第12章 二端口网络

重点内容

1. 二端口的Y、Z、T（A）、H等参数矩阵以及它们之间的相互关系。

2. 二端口的连接和等效电路。

3. 回转器和负阻抗变换器。

主要内容：

12.1 二端口网络的基本概念

12.2 二端口网络的方程和参数

12.3 二端口网络的等效电路

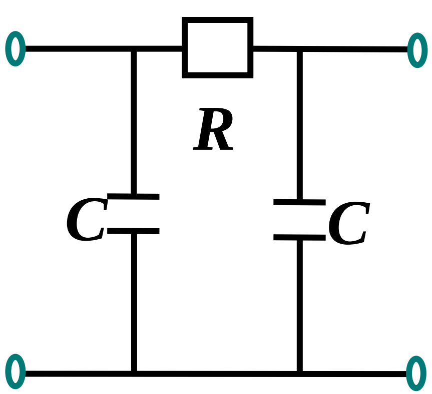
12.4 二端口网络的连接

12.5 回转器和负阻抗变换器

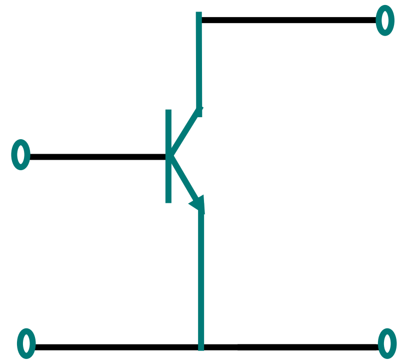
§ 12-1 二端口网络的基本概念

端口由二对端钮构成，且满足如下条件：从一个端钮流入的电流等于从另一个端钮流出的电流。

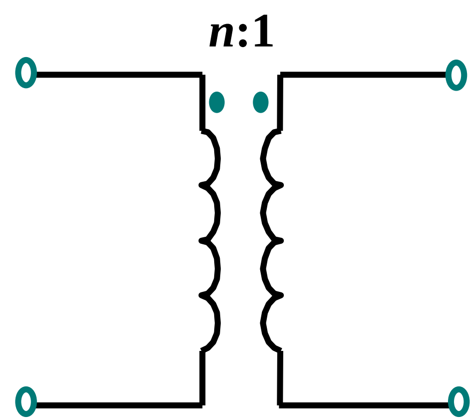
例



滤波器电路



放大电路



变压器

§ 12-2 二端口的方程和参数

四个参变量: $\dot{U}_1, \dot{I}_1, \dot{U}_2, \dot{I}_2$

$$C_4^2 = 6$$

Y $\begin{cases} \dot{I}_1 = f_1(\dot{U}_1, \dot{U}_2) \\ \dot{I}_2 = f_2(\dot{U}_1, \dot{U}_2) \end{cases}$

Z $\begin{cases} \dot{U}_1 = f_1(\dot{I}_1, \dot{I}_2) \\ \dot{U}_2 = f_1(\dot{I}_1, \dot{I}_2) \end{cases}$

T $\begin{cases} \dot{U}_1 = f_1(\dot{U}_2, \dot{I}_2) \\ \dot{I}_1 = f_2(\dot{U}_2, \dot{I}_2) \end{cases}$

H $\begin{cases} \dot{U}_1 = f_1(\dot{I}_1, \dot{U}_2) \\ \dot{I}_2 = f_2(\dot{I}_1, \dot{U}_2) \end{cases}$

$\begin{cases} \dot{U}_2 = f_1(\dot{U}_1, \dot{I}_1) \\ \dot{I}_2 = f_2(\dot{U}_1, \dot{I}_1) \end{cases}$

$\begin{cases} \dot{U}_2 = f_1(\dot{U}_1, \dot{I}_2) \\ \dot{I}_1 = f_2(\dot{U}_1, \dot{I}_2) \end{cases}$

一、 Y 参数和方程

$\dot{U}_1$和$\dot{U}_2$看成电源

$\dot{I}_1$和$\dot{I}_2$看成响应

$$\begin{cases} \dot{I}_1 = \dot{I}_1^{(1)} + \dot{I}_1^{(2)} = Y_{11}\dot{U}_1 + Y_{12}\dot{U}_2 \\ \dot{I}_2 = \dot{I}_2^{(1)} + \dot{I}_2^{(2)} = Y_{21}\dot{U}_1 + Y_{22}\dot{U}_2 \end{cases}$$

端口电流$\dot{I}_1$和$\dot{I}_2$可视为$\dot{U}_1$和$\dot{U}_2$共同作用产生。

矩阵形式

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

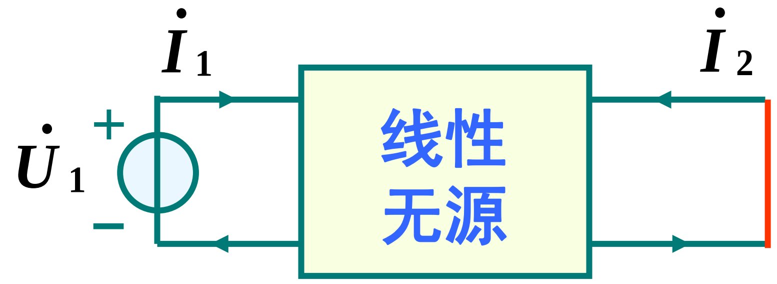
令 $Y = \begin{bmatrix} Y_{11} & Y_{12} \\ Y_{21} & Y_{22} \end{bmatrix}$ 称为Y 参数矩阵

Y参数的实验测定

Y 短路导纳参数

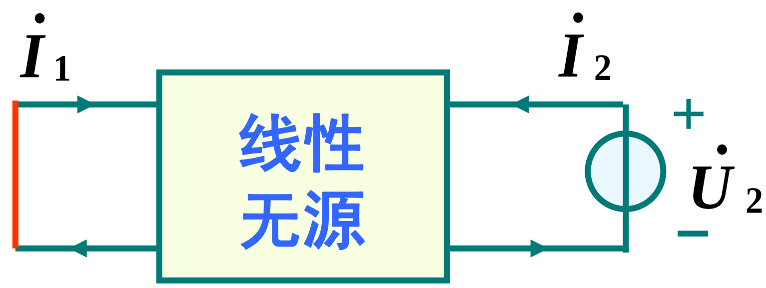
$$Y_{11}=\frac{\dot I_1}{\dot U_1}\bigg|_{\dot U_2=0}$$ 驱动点导纳

$$Y_{21}=\frac{\dot I_2}{\dot U_1}\bigg|_{\dot U_2=0}$$ 转移导纳



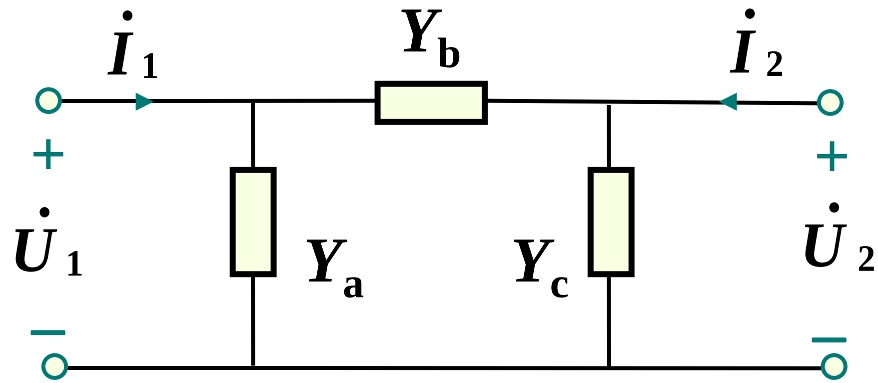
$$Y_{12}=\frac{\dot I_1}{\dot U_2}\bigg|_{\dot U_1=0}$$ 转移导纳

$$Y_{22}=\frac{\dot I_2}{\dot U_2}\bigg|_{\dot U_1=0}$$ 驱动点导纳

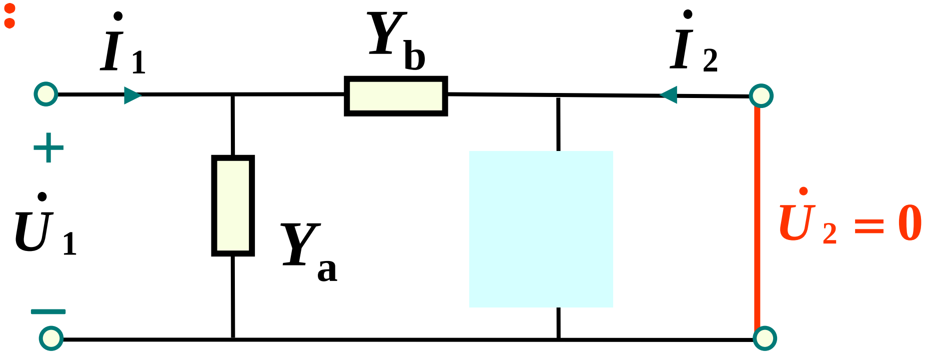


例1. 求Y 参数。

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

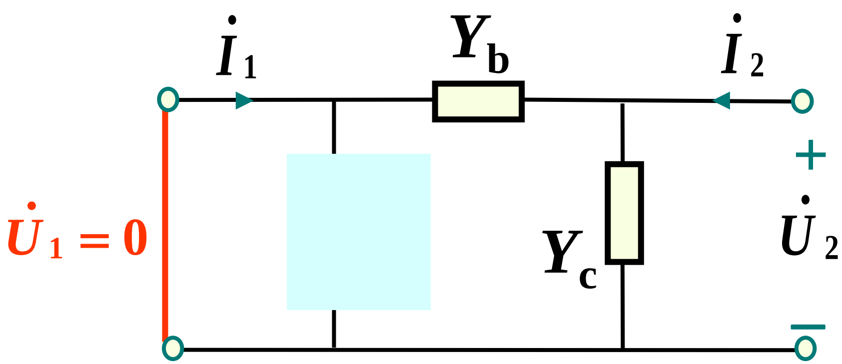


解:



