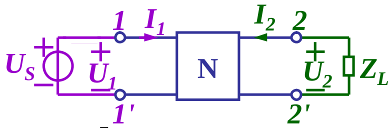
§ 16-4 二端口的转移函数

转移函数

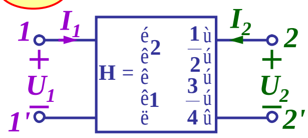


$$H_1(s)=\frac{U_2}{U_1}\quad H_2(s)=\frac{I_2}{U_1}\quad H_3(s)=\frac{U_2}{I_1}\quad H_4(s)=\frac{I_2}{I_1}$$

$$\begin{bmatrix}U_1\\U_2\end{bmatrix}=\begin{bmatrix}Z_{11}&Z_{12}\\Z_{21}&Z_{22}\end{bmatrix}\begin{bmatrix}I_1\\I_2\end{bmatrix}\Rightarrow\begin{bmatrix}U_S-Z_iI_1\\-Z_LI_2\end{bmatrix}=\begin{bmatrix}Z_{11}&Z_{12}\\Z_{21}&Z_{22}\end{bmatrix}\begin{bmatrix}I_1\\I_2\end{bmatrix}$$

$Z_i=0,\quad Z_L\rightarrow\infty\qquad Z_i=Z_L=0$

补例1 求出2-2′端口开路和短路时的四个转移函数:



$$H_1(s)=\frac{U_2}{U_1},H_2(s)=\frac{U_2}{I_1}\qquad H_3(s)=\frac{I_2}{U_1},H_4(s)=\frac{I_2}{I_1}$$

解: 2-2′ 端口开路时 $I_2=0$　$H_3(s)=0, H_4(s)=0$

$$\begin{cases}U_1=H_{11}I_1+H_{12}U_2 \Rightarrow U_1=-U_2\\ I_2=H_{21}I_1+H_{22}U_2=0 \Rightarrow I_1=-\dfrac{H_{22}U_2}{H_{21}}=-\dfrac{3U_2}{4}\end{cases}$$

$$H_1(s)=\frac{U_2}{U_1}=-1\qquad H_2(s)=\frac{U_2}{I_1}=-\frac{4}{3}$$

2-2′ 端口短路时

$U_2=0$

$$H_1(s)=0, H_2(s)=0$$

$$\begin{cases}U_1=H_{11}I_1\\ I_2=H_{21}I_1\end{cases}$$

$$H_3(s)=\frac{I_2}{U_1}=\frac{H_{21}}{H_{11}}=\frac{1}{2}$$

$$H_4(s)=\frac{I_2}{I_1}=\frac{1}{H_{21}}=1$$

End}

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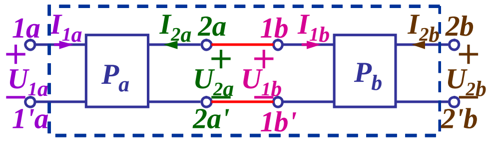
§ 16-5 二端口的连接

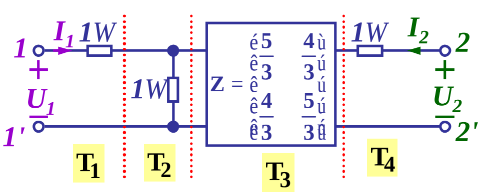
一、级联



$$\begin{bmatrix}U_{1a}\\I_{1a}\end{bmatrix}=\mathbf{T}_a\begin{bmatrix}U_{2a}\\-I_{2a}\end{bmatrix}\qquad\begin{bmatrix}U_{1b}\\I_{1b}\end{bmatrix}=\mathbf{T}_b\begin{bmatrix}U_{2b}\\-I_{2b}\end{bmatrix}$$

$$\begin{bmatrix}U_1\\I_1\end{bmatrix}=\mathbf{T}_a\mathbf{T}_b\begin{bmatrix}U_2\\-I_2\end{bmatrix}=\mathbf{T}\begin{bmatrix}U_2\\-I_2\end{bmatrix}\qquad \mathbf{T}=\mathbf{T}_a\mathbf{T}_b$$

补例1 求出图示电路的T参数矩阵



解:

$$\mathbf{T}_1=\mathbf{T}_4=\begin{bmatrix}1&1\\0&1\end{bmatrix}\qquad \mathbf{T}_2=\begin{bmatrix}1&0\\1&1\end{bmatrix}$$

