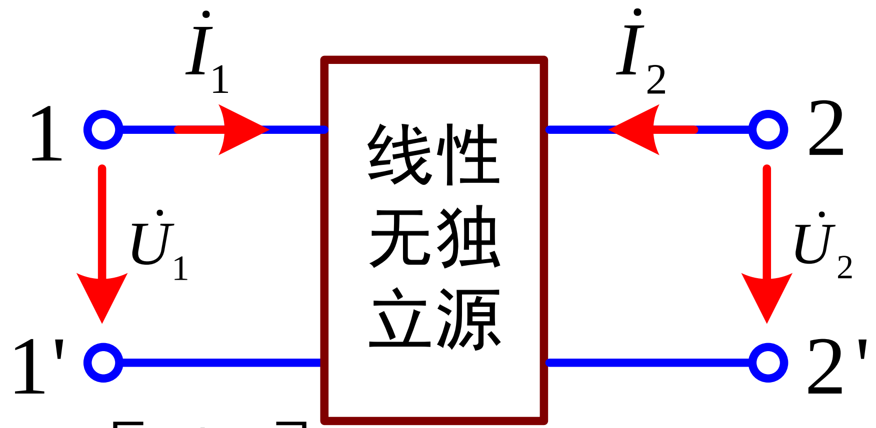
$$Z_{12} = \frac{\dot{U}_1}{\dot{I}_2}\bigg|_{\dot{I}_1=0}$$ 端口1-1’开路时的转移阻抗

$$Z_{22} = \frac{\dot{U}_2}{\dot{I}_2}\bigg|_{\dot{I}_1=0}$$ 端口1-1’开路, 端口2-2’处输入阻抗

3. 二端口网络的T参数方程 T参数 （传输参数，一般参数） （二端口网络的A参数方程 A参数）

$$\dot{U}_1 = A\dot{U}_2 - B\dot{I}_2$$

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

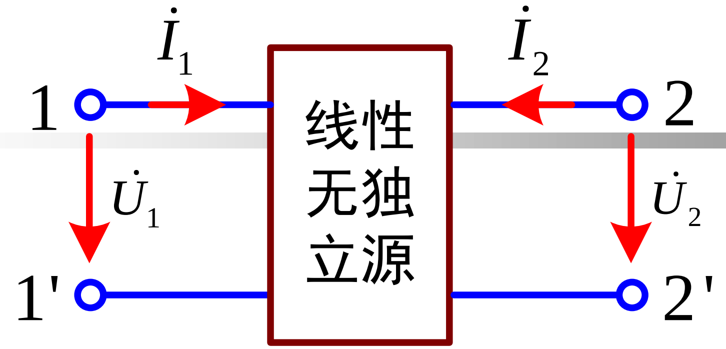


$$\begin{bmatrix} \dot{U}_1 \\ \dot{I}_1 \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \begin{bmatrix} \dot{U}_2 \\ -\dot{I}_2 \end{bmatrix} = \mathbf{T} \begin{bmatrix} \dot{U}_2 \\ -\dot{I}_2 \end{bmatrix}$$

线性无源(无独立源，无受控源)： $AD - BC = 1$

对称： $A = D$

$$\begin{bmatrix} \dot{U}_1 \\ \dot{I}_1 \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \begin{bmatrix} \dot{U}_2 \\ -\dot{I}_2 \end{bmatrix}$$



$$A = \left.\frac{\dot{U}_1}{\dot{U}_2}\right|_{\dot{I}_2=0}$$ 端口2-2’开路时的转移电压比

$$B = \left.\frac{\dot{U}_1}{-\dot{I}_2}\right|_{\dot{U}_2=0}$$ 端口2-2’短路时的转移阻抗

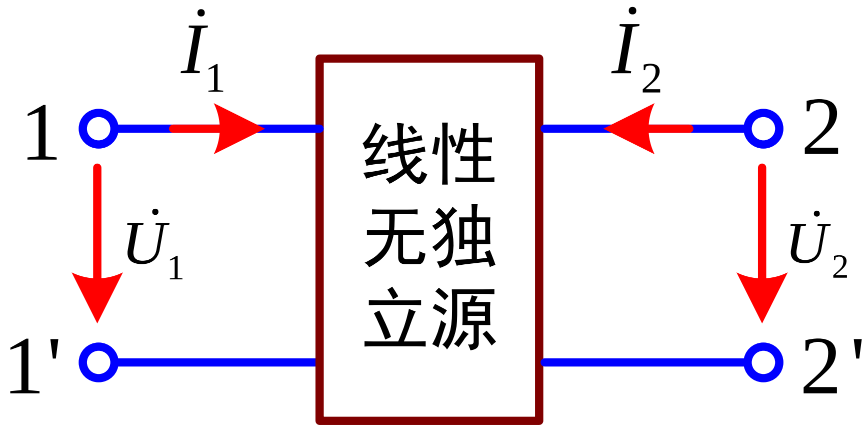
$$C = \left.\frac{\dot{I}_1}{\dot{U}_2}\right|_{\dot{I}_2=0}$$ 端口2-2’开路时的转移导纳

$$D = \left.\frac{\dot{I}_1}{-\dot{I}_2}\right|_{\dot{U}_2=0}$$ 端口2-2’短路时的转移电流比

4. 二端口网络的H参数方程　H参数（混合参数）

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

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

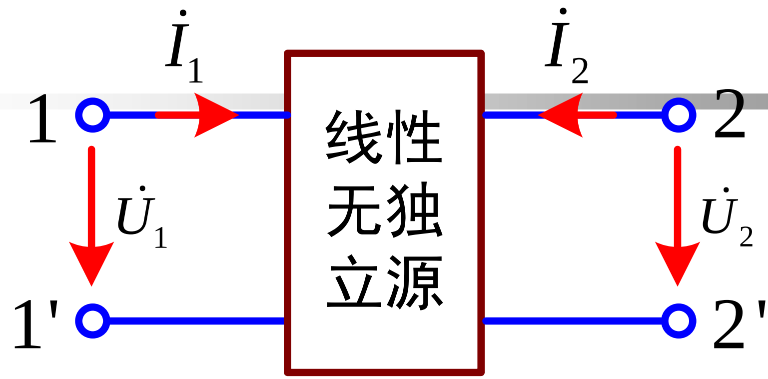


$$\begin{bmatrix} \dot{U}_1 \\ \dot{I}_2 \end{bmatrix} = \begin{bmatrix} H_{11} & H_{12} \\ H_{21} & H_{22} \end{bmatrix} \begin{bmatrix} \dot{I}_1 \\ \dot{U}_2 \end{bmatrix} = \mathbf{H} \begin{bmatrix} \dot{I}_1 \\ \dot{U}_2 \end{bmatrix}$$