$$Y_{11} = \frac{\dot{I}_1}{\dot{U}_1}\bigg|_{\dot{U}_2=0} = Y_a + Y_b$$

$$Y_{21} = \frac{\dot{I}_2}{\dot{U}_1}\bigg|_{\dot{U}_2=0} = -Y_b$$



$$Y_{12} = \frac{\dot{I}_1}{\dot{U}_2}\bigg|_{\dot{U}_1=0} = -Y_b$$

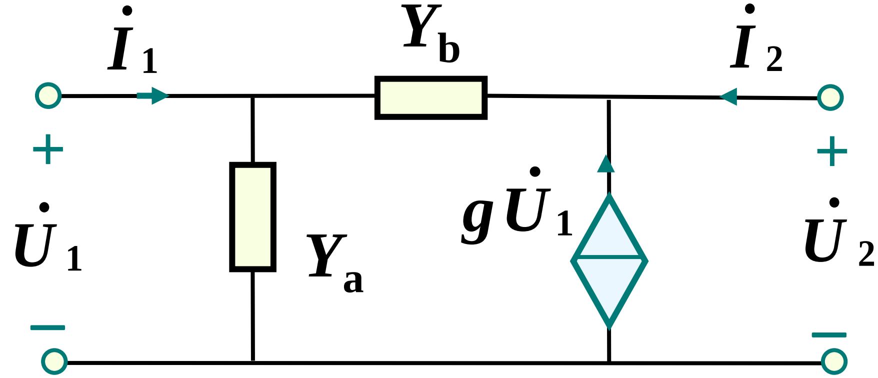
$$Y_{22} = \frac{\dot{I}_2}{\dot{U}_2}\bigg|_{\dot{U}_2=0} = Y_b + Y_c$$

$$Y_{12} = Y_{21} = -Y_b$$

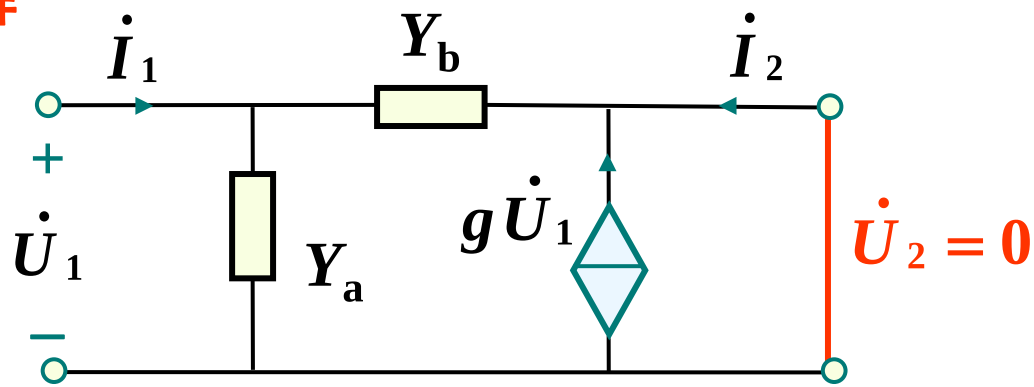
互易二端口

例2 求所示电路的Y参数

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

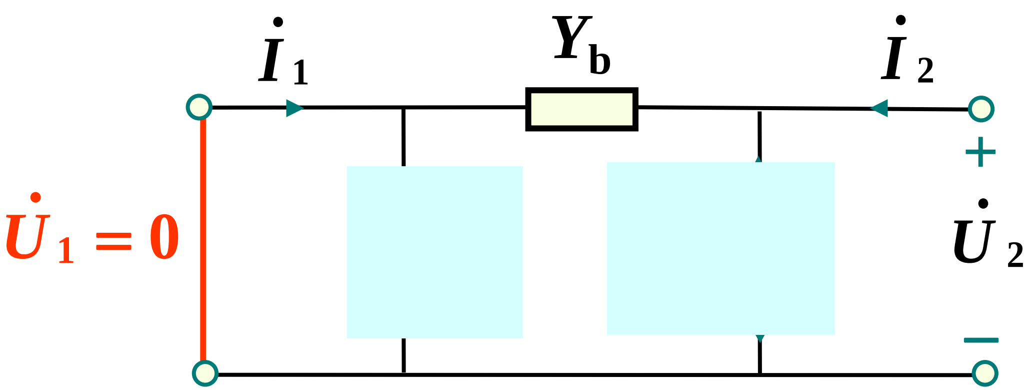


解一



$$Y_{11} = \left.\frac{\dot{I}_1}{\dot{U}_1}\right|_{\dot{U}_2=0} = Y_a + Y_b$$

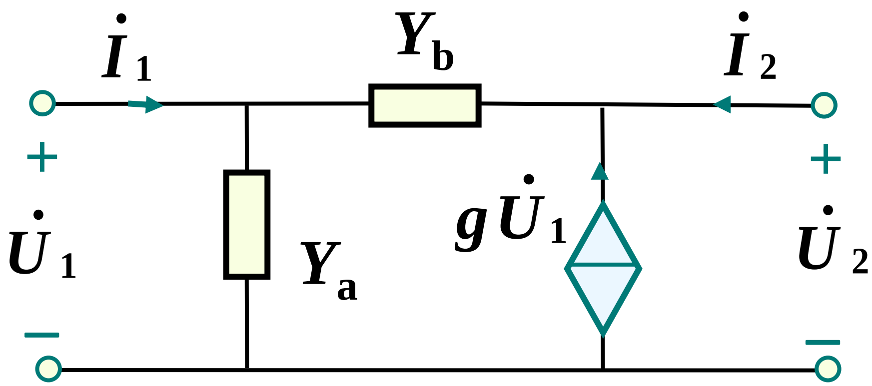
$$Y_{21} = \left.\frac{\dot{I}_2}{\dot{U}_1}\right|_{\dot{U}_2=0} = -Y_b - g$$



$$Y_{12} = \left.\frac{\dot{I}_1}{\dot{U}_2}\right|_{\dot{U}_1=0} = -Y_b$$

$$Y_{22} = \left.\frac{\dot{I}_2}{\dot{U}_2}\right|_{\dot{U}_1=0} = Y_b$$

解二



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

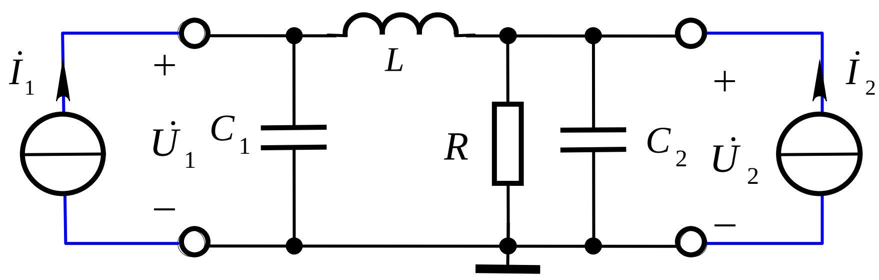
$$\Rightarrow$$

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

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

非互易二端口网络（网络内部有受控源）四个参数独立。

例3：求如图所示二端口 Y参数矩阵。



解：用电流源置换两个端口列结点电压方程

$$\dot{I}_1 = (j\omega C_1 + \frac{1}{j\omega L})\dot{U}_1 - \frac{1}{j\omega L}\dot{U}_2$$

$$\dot{I}_2 = -\frac{1}{j\omega L}\dot{U}_1 + (\frac{1}{R} + j\omega C_2 + \frac{1}{j\omega L})\dot{U}_2$$

上式的系数矩阵就是所求Y 参数矩阵：

$$Y = \begin{bmatrix} j\omega C_1 + \frac{1}{j\omega L} & -\frac{1}{j\omega L} \\ -\frac{1}{j\omega L} & \frac{1}{R} + j\omega C_2 + \frac{1}{j\omega L} \end{bmatrix}$$

讨论:

（1） 若无源二端口网络中无受控源时,

$\longrightarrow$ Y参数只有三个独立参数.

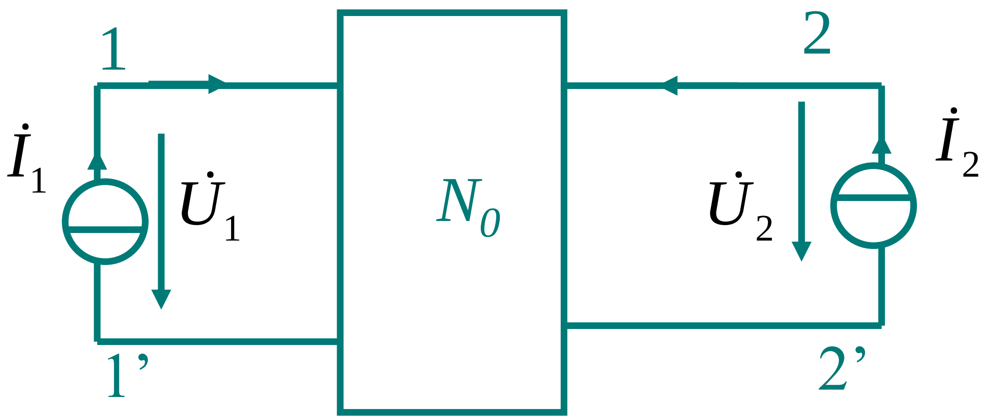
$$Y_{12} = Y_{21}$$

(2) 若无源二端口网络对称时,

$\longrightarrow$ Y参数只有两个独立参数.

$$Y_{11} = Y_{22}$$

二. Z参数方程 (又称开路参数)



Z参数方程为

$$
\begin{cases}
\dot{U}_1 = \dot{U}_1^{(1)} + \dot{U}_1^{(2)} = Z_{11}\dot{I}_1 + Z_{12}\dot{I}_2 \\
\dot{U}_2 = \dot{U}_2^{(1)} + \dot{U}_2^{(2)} = Z_{21}\dot{I}_1 + Z_{22}\dot{I}_2
\end{cases}
\qquad
\mathbf{Z} = \begin{bmatrix} Z_{11} & Z_{12} \\ Z_{21} & Z_{22} \end{bmatrix}
$$

$$
Z_{11} = \left.\frac{\dot{U}_1}{\dot{I}_1}\right|_{\dot{I}_2=0} \qquad Z_{21} = \left.\frac{\dot{U}_2}{\dot{I}_1}\right|_{\dot{I}_2=0} \qquad Z_{12} = \left.\frac{\dot{U}_1}{\dot{I}_2}\right|_{\dot{I}_1=0} \qquad Z_{22} = \left.\frac{\dot{U}_2}{\dot{I}_2}\right|_{\dot{I}_1=0}
$$