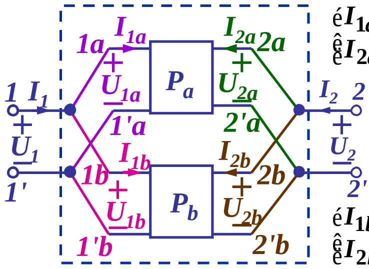
$$\mathbf{T}_3=\begin{bmatrix}\dfrac{Z_{11}}{Z_{21}}&\dfrac{\Delta Z}{Z_{21}}\\ \dfrac{1}{Z_{21}}&\dfrac{Z_{22}}{Z_{21}}\end{bmatrix}=\begin{bmatrix}\dfrac{5}{4}&\dfrac{3}{4}\\ \dfrac{3}{4}&\dfrac{5}{4}\end{bmatrix}$$

采用变换方程的方法

$$\mathbf{T}=\mathbf{T}_1\mathbf{T}_2\mathbf{T}_3\mathbf{T}_4=\begin{bmatrix}\dfrac{13}{4}&6\\ 2&4\end{bmatrix}$$

$AD-BC=1$　互易网络

二、并联



$$\begin{bmatrix} I_{1a} \\ I_{2a} \end{bmatrix} = \mathbf{Y}_1 \begin{bmatrix} U_{1a} \\ U_{2a} \end{bmatrix}$$

$$\mathbf{I} = \mathbf{Y}\mathbf{U}$$

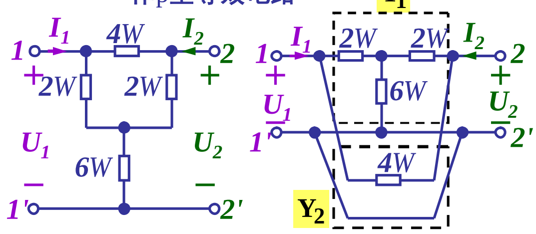
$$\mathbf{Y} = \mathbf{Y}_1 + \mathbf{Y}_2$$

$$\begin{bmatrix} I_{1b} \\ I_{2b} \end{bmatrix} = \mathbf{Y}_2 \begin{bmatrix} U_{1b} \\ U_{2b} \end{bmatrix}$$

$$\begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} I_{1a} \\ I_{2a} \end{bmatrix} + \begin{bmatrix} I_{1b} \\ I_{2b} \end{bmatrix} = (\mathbf{Y}_1 + \mathbf{Y}_2)\begin{bmatrix} U_1 \\ U_2 \end{bmatrix}$$

HOME BACK NEXT

补例2 求出图示电路的Y参数矩阵，并作π型等效电路



解：

$$\mathbf{Y} = \mathbf{Y}_1 + \mathbf{Y}_2$$

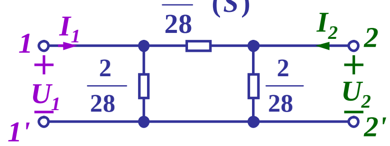
HOME BACK NEXT

$$\mathbf{Z}_1 = \begin{bmatrix} 8 & 6 \\ 6 & 8 \end{bmatrix} \qquad \mathbf{Y}_1 = \mathbf{Z}_1^{-1} = \frac{1}{28}\begin{bmatrix} 8 & -6 \\ -6 & 8 \end{bmatrix}$$

$$\mathbf{Y}_2 = \begin{bmatrix} \frac{1}{4} & -\frac{1}{4} \\ -\frac{1}{4} & \frac{1}{4} \end{bmatrix} \qquad \mathbf{Y} = \mathbf{Y}_1 + \mathbf{Y}_2 = \begin{bmatrix} \frac{15}{28} & -\frac{13}{28} \\ -\frac{13}{28} & \frac{15}{28} \end{bmatrix}(S)$$

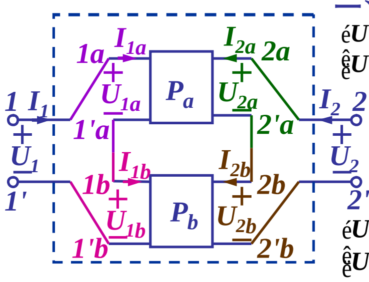
$Y_{12} = Y_{21}$ & $Y_{11} = Y_{22}$ 网络对称