线性无源(无独立源, 无受控源)： $H_{21} = -H_{12}$

对称： $H_{11}H_{22} - H_{12}H_{21} = 1$

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



$$H_{11} = \frac{\dot{U}_1}{\dot{I}_1}\bigg|_{\dot{U}_2=0}$$ 端口2-2’短路，端口1-1’处输入阻抗

$$H_{12} = \frac{\dot{U}_1}{\dot{U}_2}\bigg|_{\dot{I}_1=0}$$ 端口1-1’开路时的转移电压比

$$H_{21} = \frac{\dot{I}_2}{\dot{I}_1}\bigg|_{\dot{U}_2=0}$$ 端口2-2’短路时的转移电流比

$$H_{22} = \frac{\dot{I}_2}{\dot{U}_2}\bigg|_{\dot{I}_1=0}$$ 端口1-1’开路，端口2-2’输入导纳

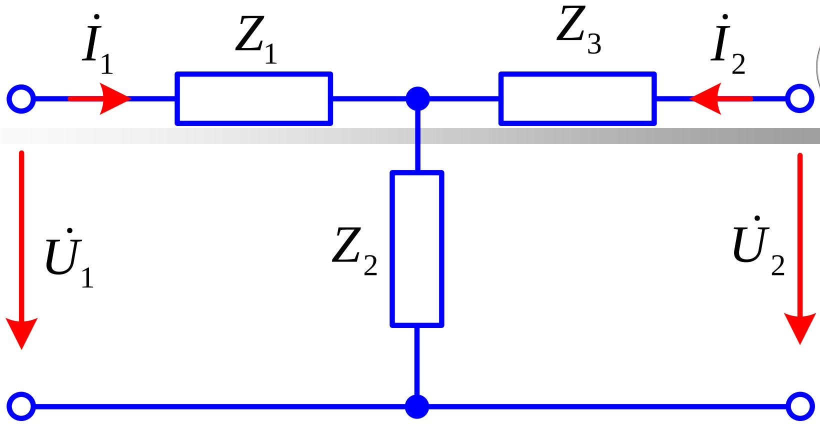
$$\begin{bmatrix} \dot{I}_1 \\ \dot{I}_2 \end{bmatrix} = \mathbf{Y} \begin{bmatrix} \dot{U}_1 \\ \dot{U}_2 \end{bmatrix} \qquad \begin{bmatrix} \dot{U}_1 \\ \dot{U}_2 \end{bmatrix} = \mathbf{Z} \begin{bmatrix} \dot{I}_1 \\ \dot{I}_2 \end{bmatrix}$$

短路导纳矩阵　　　　开路阻抗矩阵

$$\begin{bmatrix} \dot{U}_1 \\ \dot{I}_1 \end{bmatrix} = \mathbf{T} \begin{bmatrix} \dot{U}_2 \\ -\dot{I}_2 \end{bmatrix} \qquad \begin{bmatrix} \dot{U}_1 \\ \dot{I}_2 \end{bmatrix} = \mathbf{H} \begin{bmatrix} \dot{I}_1 \\ \dot{U}_2 \end{bmatrix}$$

二端口的信息可用任一参数（一组参数）来表示；
四个参数矩阵可以互相转换。

【例】 求Z参数。



解 法1：

$$Z_{11}=\frac{\dot{U}_1}{\dot{I}_1}\bigg|_{\dot{I}_2=0}=Z_1+Z_2$$

$$Z_{12}=\frac{\dot{U}_1}{\dot{I}_2}\bigg|_{\dot{I}_1=0}=Z_2=Z_{21}$$

$$Z_{22}=\frac{\dot{U}_2}{\dot{I}_2}\bigg|_{\dot{I}_1=0}=Z_2+Z_3$$

$$\mathbf{Z}=\begin{bmatrix} Z_1+Z_2 & Z_2 \\ Z_2 & Z_2+Z_3 \end{bmatrix}$$

法2：

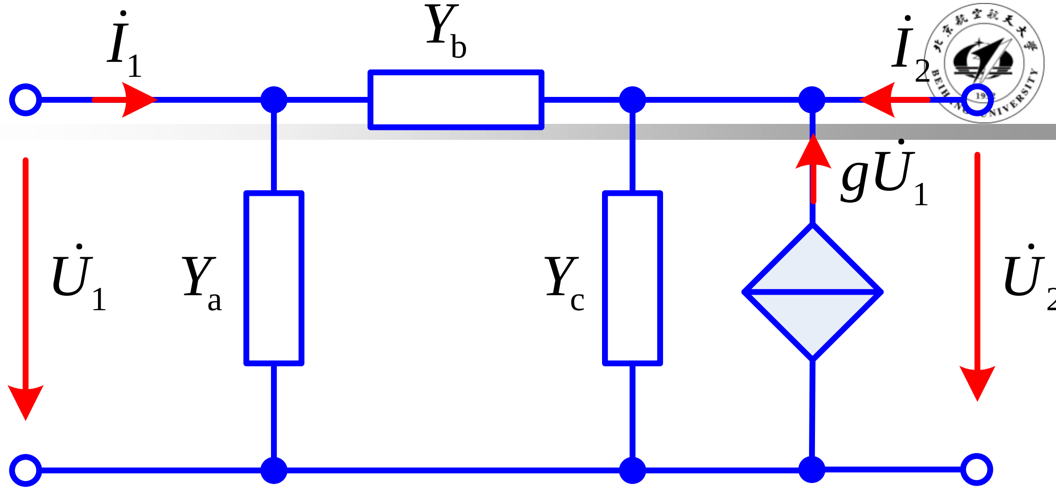
$$\begin{cases} \dot{U}_1=(Z_1+Z_2)\dot{I}_1+Z_2\dot{I}_2 \\ \dot{U}_2=Z_2\dot{I}_1+(Z_2+Z_3)\dot{I}_2 \end{cases}$$