讨论：

（1） 若无源二端口网络中无受控源时,

$\longrightarrow$ **Z参数只有三个独立参数.**

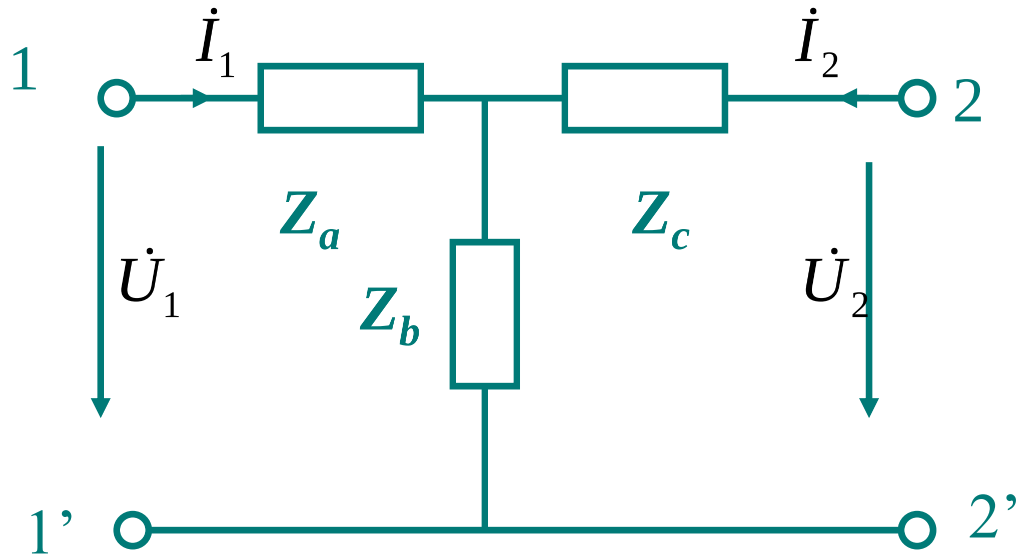
$$Z_{12} = Z_{21}$$

(2) 若无源二端口网络对称时,

$\longrightarrow$ **Z参数只有两个独立参数.**

$$Z_{11} = Z_{22}$$

例4: 求下述二端口的的Z参数方程.

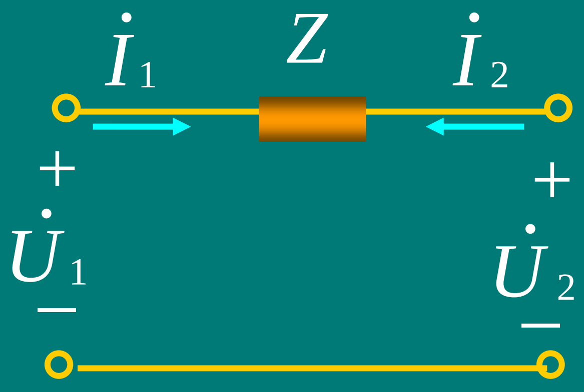


$$\mathbf{Z}=\begin{bmatrix} Z_a+Z_b & Z_b \\ Z_b & Z_b+Z_c \end{bmatrix}$$

$$Z_{11}=\frac{\dot U_1}{\dot I_1}\bigg|_{\dot I_2=0}=Z_a+Z_b \qquad Z_{12}=\frac{\dot U_1}{\dot I_2}\bigg|_{\dot I_1=0}=Z_b$$

$$Z_{21}=\frac{\dot U_2}{\dot I_1}\bigg|_{\dot I_2=0}=Z_b \qquad Z_{22}=\frac{\dot U_2}{\dot I_2}\bigg|_{\dot I_1=0}=Z_b+Z_c$$

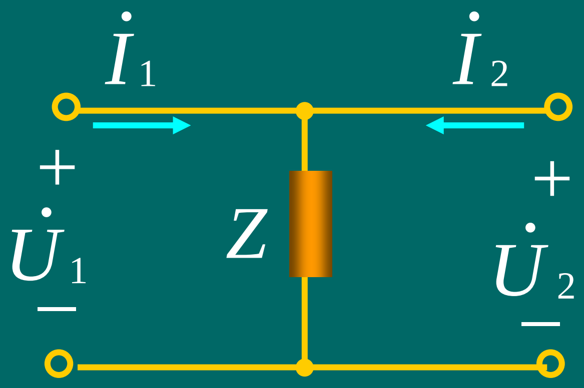
注意 并非所有的二端口均有Z、Y参数。



$$\dot{I}_1 = -\dot{I}_2 = \frac{\dot{U}_1 - \dot{U}_2}{Z}$$

$$\rightarrow \quad [Y] = \begin{bmatrix} \frac{1}{Z} & -\frac{1}{Z} \\ -\frac{1}{Z} & \frac{1}{Z} \end{bmatrix}$$

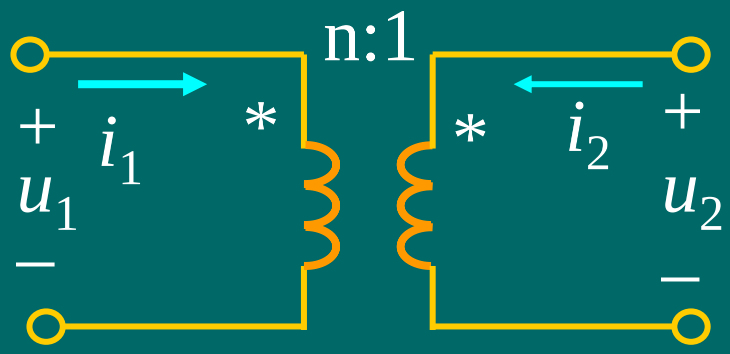
$$[Z] = [Y]^{-1}$$ 不存在



$$\dot{U}_1 = \dot{U}_2 = Z(\dot{I}_1 + \dot{I}_2)$$

$$\rightarrow [Z] = \begin{bmatrix} Z & Z \\ Z & Z \end{bmatrix}$$

$$[Y] = [Z]^{-1}$$ 不存在

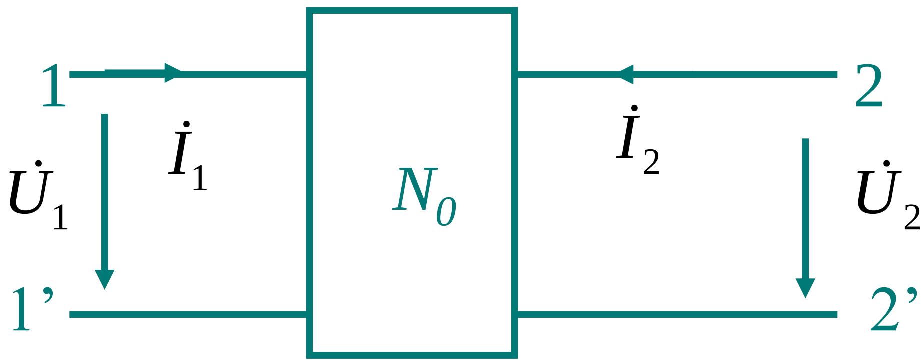


$$\dot{U}_1 = n\dot{U}_2$$

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

$[Y]$ $[Z]$ 均不存在

三. T参数方程（又称传输, A参数）



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

由Y参数方程，可推出T传输参数方程

$$\begin{cases} \dot{I}_1 = Y_{11}\dot{U}_1 + Y_{12}\dot{U}_2 \\ \dot{I}_2 = Y_{21}\dot{U}_1 + Y_{22}\dot{U}_2 \end{cases} \Rightarrow \begin{cases} \dot{U}_1 = A\dot{U}_2 + B(-\dot{I}_2) \\ \dot{I}_1 = C\dot{U}_2 + D(-\dot{I}_2) \end{cases}$$

由Y参数的第二式得:

$$\dot{U}_1 = -\frac{Y_{22}}{Y_{21}}\dot{U}_2 + \frac{1}{Y_{21}}\dot{I}_2$$

将上式代入Y参数的第一式得:

$$\dot{I}_1 = \left(Y_{12} - \frac{Y_{11}Y_{22}}{Y_{21}}\right)\dot{U}_2 + \frac{Y_{11}}{Y_{21}}\dot{I}_2$$

$$A = -\frac{Y_{22}}{Y_{21}} \qquad B = -\frac{1}{Y_{21}} \quad C = \left(Y_{12} - \frac{Y_{11}Y_{22}}{Y_{21}}\right) \qquad D = -\frac{Y_{11}}{Y_{21}}$$

讨论:

（1） 若无源二端口网络中无受控源时,

⟶ T参数只有三个独立参数.

$$Y_{12} = Y_{21} \Rightarrow AD - BC = 1$$

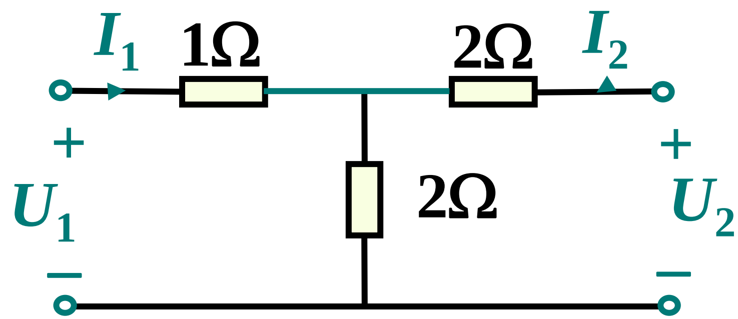
(2) 若无源二端口网络对称时,

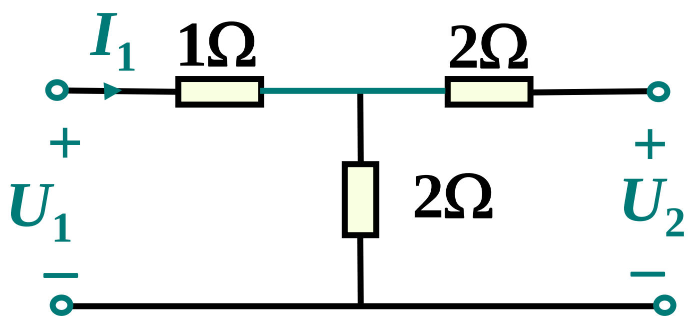
⟶ T参数只有两个独立参数.