HOME BACK NEXT



HOME BACK NEXT

三、串联



$$\begin{bmatrix} U_{1a} \\ U_{2a} \end{bmatrix} = \mathbf{Z}_1 \begin{bmatrix} I_{1a} \\ I_{2a} \end{bmatrix}$$

$$\mathbf{U} = \mathbf{Z}\mathbf{I}$$

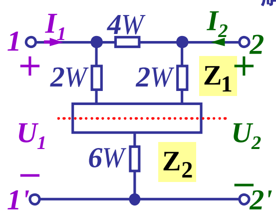
$$\mathbf{Z} = \mathbf{Z}_1 + \mathbf{Z}_2$$

$$\begin{bmatrix} U_{1b} \\ U_{2b} \end{bmatrix} = \mathbf{Z}_2 \begin{bmatrix} I_{1b} \\ I_{2b} \end{bmatrix}$$

$$\begin{bmatrix} U_1 \\ U_2 \end{bmatrix} = \begin{bmatrix} U_{1a} \\ U_{2a} \end{bmatrix} + \begin{bmatrix} U_{1b} \\ U_{2b} \end{bmatrix} = (\mathbf{Z}_1 + \mathbf{Z}_2)\begin{bmatrix} I_1 \\ I_2 \end{bmatrix}$$

HOME BACK NEXT

补例3 求出图示电路的Z参数矩阵，并作T型等效电路



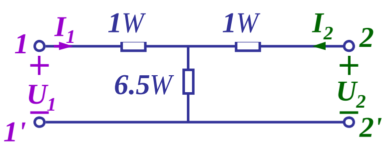
解：

$$\mathbf{Y}_1 = \begin{bmatrix} \frac{3}{4} & -\frac{1}{4} \\ -\frac{1}{4} & \frac{3}{4} \end{bmatrix}$$

$$\mathbf{Z}_1 = \mathbf{Y}_1^{-1} = \frac{1}{2}\begin{bmatrix} 3 & 1 \\ 1 & 3 \end{bmatrix}$$

$$\mathbf{Z}_2 = \begin{bmatrix} 6 & 6 \\ 6 & 6 \end{bmatrix} \qquad \mathbf{Z} = \mathbf{Z}_1 + \mathbf{Z}_2 = \frac{1}{2}\begin{bmatrix} 15 & 13 \\ 13 & 15 \end{bmatrix}(\Omega)$$

HOME BACK NEXT



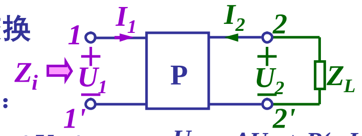
$Z_{12} = Z_{21}$ & $Z_{11} = Z_{22}$ 网络对称

End}

HOME BACK

§ 16-6 回转器和负阻抗变换器

一、阻抗变换



T参数方程：

$$\begin{bmatrix} U_1 \\ I_1 \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix}\begin{bmatrix} U_2 \\ -I_2 \end{bmatrix}$$

2-2' 外特性方程：

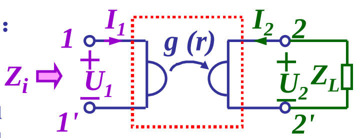
$$U_2 = -Z_L I_2$$

$$Z_i = \frac{U_1}{I_1} = \frac{AU_2 + B(-I_2)}{CU_2 + D(-I_2)} = \frac{A(-Z_L I_2) + B(-I_2)}{C(-Z_L I_2) + D(-I_2)} = \frac{AZ_L + B}{CZ_L + D}$$

HOME NEXT

二、几种特殊二端口网络

1、回转器：



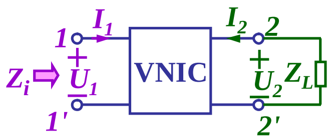
$$T = \begin{bmatrix} 0 & \frac{1}{g} \\ g & 0 \end{bmatrix}$$

$$T = \begin{bmatrix} 0 & r \\ \frac{1}{r} & 0 \end{bmatrix}$$

$$Z_i = \frac{AZ_L + B}{CZ_L + D} = \frac{0 \times Z_L + r}{\frac{1}{r} \times Z_L + 0} = \frac{r^2}{Z_L} = \frac{1}{g^2 Z_L}$$