$$\mathbf{Z}=\begin{bmatrix} Z_1+Z_2 & Z_2 \\ Z_2 & Z_2+Z_3 \end{bmatrix}$$

【例】

求Y参数矩阵。

解 KCL方程

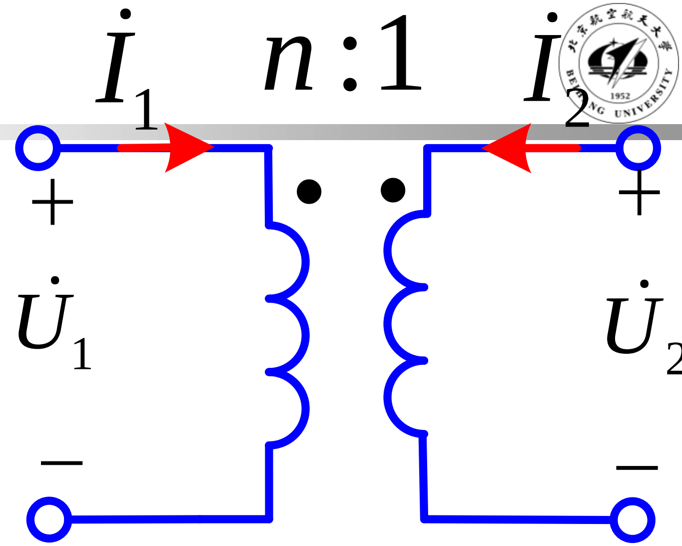


$$\begin{cases} \dot{I}_1 = Y_a\dot{U}_1 + Y_b(\dot{U}_1 - \dot{U}_2) \\ \dot{I}_2 = -g\dot{U}_1 + Y_c\dot{U}_2 + Y_b(\dot{U}_2 - \dot{U}_1) \end{cases}$$

$$\begin{cases} \dot{I}_1 = (Y_a + Y_b)\dot{U}_1 - Y_b\dot{U}_2 \\ \dot{I}_2 = (-Y_b - g)\dot{U}_1 + (Y_b + Y_c)\dot{U}_2 \end{cases}$$

$$\mathbf{Y} = \begin{bmatrix} Y_a + Y_b & -Y_b \\ -Y_b - g & Y_b + Y_c \end{bmatrix}$$

【例】 求T参数矩阵。



解 $\dfrac{\dot{U}_1}{\dot{U}_2}=n \qquad \dfrac{\dot{I}_1}{\dot{I}_2}=-\dfrac{1}{n}$

$$\begin{cases}\dot{U}_1=n\dot{U}_2\\ \dot{I}_1=-\dfrac{1}{n}\dot{I}_2\end{cases}$$

$$\begin{cases}\dot{U}_1=A\dot{U}_2-B\dot{I}_2\\ \dot{I}_1=C\dot{U}_2-D\dot{I}_2\end{cases}$$

$$\Rightarrow \mathbf{T}=\begin{bmatrix} n & 0 \\ 0 & \dfrac{1}{n}\end{bmatrix}$$

16.3 二端口的等效电路

一个无源二端口网络可以用一个简单的二端口等效模型来代替，要注意的是：

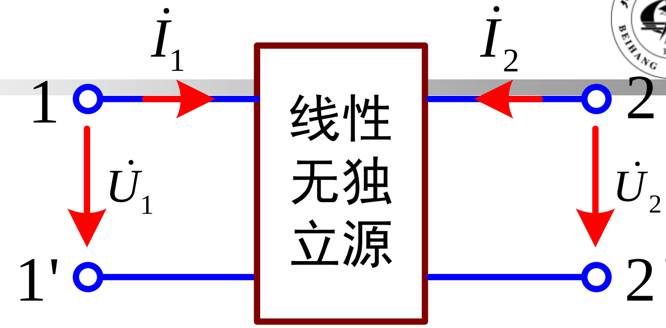
（1）等效条件：等效模型的方程与原二端口网络的方程相同；

（2）根据不同的网络参数和方程可以得到结构完全不同的等效电路；

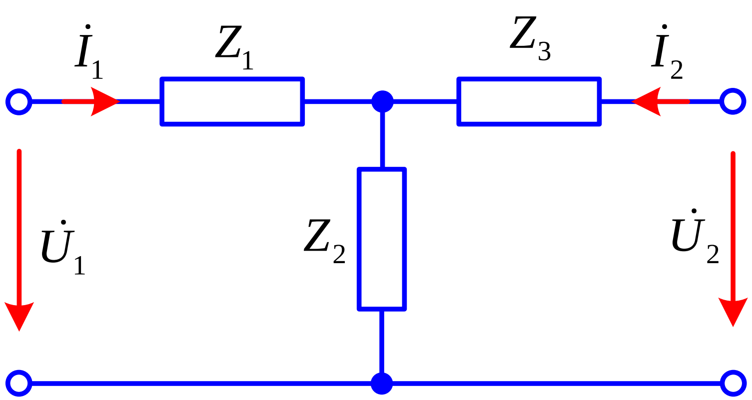
（3）等效目的是为了分析方便。

1. T和π型等效电路

(1) Z参数T型等效电路



$$\begin{cases} \dot{U}_1 = Z_{11}\dot{I}_1 + Z_{12}\dot{I}_2 \\ \dot{U}_2 = Z_{21}\dot{I}_1 + Z_{22}\dot{I}_2 \end{cases}$$



$$\begin{cases} \dot{U}_1 = (Z_1 + Z_2)\dot{I}_1 + Z_2\dot{I}_2 \\ \dot{U}_2 = Z_2\dot{I}_1 + (Z_2 + Z_3)\dot{I}_2 \end{cases}$$

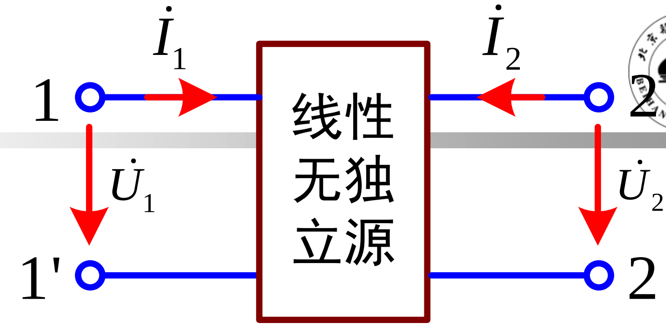
$$\begin{cases} Z_{11} = Z_1 + Z_2 \\ Z_{12} = Z_{21} = Z_2 \\ Z_{22} = Z_2 + Z_3 \end{cases}$$