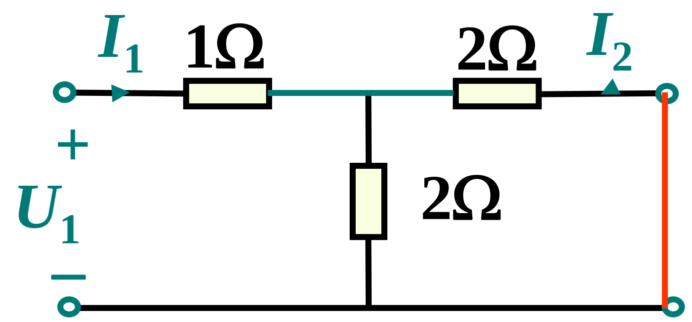
$$Y_{11} = Y_{22} \Rightarrow A = D$$

例：求T参数

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







$$A = \frac{U_1}{U_2}\bigg|_{I_2=0} = \frac{1+2}{2} = 1.5$$

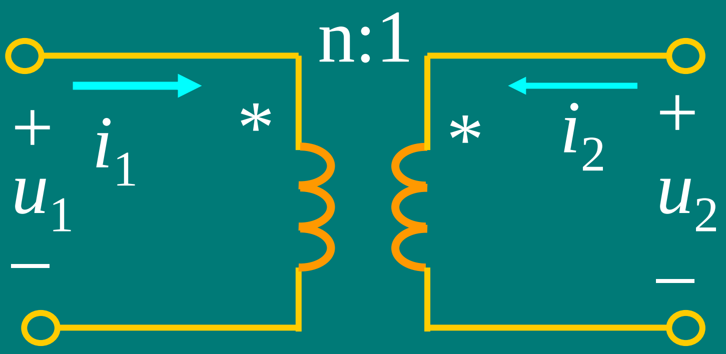
$$B = \frac{U_1}{-I_2}\bigg|_{U_2=0} = \frac{I_1[1+(2//2)]}{0.5I_1} = 4\ \Omega$$

$$C = \frac{I_1}{U_2}\bigg|_{I_2=0} = 0.5\ S$$

$$D = \frac{I_1}{-I_2}\bigg|_{U_2=0} = \frac{I_1}{0.5I_1} = 2$$

例

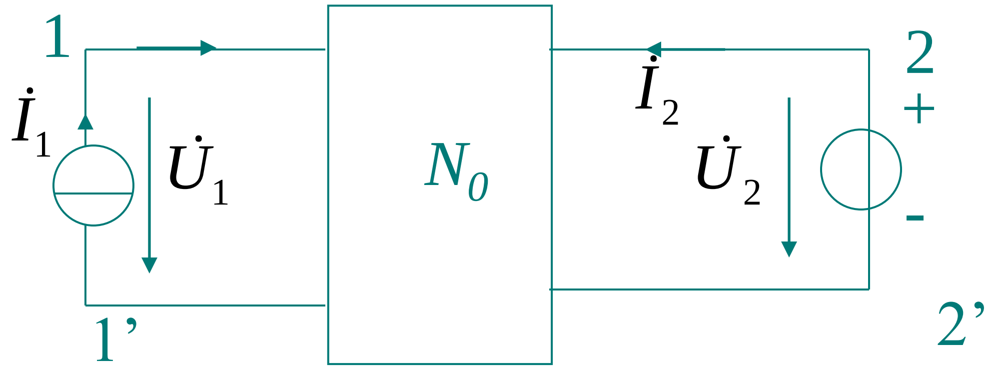
$$\begin{cases} u_1 = nu_2 \\ i_1 = -\dfrac{1}{n} i_2 \end{cases}$$



即

$$\begin{bmatrix} u_1 \\ i_1 \end{bmatrix} = \begin{bmatrix} n & 0 \\ 0 & \dfrac{1}{n} \end{bmatrix} \begin{bmatrix} u_2 \\ -i_2 \end{bmatrix} \quad \rightarrow \quad [T] = \begin{bmatrix} n & 0 \\ 0 & \dfrac{1}{n} \end{bmatrix}$$

四. H参数方程 （又称混合参数）



H参数方程为

$$
\begin{cases}
\dot{U}_1 = \dot{U}_1^{(1)} + \dot{U}_1^{(2)} = H_{11}\dot{I}_1 + H_{12}\dot{U}_2 \\
\dot{I}_2 = \dot{I}_2^{(1)} + \dot{I}_2^{(2)} = H_{21}\dot{I}_1 + H_{22}\dot{U}_2
\end{cases}
\qquad
\mathbf{H} = \begin{bmatrix} H_{11} & H_{12} \\ H_{21} & H_{22} \end{bmatrix}
$$

$$
H_{11} = \left.\frac{\dot{U}_1}{\dot{I}_1}\right|_{\dot{U}_2=0} \quad H_{21} = \left.\frac{\dot{I}_2}{\dot{I}_1}\right|_{\dot{U}_2=0} \quad H_{12} = \left.\frac{\dot{U}_1}{\dot{U}_2}\right|_{\dot{I}_1=0} \quad H_{22} = \left.\frac{\dot{I}_2}{\dot{U}_2}\right|_{\dot{I}_1=0}
$$

讨论：

(1) 若无源二端口网络中无受控源时,

$\longrightarrow$ **H参数只有三个独立参数.**

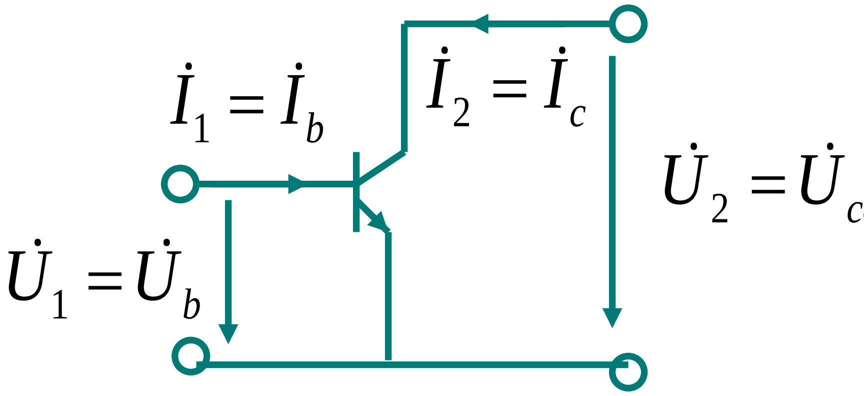
$$H_{12} = -H_{21}$$

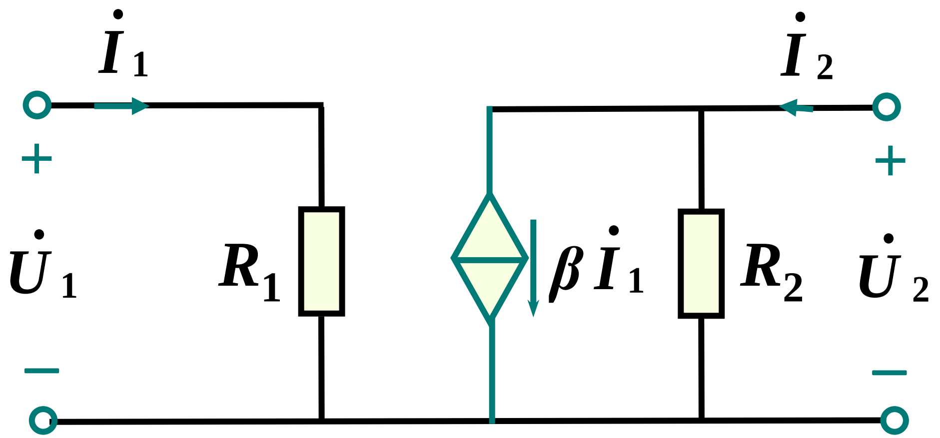
(2) 若无源二端口网络对称时,

$\longrightarrow$ **H参数只有两个独立参数.**

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

例　求所示电路的H参数





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

$$\dot{U}_1 = R_1\dot{I}_1$$

$$\dot{I}_2 = \beta\dot{I}_1 + \frac{1}{R_2}\dot{U}_2$$

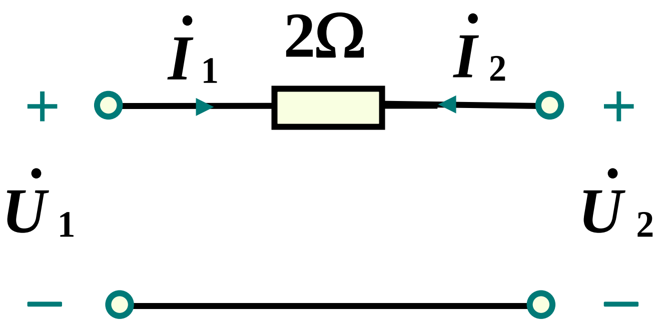
$$H = \begin{bmatrix} R_1 & 0 \\ \beta & 1/R_2 \end{bmatrix}$$