HOME BACK NEXT

2、负阻抗变换器：

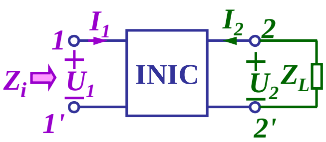


$$T = \begin{bmatrix} -k & 0 \\ 0 & 1 \end{bmatrix}$$

$$Z_i = \frac{AZ_L + B}{CZ_L + D} = \frac{-kZ_L + 0}{0 \times Z_L + 1} = -kZ_L$$

HOME BACK NEXT

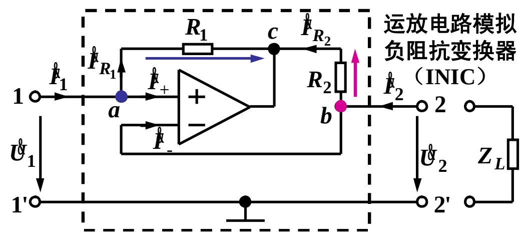
2、负阻抗变换器：



$$T = \begin{bmatrix} 1 & 0 \\ 0 & -k \end{bmatrix}$$

$$Z_i = \frac{AZ_L + B}{CZ_L + D} = \frac{Z_L + 0}{0 \times Z_L + (-k)} = -\frac{1}{k} Z_L$$

HOME BACK NEXT



运放电路模拟负阻抗变换器（INIC）

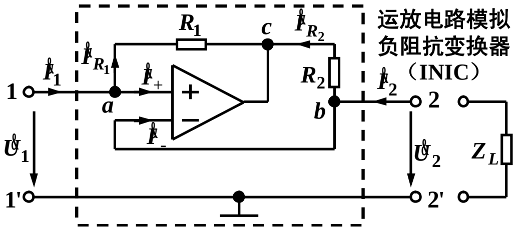
由“虚短”：$U_1 = U_2$　　由“虚断”：$I_+ = I_- = 0$

$$I_1 = I_{R_1},\ I_2 = I_{R_2}$$

$$I_1 R_1 = I_2 R_2$$

$$I_1 = -\frac{R_2}{R_1}(-I_2)$$

HOME BACK NEXT



运放电路模拟负阻抗变换器（INIC）

$$\begin{bmatrix}\dot U_1\\ \dot I_1\end{bmatrix}=\begin{bmatrix}1 & 0\\ 0 & -\dfrac{R_2}{R_1}\end{bmatrix}\begin{bmatrix}\dot U_2\\ -\dot I_2\end{bmatrix}$$

$$T=\begin{bmatrix}1 & 0\\ 0 & -k\end{bmatrix}$$

三、特征阻抗

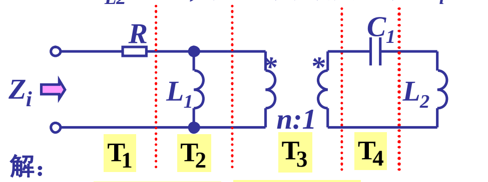
$A = D \qquad Z_i = Z_L = Z_C$

特征阻抗

$$Z_C=\frac{AZ_C+B}{CZ_C+D}$$

$$\Rightarrow Z_C=\sqrt{\frac{B}{C}}$$

补例 R=2Ω, n=2, X_{L1}=4Ω, X_{C1}=-1Ω, X_{L2}=2Ω, 求入端等效复阻抗 Z_i=?



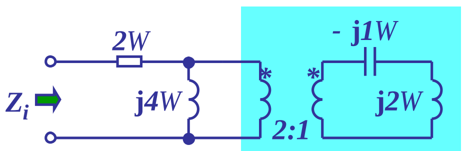
解:

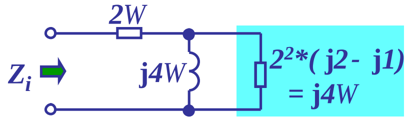
$$T_1=\begin{bmatrix}1 & 2\\ 0 & 1\end{bmatrix}\quad T_2=\begin{bmatrix}1 & 0\\ \dfrac{1}{j4} & 1\end{bmatrix}\quad T_3=\begin{bmatrix}2 & 0\\ 0 & \dfrac{1}{2}\end{bmatrix}\quad T_4=\begin{bmatrix}1 & -j1\\ 0 & 1\end{bmatrix}$$

$$T=T_1T_2T_3T_4=\begin{bmatrix}2-j1 & -j2\\ -j\dfrac{1}{2} & 0\end{bmatrix}$$

$$Z_i=\frac{AZ_L+B}{CZ_L+D}=\frac{(2-j1)\times j2-j2}{-j\dfrac{1}{2}\times j2+0}$$

$$=2+j2\ \Omega$$





Z_i =2+ j2 Ω

End}