联立解出

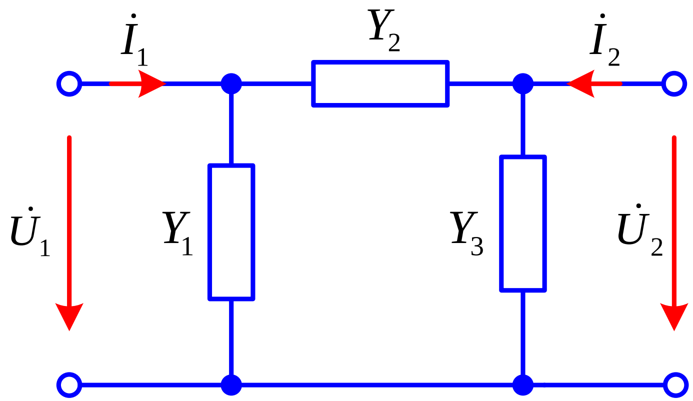
$$\begin{cases} Z_1 = Z_{11} - Z_{12} \\ Z_2 = Z_{12} \\ Z_3 = Z_{22} - Z_{12} \end{cases}$$

1. T和π型等效电路

(2) Y参数π型等效电路



$$\begin{cases} \dot{I}_1 = Y_{11}\dot{U}_1 + Y_{12}\dot{U}_2 \\ \dot{I}_2 = Y_{21}\dot{U}_1 + Y_{22}\dot{U}_2 \end{cases}$$



$$\begin{cases} \dot{I}_1 = Y_1\dot{U}_1 + Y_2(\dot{U}_1 - \dot{U}_2) \\ \dot{I}_2 = Y_3\dot{U}_2 + Y_2(\dot{U}_2 - \dot{U}_1) \end{cases}$$

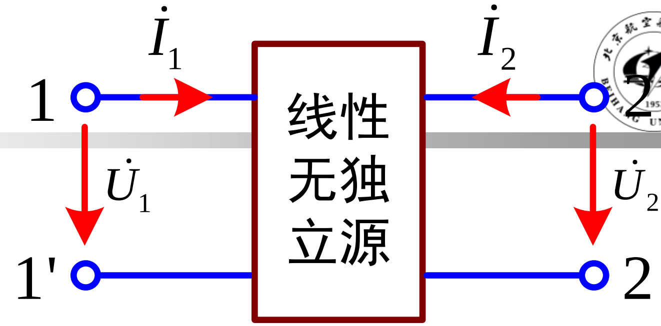
$$\begin{cases} \dot{I}_1 = (Y_1 + Y_2)\dot{U}_1 - Y_2\dot{U}_2 \\ \dot{I}_2 = -Y_2\dot{U}_1 + (Y_2 + Y_3)\dot{U}_2 \end{cases}$$

$$\begin{cases} Y_{11} = Y_1 + Y_2 \\ Y_{12} = Y_{21} = -Y_2 \\ Y_{22} = Y_2 + Y_3 \end{cases}$$

联立解出

$$\begin{cases} Y_1 = Y_{11} + Y_{12} \\ Y_2 = -Y_{12} \\ Y_3 = Y_{22} + Y_{12} \end{cases}$$

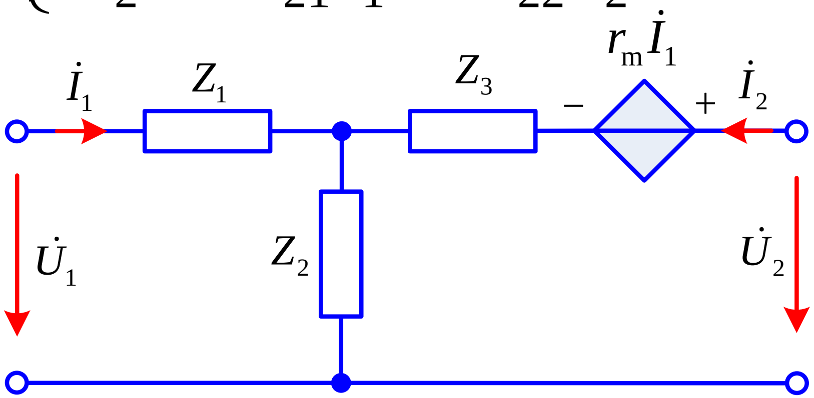
2. 含受控源的T和π型等效电路



(1) Z参数含受控源T型等效电路

$$\begin{cases} \dot{U}_1 = Z_{11}\dot{I}_1 + Z_{12}\dot{I}_2 \\ \dot{U}_2 = Z_{21}\dot{I}_1 + Z_{22}\dot{I}_2 \end{cases}$$

$$\begin{cases} Z_1 = Z_{11} - Z_{12} \\ Z_2 = Z_{12} \\ Z_3 = Z_{22} - Z_{12} \\ r_m = Z_{21} - Z_{12} \end{cases}$$



联立解出

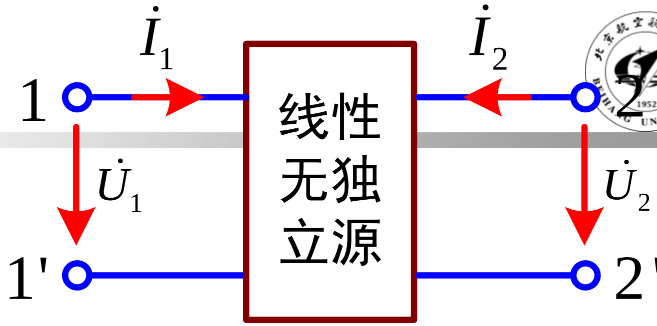
$$\begin{cases} \dot{U}_1 = Z_1\dot{I}_1 + Z_2(\dot{I}_1 + \dot{I}_2) \\ \dot{U}_2 = r_m\dot{I}_1 + Z_3\dot{I}_2 + Z_2(\dot{I}_1 + \dot{I}_2) \end{cases}$$

$$\begin{cases} \dot{U}_1 = (Z_1 + Z_2)\dot{I}_1 + Z_2\dot{I}_2 \\ \dot{U}_2 = (r_m + Z_2)\dot{I}_1 + (Z_2 + Z_3)\dot{I}_2 \end{cases}$$