小结

1 .为什么用这么多参数表示（互换表13-1）

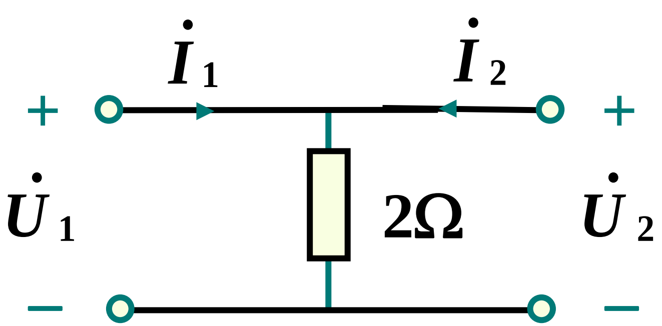
（1）为描述电路方便，测量方便。

（2）有些电路只存在某几种参数。



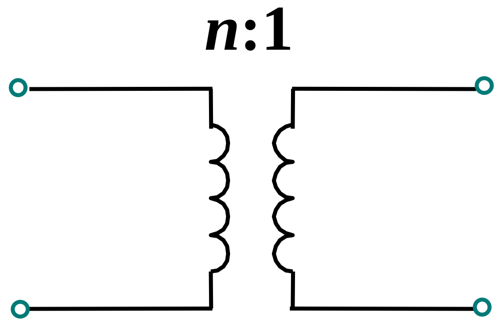
$$Y = \begin{bmatrix} 0.5\text{s} & -0.5\text{s} \\ -0.5\text{s} & 0.5\text{s} \end{bmatrix}$$

Z参数 不存在



$$Z = \begin{bmatrix} 2\Omega & 2\Omega \\ 2\Omega & 2\Omega \end{bmatrix}$$

Y 参数不存在



存在T参数H参数

Z,Y 均不存在

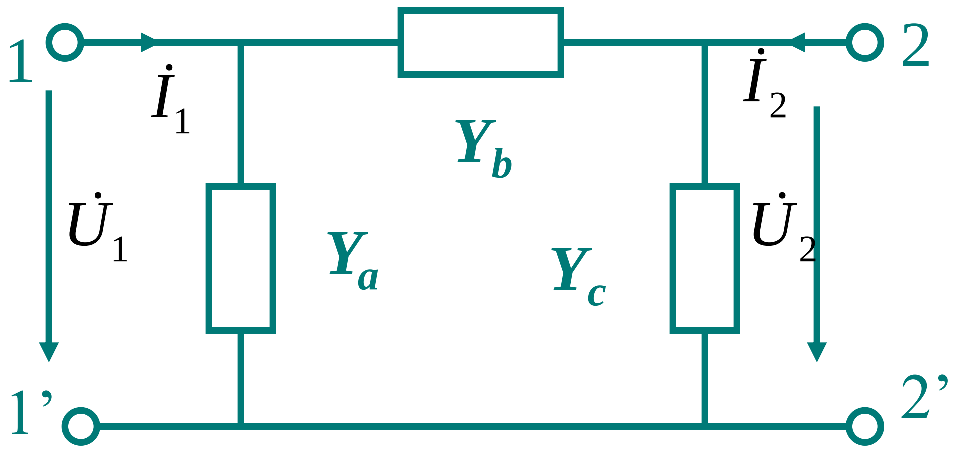
3. 可用不同的参数表示以不同的方式连接的二端口。

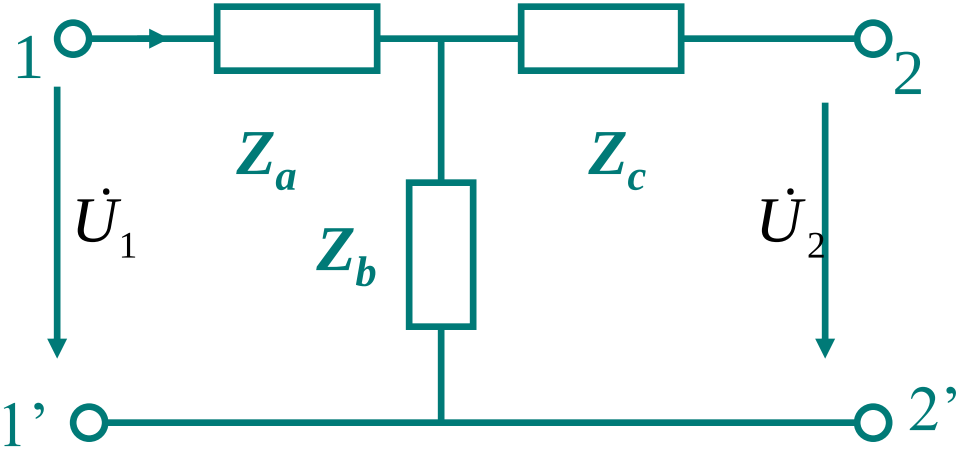
4.含有受控源的电路有四个独立参数。

§ 12-3 二端口的等效电路

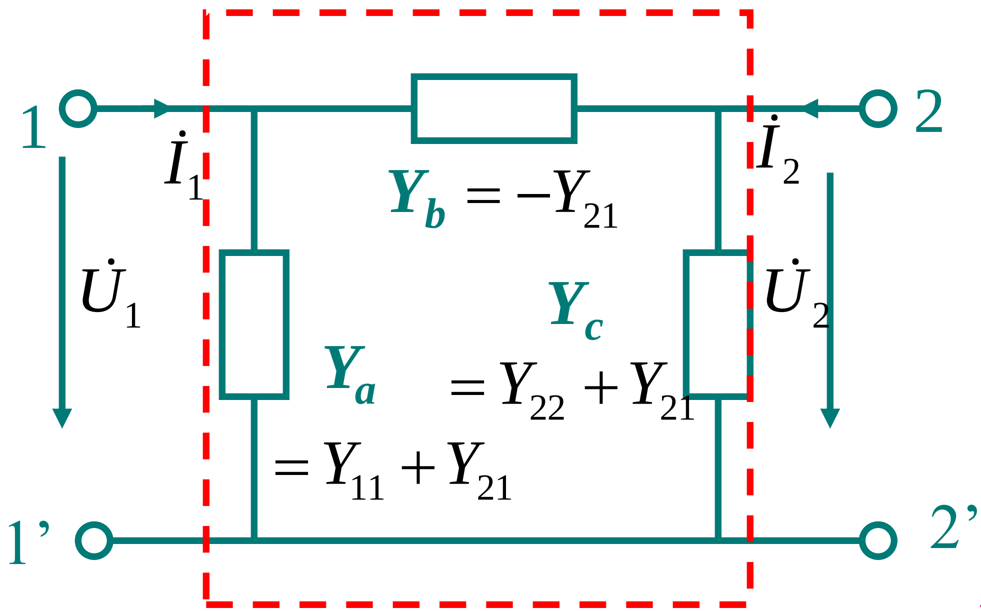
一. 当无受控源时，二端口有三个独立参数

用具有三个不同的阻抗或导纳构成等效电路





1. π型等效电路中参数(Y_a,Y_b,Y_c)的求得



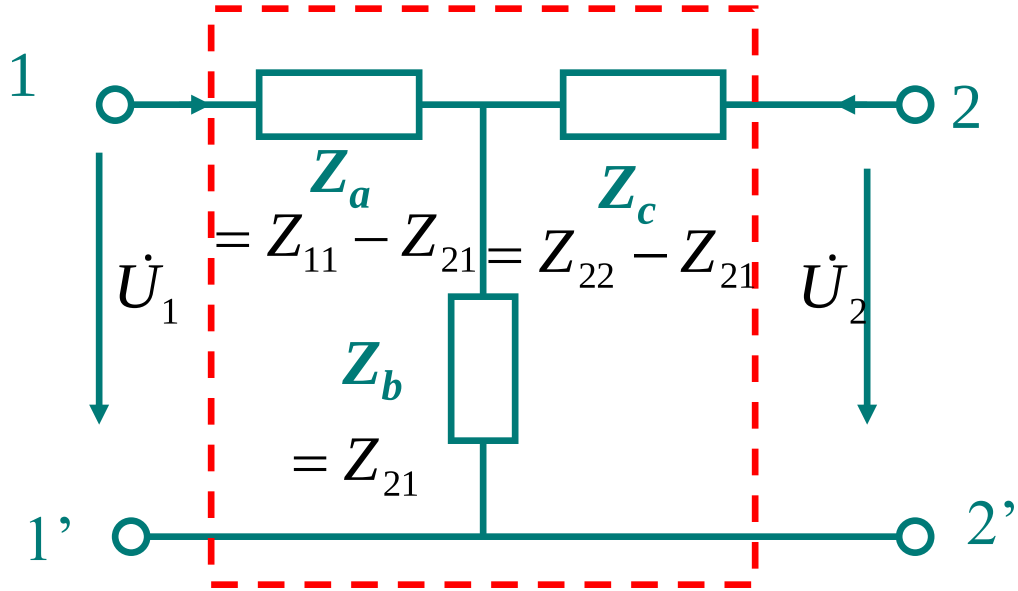
$$\begin{cases} Y_{11} = Y_a + Y_b \\ Y_{21} = Y_{12} = -Y_b \\ Y_{22} = Y_b + Y_c \end{cases}$$

$$\Rightarrow \begin{cases} Y_a = Y_{11} + Y_{21} \\ Y_b = -Y_{21} = -Y_{12} \\ Y_c = Y_{21} + Y_{22} \end{cases}$$

注意:

其他非Y参数方程,可将其化为Y参数方程.