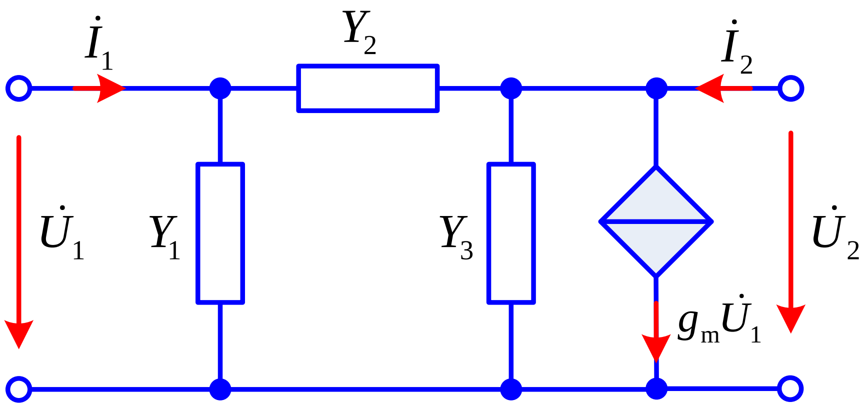
$$\begin{cases} Z_{11} = Z_1 + Z_2 \\ Z_{12} = Z_2 \\ Z_{21} = r_m + Z_2 \\ Z_{22} = Z_2 + Z_3 \end{cases}$$

2. 含受控源的T和π型等效电路

(2) Y参数含受控源π型等效电路



$$\begin{cases} \dot{I}_1 = Y_{11}\dot{U}_1 + Y_{12}\dot{U}_2 \\ \dot{I}_2 = Y_{21}\dot{U}_1 + Y_{22}\dot{U}_2 \end{cases}$$



$$\begin{cases} \dot{I}_1 = Y_1\dot{U}_1 + Y_2(\dot{U}_1 - \dot{U}_2) \\ \dot{I}_2 = g_m\dot{U}_1 + Y_3\dot{U}_2 + Y_2(\dot{U}_2 - \dot{U}_1) \end{cases}$$

$$\begin{cases} \dot{I}_1 = (Y_1 + Y_2)\dot{U}_1 - Y_2\dot{U}_2 \\ \dot{I}_2 = (g_m - Y_2)\dot{U}_1 + (Y_2 + Y_3)\dot{U}_2 \end{cases}$$

$$\begin{cases} Y_{11} = Y_1 + Y_2 \\ Y_{12} = -Y_2 \\ Y_{21} = g_m - Y_2 \\ Y_{22} = Y_2 + Y_3 \end{cases}$$

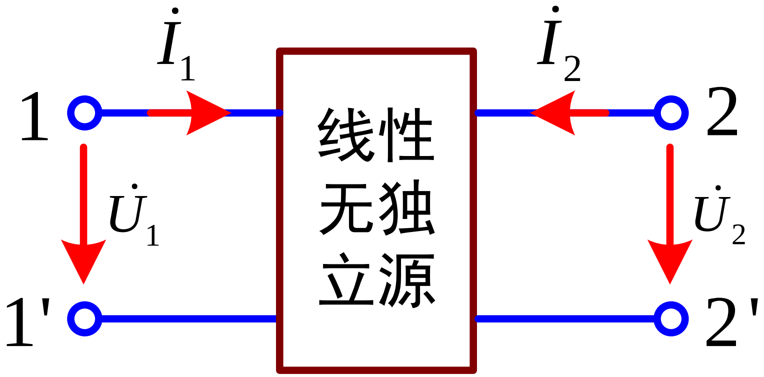
联立解出

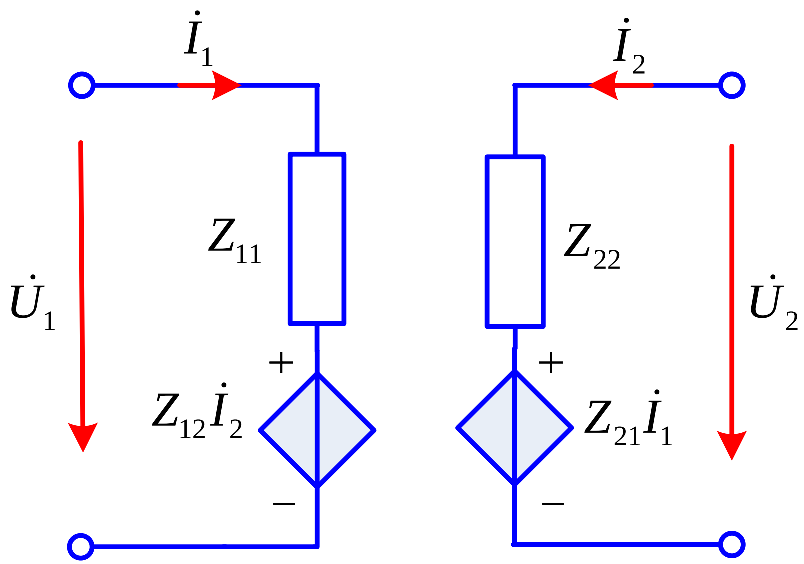
$$\begin{cases} Y_1 = Y_{11} + Y_{12} \\ Y_2 = -Y_{12} \\ Y_3 = Y_{22} + Y_{12} \\ g_m = Y_{21} - Y_{12} \end{cases}$$

3. 受控源等效电路

(1)Z参数受控源等效电路

$$\begin{cases} \dot{U}_1 = Z_{11}\dot{I}_1 + Z_{12}\dot{I}_2 \\ \dot{U}_2 = Z_{21}\dot{I}_1 + Z_{22}\dot{I}_2 \end{cases}$$