2.T型等效电路中参数(Z_a,Z_b,Z_c)的求得



$$\begin{cases} Z_{11} = Z_a + Z_b \\ Z_{21} = Z_{12} = Z_b \\ Z_{22} = Z_b + Z_c \end{cases}$$

$$\Rightarrow \begin{cases} Z_a = Z_{11} - Z_{21} \\ Z_b = Z_{21} = Z_{12} \\ Z_c = Z_{22} - Z_{21} \end{cases}$$

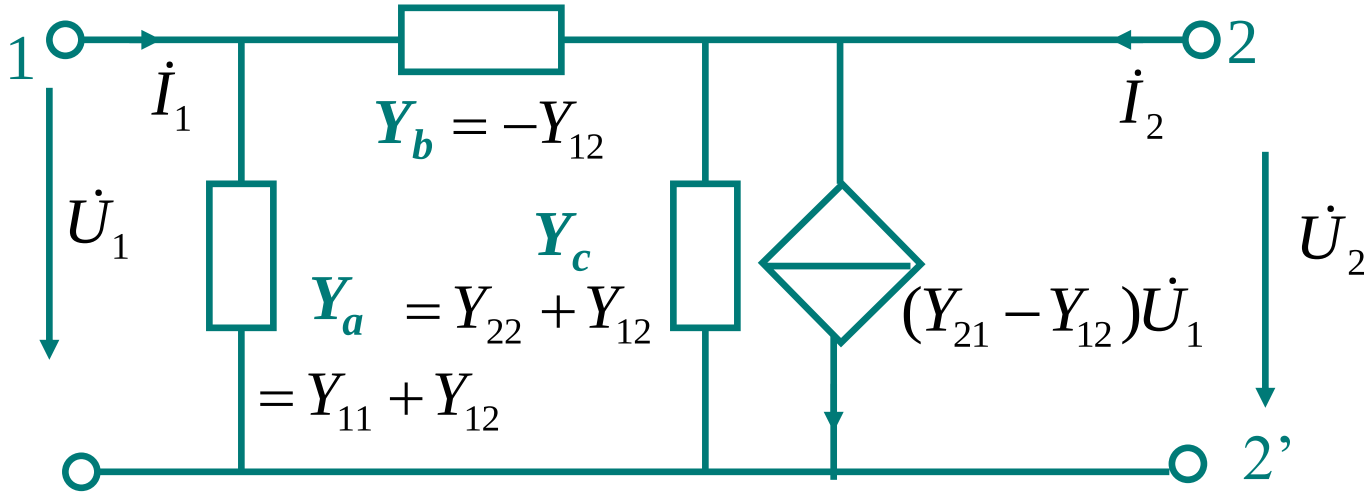
注意:

其他非Z参数方程,可将其化为Z参数方程.

二. 当有受控源时, 二端口有四个独立参数

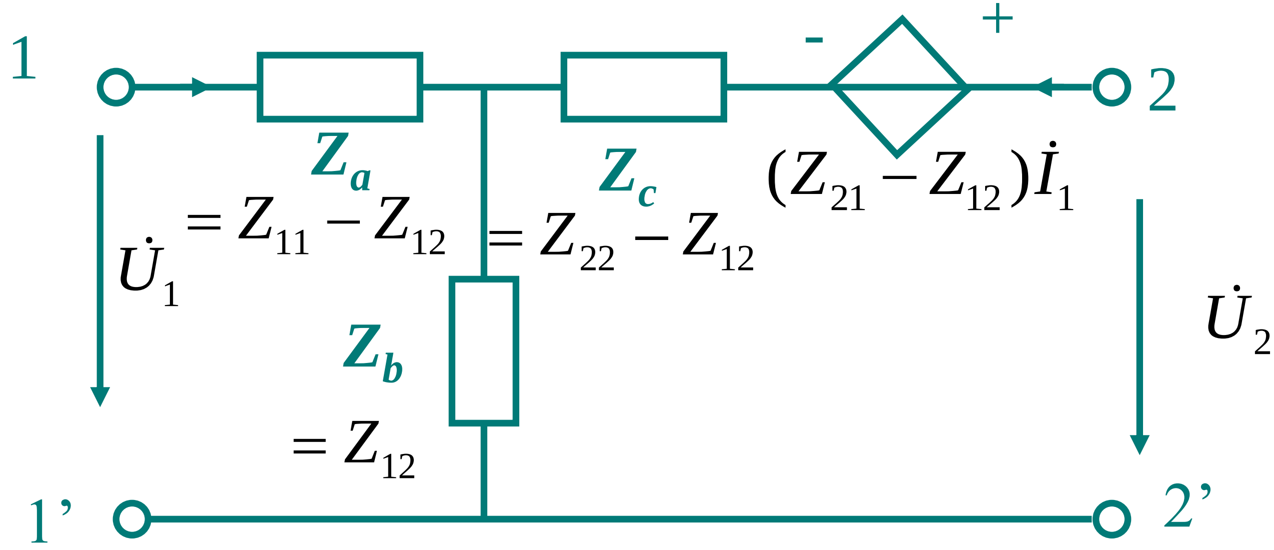
1. π型+压控流源

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



2.T型+流控压源

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

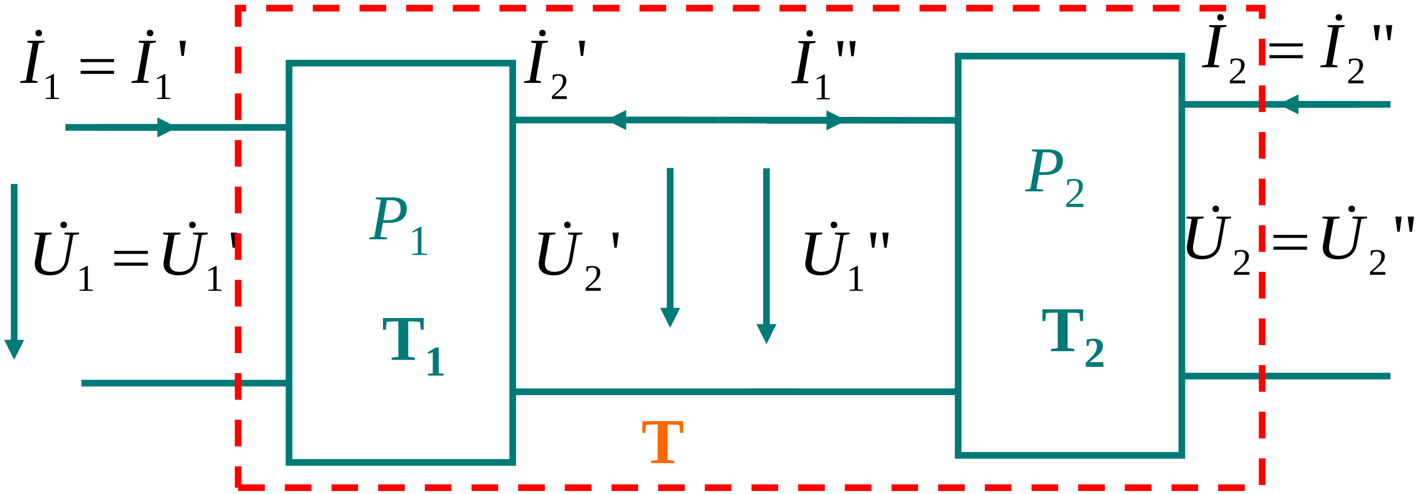


§12-4 二端口的连接

如果把复杂的二端口看成是由若干个二端口按某种方式的连接而成,可使电路简化.

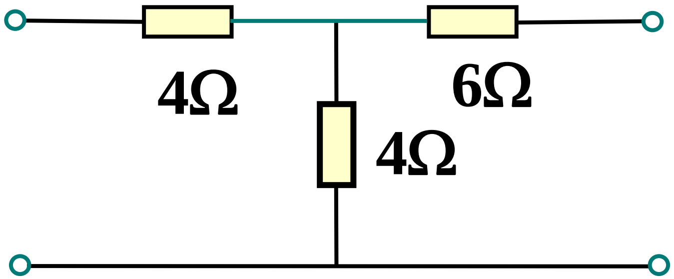
三种连接方式：1. 链联 2. 串联 3. 并联

1. 链联

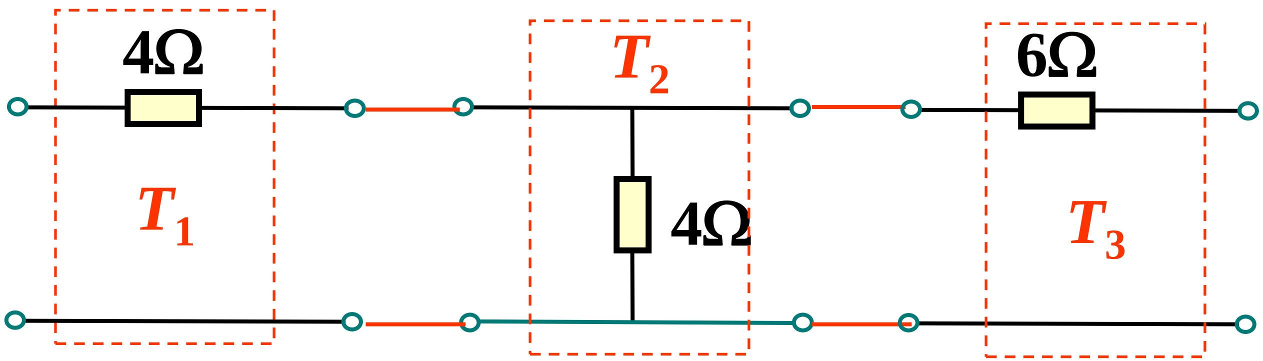


$$\begin{bmatrix}\dot{U}_1\\ \dot{I}_1\end{bmatrix}=\boldsymbol{T}_1\begin{bmatrix}\dot{U}_2'\\ -\dot{I}_2'\end{bmatrix}=\boldsymbol{T}_1\boldsymbol{T}_2\begin{bmatrix}\dot{U}_2''\\ -\dot{I}_2''\end{bmatrix}=\boldsymbol{T}\begin{bmatrix}\dot{U}_2\\ -\dot{I}_2\end{bmatrix}$$

例



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

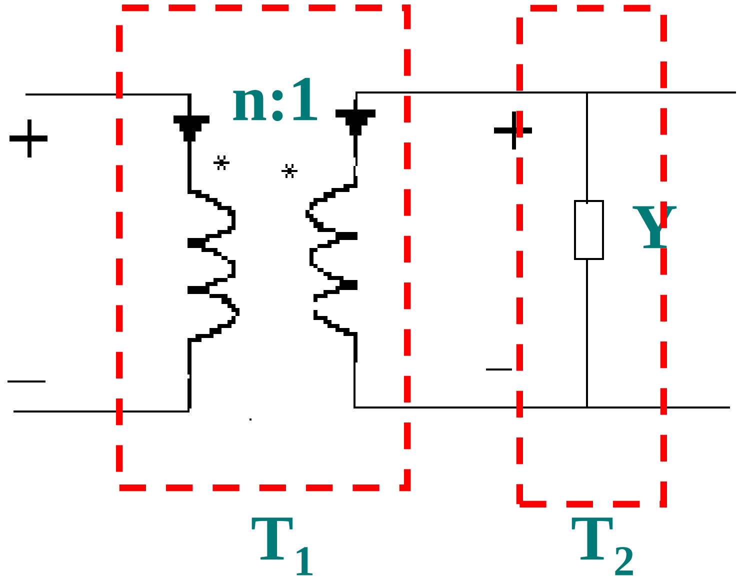


易求出 $T_1 = \begin{bmatrix} 1 & 4\Omega \\ 0 & 1 \end{bmatrix}$ $T_2 = \begin{bmatrix} 1 & 0 \\ 0.25\,\text{S} & 1 \end{bmatrix}$ $T_3 = \begin{bmatrix} 1 & 6\Omega \\ 0 & 1 \end{bmatrix}$