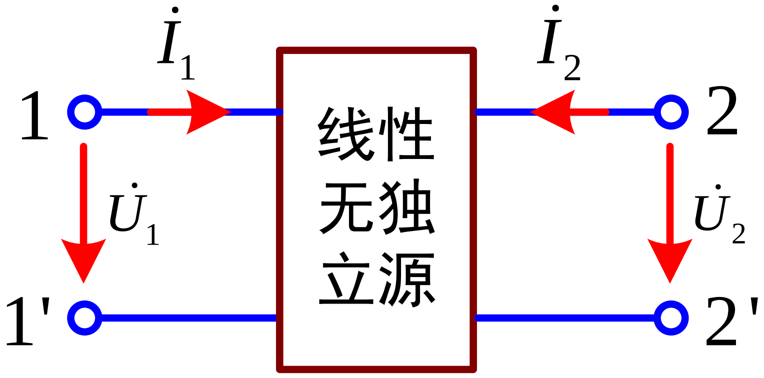


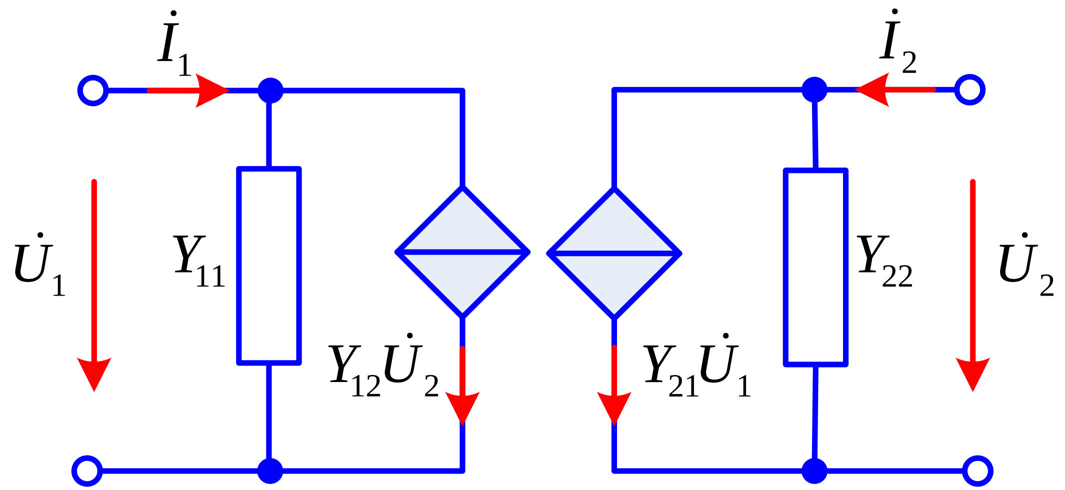


3. 受控源等效电路

(2)Y参数受控源等效电路

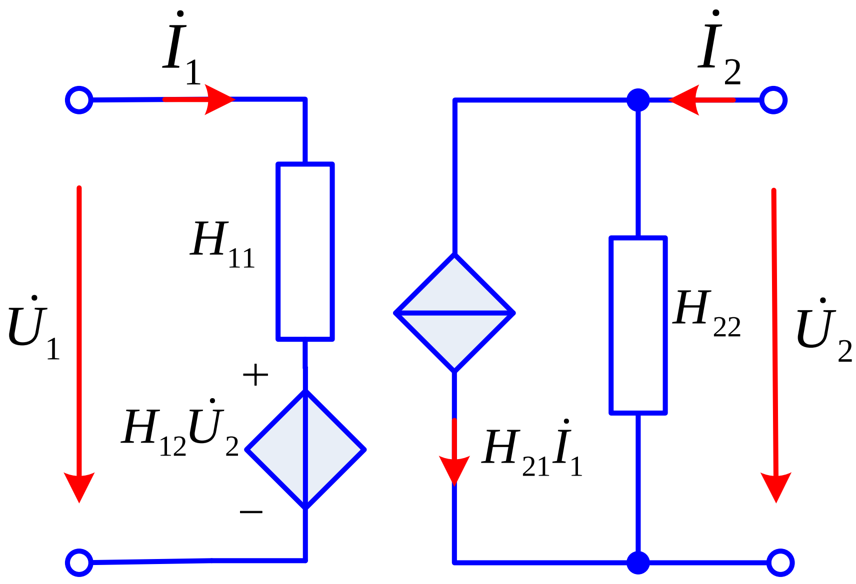
$$\begin{cases} \dot{I}_1 = Y_{11}\dot{U}_1 + Y_{12}\dot{U}_2 \\ \dot{I}_2 = Y_{21}\dot{U}_1 + Y_{22}\dot{U}_2 \end{cases}$$





(3) H 参数表示的等效电路

$$\begin{cases} \dot{U}_1 = H_{11}\dot{I}_1 + H_{12}\dot{U}_2 \\ \dot{I}_2 = H_{21}\dot{I}_1 + H_{22}\dot{U}_2 \end{cases}$$



注意：

（1）等效只对两个端口上的电压、电流关系成立。

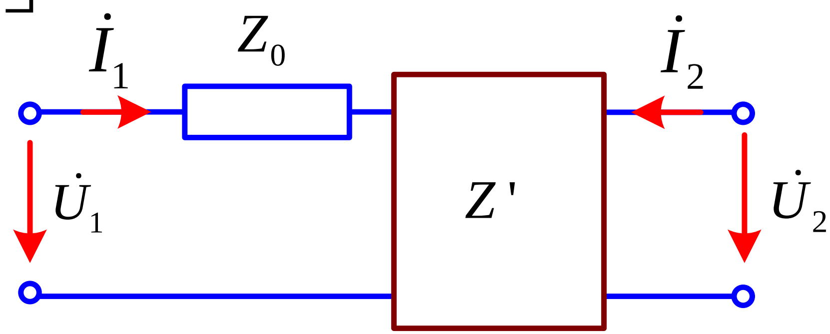
（2）一个二端口网络在满足相同网络方程的条件下，其等效电路模型不是唯一的。

（3）若网络对称则等效电路也对称。

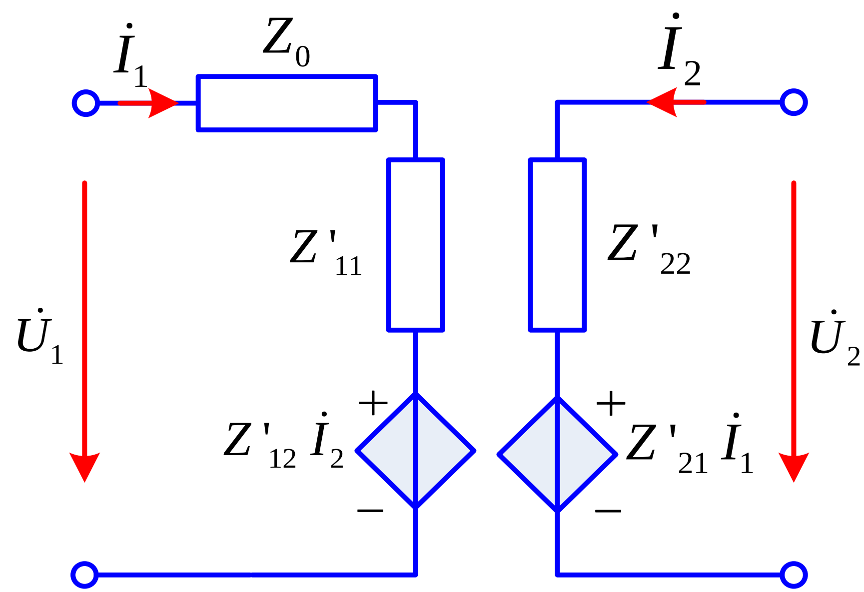
（4）π型和T型等效电路可以互换，根据其它参数与Y、Z参数的关系，可以得到用其它参数表示的π型和T型等效电路。

【例】 已知 $\mathbf{Z}'=\begin{bmatrix} Z'_{11} & Z'_{12} \\ Z'_{21} & Z'_{22} \end{bmatrix}$ 求Z参数。

解 法1：

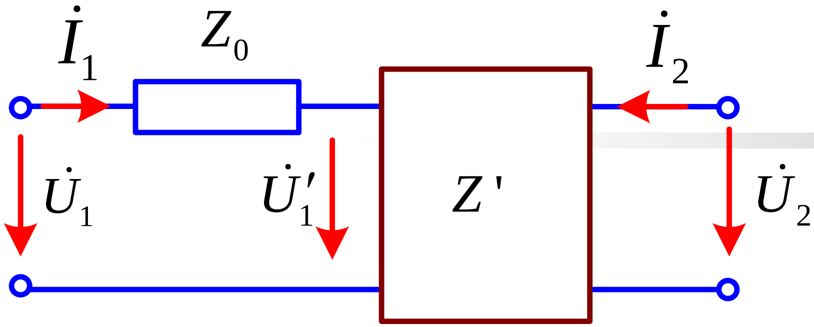


$$\begin{cases} \dot{U}_1=(Z_0+Z'_{11})\dot{I}_1+Z'_{12}\dot{I}_2 \\ \dot{U}_2=Z'_{21}\dot{I}_1+Z'_{22}\dot{I}_2 \end{cases}$$



$$\mathbf{Z}=\begin{bmatrix} Z_0+Z'_{11} & Z'_{12} \\ Z'_{21} & Z'_{22} \end{bmatrix}$$

法2：

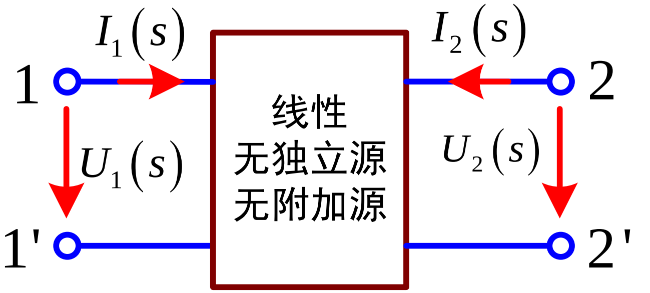


$$\begin{cases} \dot{U}_1' = Z_{11}'\dot{I}_1 + Z_{12}'\dot{I}_2 \\ \dot{U}_2 = Z_{21}'\dot{I}_1 + Z_{22}'\dot{I}_2 \end{cases}$$

$$\dot{U}_1 = Z_0\dot{I}_1 + \dot{U}_1'$$

$$\begin{cases} \dot{U}_1 = (Z_0 + Z_{11}')\dot{I}_1 + Z_{12}'\dot{I}_2 \\ \dot{U}_2 = Z_{21}'\dot{I}_1 + Z_{22}'\dot{I}_2 \end{cases} \Rightarrow \mathbf{Z} = \begin{bmatrix} Z_0 + Z_{11}' & Z_{12}' \\ Z_{21}' & Z_{22}' \end{bmatrix}$$

16.4 二端口的转移函数



1. 基本概念 无独立源 零初始条件

$$转移函数=\frac{输出电压or电流的象函数}{输入电压or电流的象函数}$$

$$电流转移函数=\frac{I_2(s)}{I_1(s)} \qquad 电压转移函数=\frac{U_2(s)}{U_1(s)}$$

$$转移导纳=\frac{I_2(s)}{U_1(s)} \qquad 转移阻抗=\frac{U_2(s)}{I_1(s)}$$

无端接的二端口——无输入激励内阻 且 无外接负载

单端接的二端口——有输入激励内阻 或 有外接负载

双端接的二端口——有输入激励内阻 且 有外接负载

2. 无端接的二端口转移函数

$$\begin{cases} U_1(s) = Z_{11}I_1(s) + Z_{12}I_2(s) \\ U_2(s) = Z_{21}I_1(s) + Z_{22}I_2(s) \end{cases} \qquad I_2(s) = 0 \Rightarrow \frac{U_2(s)}{U_1(s)} = \frac{Z_{21}(s)}{Z_{11}(s)}$$

$$\begin{cases} I_1(s) = Y_{11}U_1(s) + Y_{12}U_2(s) \\ I_2(s) = Y_{21}U_1(s) + Y_{22}U_2(s) \end{cases} \qquad I_2(s) = 0 \Rightarrow \frac{U_2(s)}{U_1(s)} = -\frac{Y_{21}(s)}{Y_{22}(s)}$$

$$U_2(s) = 0 \Rightarrow \frac{I_2(s)}{I_1(s)} = \frac{Y_{21}(s)}{Y_{11}(s)} = -\frac{Z_{21}(s)}{Z_{22}(s)}$$

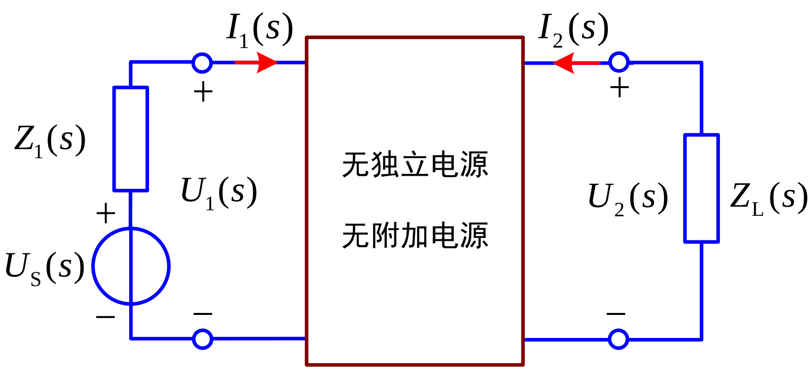
$$U_2(s) = 0 \Rightarrow \frac{I_2(s)}{U_1(s)} = Y_{21}(s)$$