得

$$[T] = [T_1][T_2][T_3] = \begin{bmatrix} 1 & 4 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 \\ 0.25 & 1 \end{bmatrix} \begin{bmatrix} 1 & 6 \\ 0 & 1 \end{bmatrix} = \begin{bmatrix} 2 & 16\Omega \\ 0.25\,\text{S} & 2.5 \end{bmatrix}$$

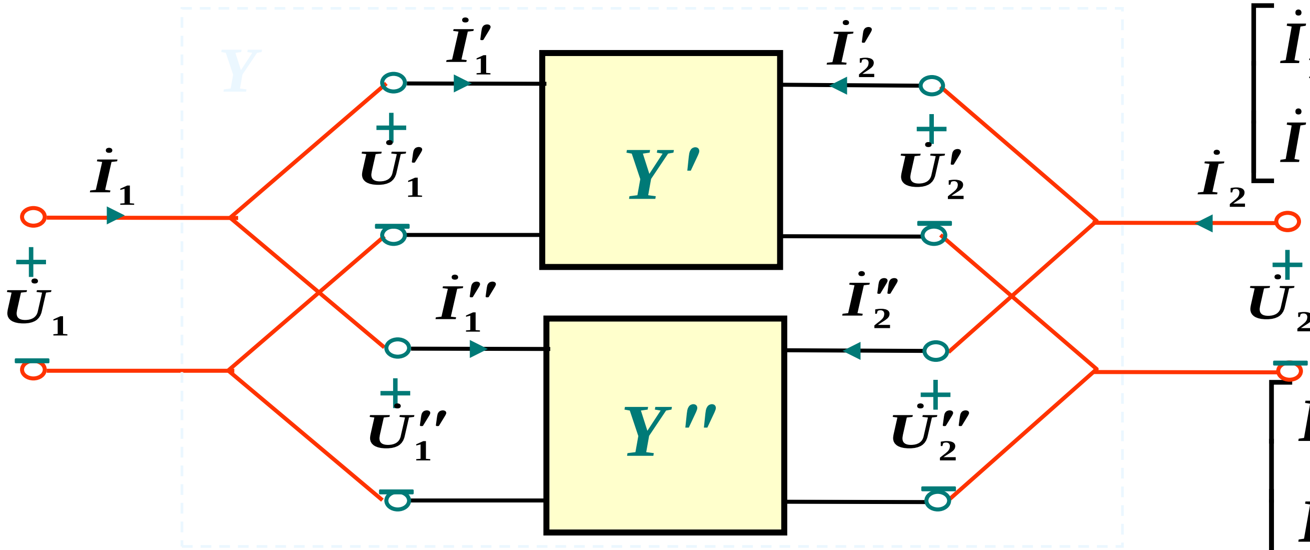
例如：求下述二端口网络的T参数方程.



$$\mathbf{T}_1=\begin{bmatrix} n & 0 \\ 0 & 1/n \end{bmatrix} \qquad \mathbf{T}_2=\begin{bmatrix} 1 & 0 \\ Y & 1 \end{bmatrix}$$

$$\mathbf{T}=\mathbf{T}_1\mathbf{T}_2=\begin{bmatrix} n & 0 \\ nY & 1/n \end{bmatrix}$$

2. 并 联　$\mathbf{Y} = \mathbf{Y}_1 + \mathbf{Y}_2$



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

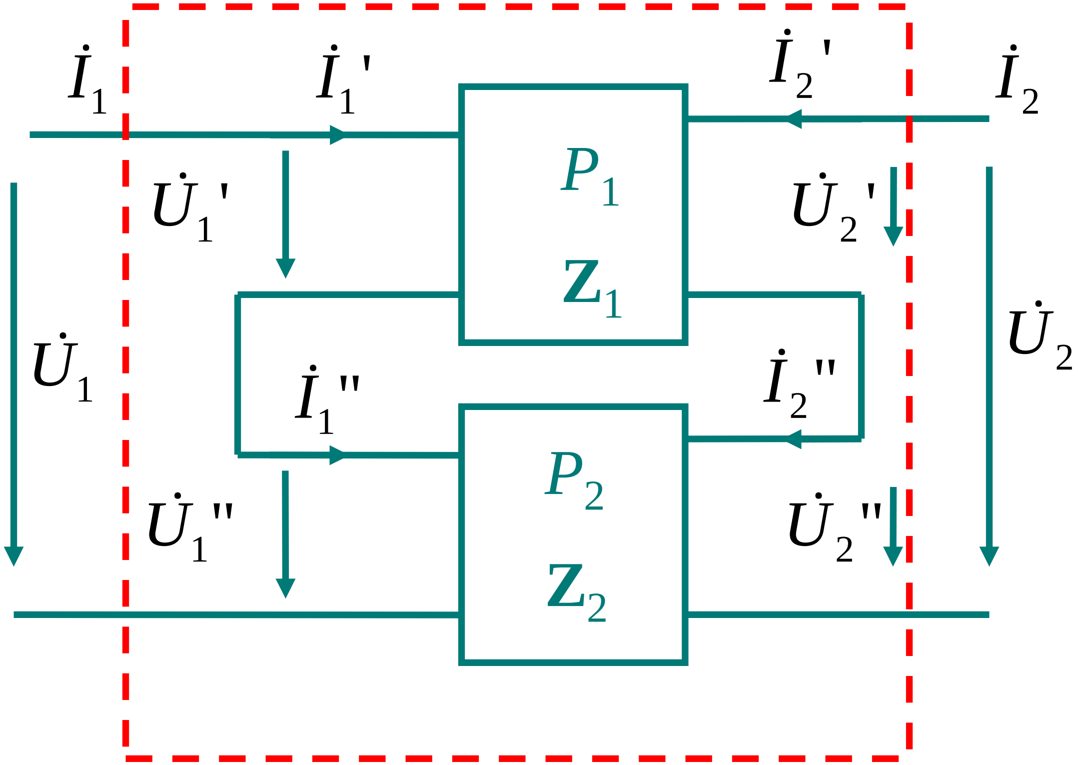
$$\begin{bmatrix} \dot{I}''_1 \\ \dot{I}''_2 \end{bmatrix} = \begin{bmatrix} Y''_{11} & Y''_{12} \\ Y''_{21} & Y''_{22} \end{bmatrix} \begin{bmatrix} \dot{U}''_1 \\ \dot{U}''_2 \end{bmatrix}$$

$$\begin{bmatrix} \dot{I}_1 \\ \dot{I}_2 \end{bmatrix} = \begin{bmatrix} \dot{I}'_1 \\ \dot{I}'_2 \end{bmatrix} + \begin{bmatrix} \dot{I}''_1 \\ \dot{I}''_2 \end{bmatrix} = \begin{bmatrix} Y'_{11} & Y'_{12} \\ Y'_{21} & Y'_{22} \end{bmatrix} \begin{bmatrix} \dot{U}_1 \\ \dot{U}_2 \end{bmatrix} + \begin{bmatrix} Y''_{11} & Y''_{12} \\ Y''_{21} & Y''_{22} \end{bmatrix} \begin{bmatrix} \dot{U}_1 \\ \dot{U}_2 \end{bmatrix}$$

可得 $$\begin{bmatrix} \dot{I}_1 \\ \dot{I}_2 \end{bmatrix} = \begin{bmatrix} Y_{11} & Y_{12} \\ Y_{11} & Y_{22} \end{bmatrix} \begin{bmatrix} \dot{U}_1 \\ \dot{U}_2 \end{bmatrix} = [Y] \begin{bmatrix} \dot{U}_1 \\ \dot{U}_2 \end{bmatrix}$$

$$\boxed{Y = Y' + Y''}$$

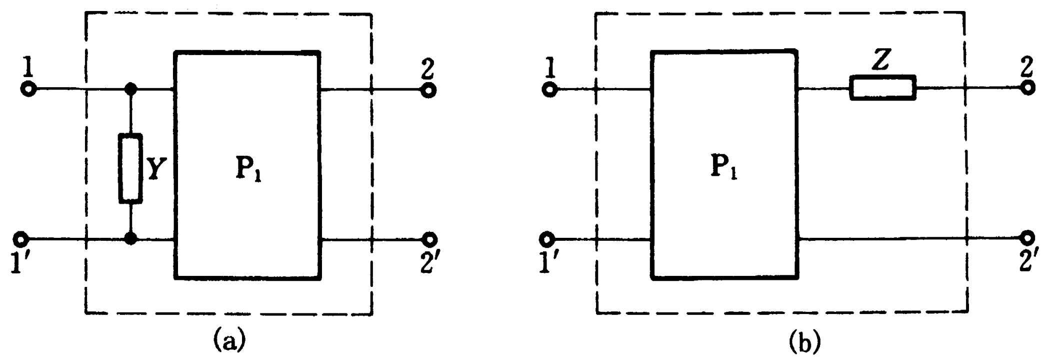
3. 串联 $\mathbf{Z} = \mathbf{Z}_1 + \mathbf{Z}_2$



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

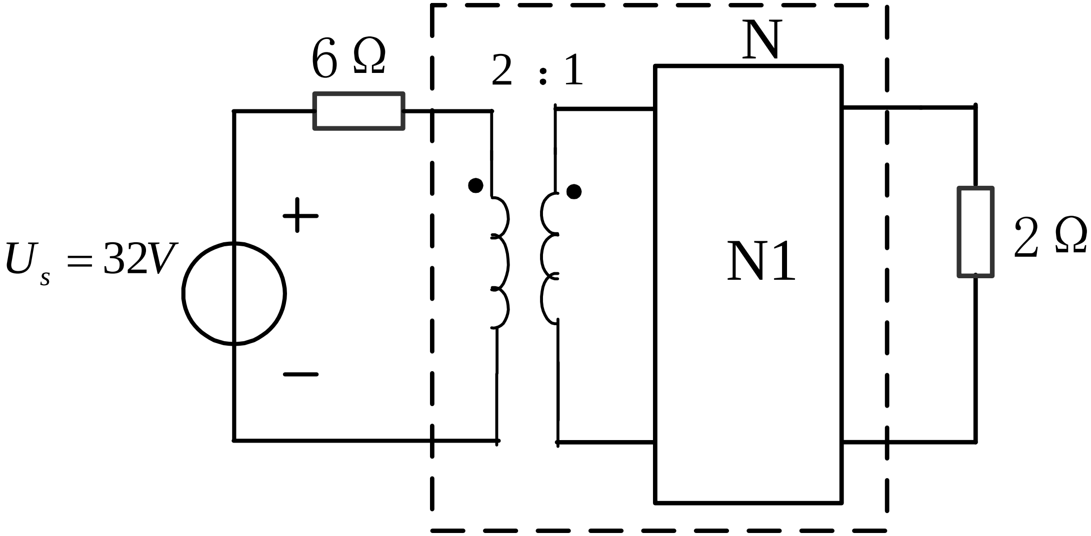
12-3．求图示二端口的 T 参数矩阵，设内部二端口 P_1 的 T 参数矩阵为

$$T_1 = \begin{bmatrix} A & B \\ C & D \end{bmatrix}$$



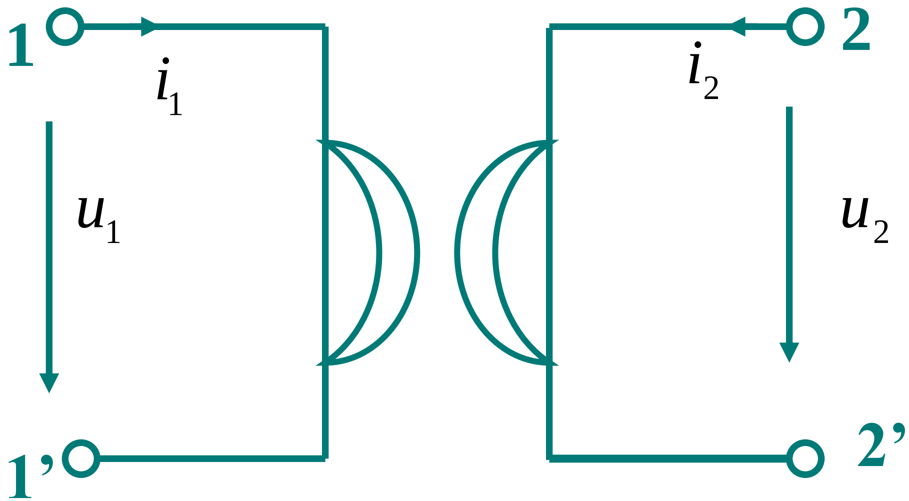
电路如图6所示， 已知二端口网络N1的T参数为： $T_{N1}=\begin{bmatrix}4 & 6\\ 4 & 4\end{bmatrix}$

求：（1）二端口网络N的T参数；
（2）电压源发出的有功功率P。



§ 12-5 回转器和负阻抗变换器

1. 回转器



端部特性:

$$\begin{cases} u_1 = -ri_2 \\ u_2 = ri_1 \end{cases}$$

或

$$\begin{cases} i_1 = gu_2 \\ i_2 = -gu_1 \end{cases}$$

R -------回转电阻　　　g=1/r-------回转电导

$$\begin{bmatrix} u_1 \\ u_2 \end{bmatrix} = \begin{bmatrix} 0 & -r \\ r & 0 \end{bmatrix} \begin{bmatrix} i_1 \\ i_2 \end{bmatrix}$$

Z参数

$$\begin{bmatrix} i_1 \\ i_2 \end{bmatrix} = \begin{bmatrix} 0 & g \\ -g & 0 \end{bmatrix} \begin{bmatrix} u_1 \\ u_2 \end{bmatrix}$$

Y参数

$$u_1 i_1 + u_2 i_2 = -r i_1 i_2 + r i_1 i_2 = 0$$

可见:回转器既不消耗功率，又不发出功率，它是一个无源线性元件，

引入回转器的意义，将电容回转成电感:

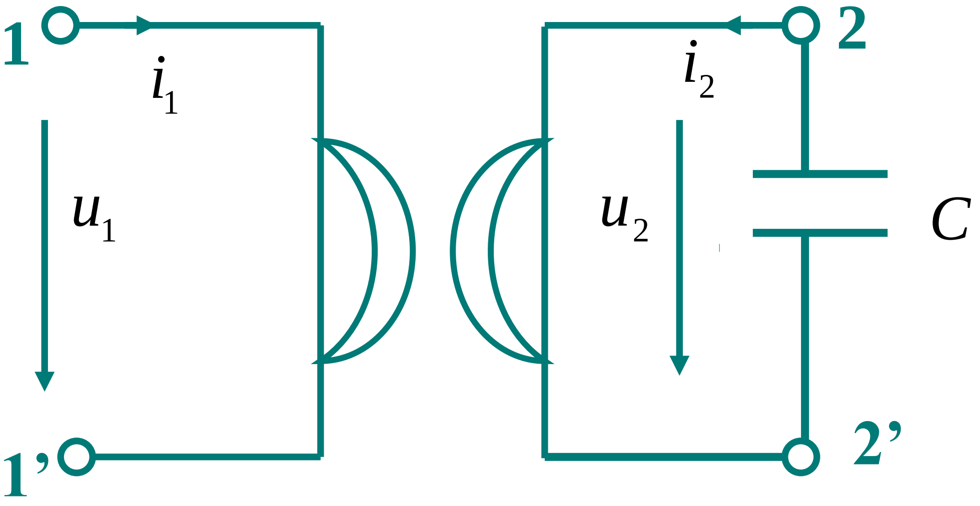
$$u_1 = -r i_2$$

$$i_2 = -C\frac{du_C}{dt}$$

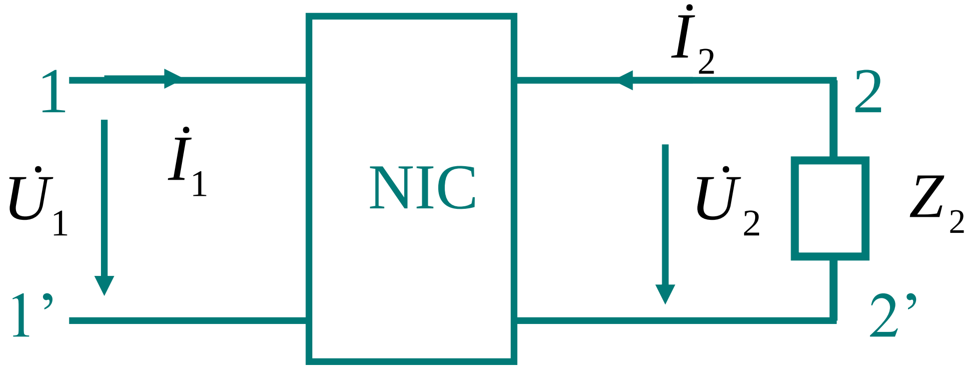
$$u_1 = -r(-C\frac{du_C}{dt})$$

$$= rc\frac{du_2}{dt} = r^2 C\frac{di_1}{dt}$$

$$令 L_d = r^2 C$$



2. 负阻抗变换器(NIC)



(1). 电流反向型INIC

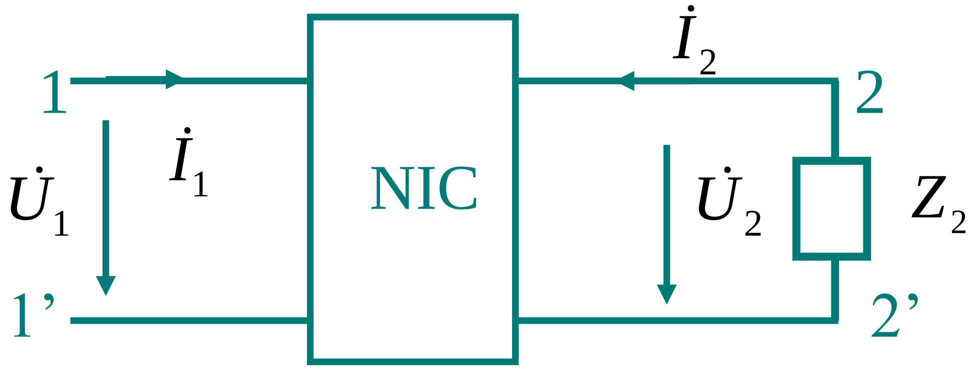
$$\begin{bmatrix} \dot{U}_1 \\ \dot{I}_1 \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ 0 & -k \end{bmatrix} \begin{bmatrix} \dot{U}_2 \\ -\dot{I}_2 \end{bmatrix}$$

k为正实常数

从1-1’端看进去的等效电阻变为负阻抗.

$$Z_{in} = \frac{\dot{U}_1}{\dot{I}_1} = \frac{\dot{U}_2}{k\dot{I}_2} = \frac{1}{k}(-Z_2)$$

(2). 电压反向型UNIC



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

k为正实常数

$$Z_{in}=\frac{\dot{U}_1}{\dot{I}_1}=\frac{-k\dot{U}_2}{-\dot{I}_2}=k(-Z_2)$$

$$Z_{in}=k(-Z_2)=kj\omega L=-j\frac{1}{\omega\dfrac{1}{\omega^2 kL}}$$

$$C_d=\frac{1}{\omega^2 kL}$$

NIC为电路设计实现负的R、L、C提供了可能.

试求二端口网络的T参数及其方程。