转移函数完全可以用**Y**或**Z**参数表示。

$$I_2(s) = 0 \Rightarrow \frac{U_2(s)}{I_1(s)} = Z_{21}(s)$$

也可用**T**或**H**参数表示。

3. 双端接的二端口转移函数



$$\begin{cases} U_1(s) = U_S(s) - Z_1(s) I_1(s) \\ U_2(s) = -Z_L(s) I_2(s) \end{cases}$$

$$\begin{cases} U_1(s) = Z_{11}(s) I_1(s) + Z_{12}(s) I_2(s) \\ U_2(s) = Z_{21}(s) I_1(s) + Z_{22}(s) I_2(s) \end{cases}$$

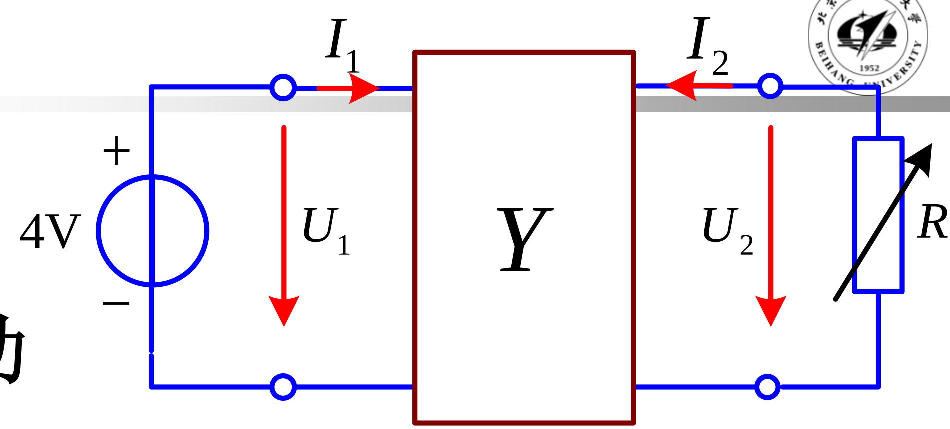
$$\begin{cases} U_S(s) - Z_1(s) I_1(s) = Z_{11}(s) I_1(s) + Z_{12}(s) I_2(s) \\ -Z_L(s) I_2(s) = Z_{21}(s) I_1(s) + Z_{22}(s) I_2(s) \end{cases}$$

$$I_2(s) = -\frac{U_S(s) Z_{21}(s)}{\left[Z_1(s) + Z_{11}(s)\right]\left[Z_L(s) + Z_{22}(s)\right] - Z_{12}(s) Z_{21}(s)}$$

$$\frac{U_2(s)}{U_S(s)} = -\frac{Z_L(s) I_2(s)}{U_S(s)} = \frac{Z_{21}(s) Z_L(s)}{\left[Z_1(s) + Z_{11}(s)\right]\left[Z_L(s) + Z_{22}(s)\right] - Z_{12}(s) Z_{21}(s)}$$

【例】

已知 $\mathbf{Y}=\begin{pmatrix} 1 & -0.25 \\ -0.25 & 0.5 \end{pmatrix}$



求：*R*为何值时，*R*获最大功率？此最大功率是多少？

解

$$\begin{cases} I_1 = U_1 - 0.25U_2 \\ I_2 = -0.25U_1 + 0.5U_2 \end{cases}$$

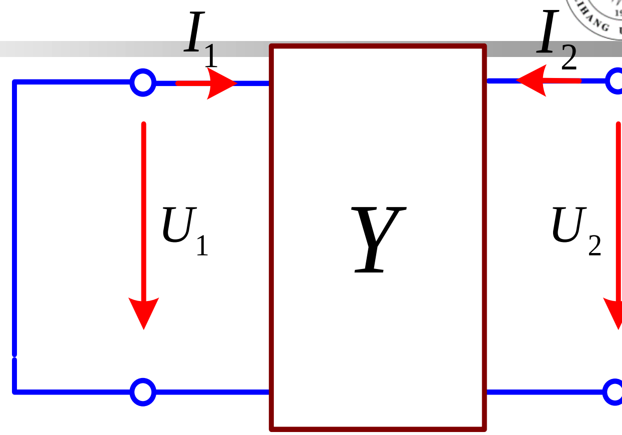
开路：$\begin{cases} U_1 = 4\text{V} \\ I_2 = 0 \end{cases}$ ⇒ $U_2 = U_{\text{OC}} = 2\text{V}$

短路：$\begin{cases} U_1 = 4\text{V} \\ U_2 = 0 \end{cases}$ ⇒ $I_{sc} = -I_2 = 1A$

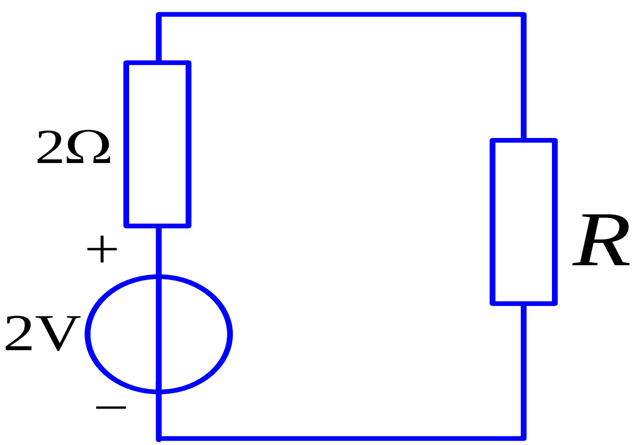
⇒ $R_{\text{eq}} = \dfrac{U_{OC}}{I_{SC}} = 2\Omega$

或采用外加电源法求R_{eq}：

$$\begin{cases} I_1 = U_1 - 0.25U_2 \\ I_2 = -0.25U_1 + 0.5U_2 \\ U_1 = 0\text{V} \end{cases}$$



$$\Rightarrow R_{eq} = \frac{U_2}{I_2} = 2\Omega$$



R=2Ω时，R获最大功率。

$$P = \left(\frac{2}{2+2}\right)^2 \times 2 = 0.5\text{W}$$

作业

- 16-2(a)　　【Y，Z矩阵】
- 16-4(a)　　【 Y矩阵】
- 16-3(b)(e)　【T矩阵】
- 16-5 (a)　　【H矩阵】

- 16-9　　　【转移函数】
- 16-10(b)　【 等效电路】