第十二章　含运算放大器的电路

12-1　　求图题 12-1 所示电路的输出电压 u_o。

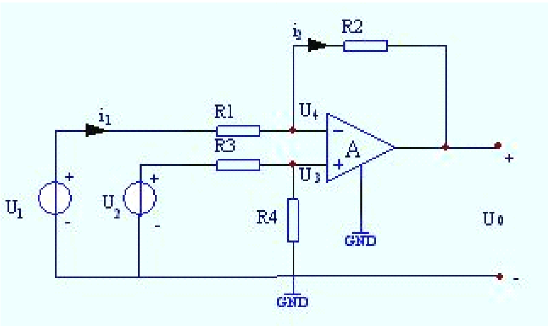


图　题 12-1

答案

解：$\because u_3 = \dfrac{R_4}{R_3+R_4}u_2$ （“虚断”）

$u_4 = u_3$ （“虚短”）

$$i_1 = \frac{u_1 - u_4}{R_1} = i_2$$

$$\therefore u_o = u_3 - i_2 R_2 = \frac{R_4}{R_3+R_4}u_2 - R_2\left[\frac{u_1}{R_1} - \frac{R_4}{R_1(R_3+R_4)}u_2\right]$$

$$= \frac{R_4(R_1+R_2)}{R_1(R_3+R_4)}u_2 - \frac{R_2}{R_1}u_1;$$

12-2　　求图题 12-2 所示电路的开路电压比 $\dfrac{\dot{U}_0}{\dot{U}_i}$。

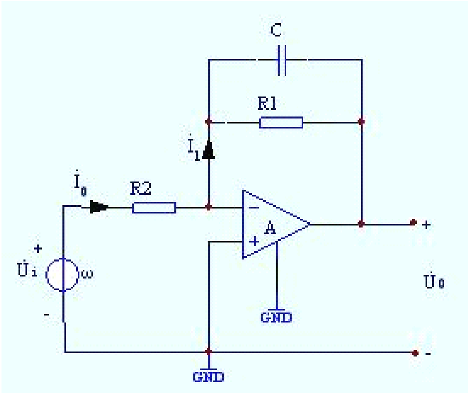


图　题 12-2

答案

解：$\because \dot{I}_1=\dot{I}_0=\dfrac{\dot{U}_i}{R_2}$

$$\dot{U}_0=-\dot{I}_1\frac{R_1}{1+j\omega CR_1}$$

$$\frac{\dot{U}_0}{\dot{U}_i}=-\frac{1}{R_2C}\frac{1}{(\dfrac{1}{R_1C}+j\omega)}$$

12-3　　图示题 12-3 所示电路可用来使一个小电容 $C=1\mu F$ 变成一个大电容，求此大电容的值，已知 $A=10^5$。

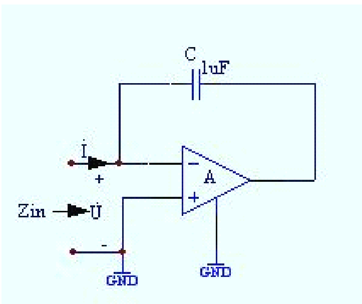


图　题 12-3

答案

解：　$\because \dot{I} = (\dot{U} + A\dot{U})j\omega C$

$$\therefore Z_{in} = \frac{\dot{U}}{\dot{I}} = \frac{1}{j\omega(1+A)C} = \frac{1}{j\omega C_0}$$

$$C_0 = (1+A)C = 0.1F$$

12-4　　求图题 12-4 所示电路的输入阻抗 Z_{in}。

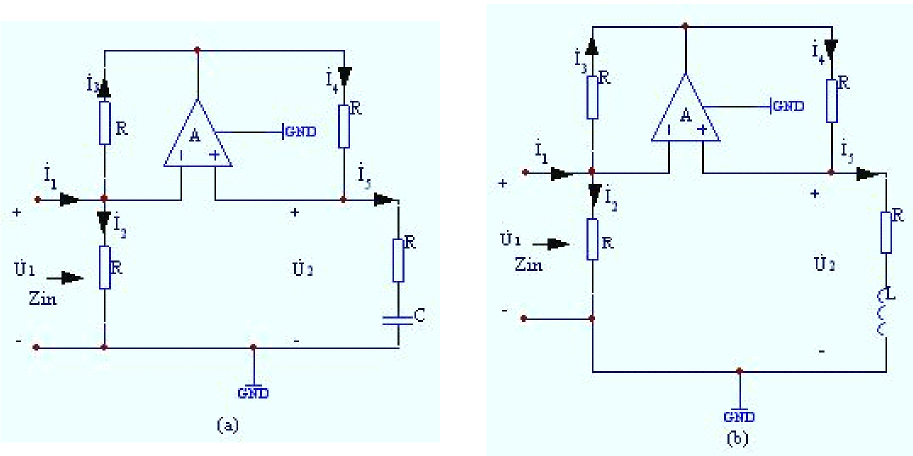


图　题 12-4

答案

解：（a）$\because \dot{U}_2 = \dot{U}_1$　　$\dot{I}_5 = \dfrac{\dot{U}_1}{R + \dfrac{1}{j\omega C}}$　　$\dot{I}_4 = \dot{I}_5$

$$\dot{I}_3 = \dot{I}_1 - \frac{\dot{U}_1}{R}$$

又$\because \dot{I}_3 R+\dot{I}_4 R=0$ 即：

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

$$\therefore Z_{in}=\frac{\dot{U}_1}{\dot{I}_1}=R+j\omega R^2 C$$

$$=R+j\omega L \text{ ， } L=R^2 C$$

（b）同理可得：

$$Z_{in}=\frac{\dot{U}_1}{\dot{I}_1}=R+\frac{1}{j\omega L/R^2}=R+\frac{1}{j\omega C}\ C=\frac{L}{R^2}$$ 。

12-5　　图题 12-5 所示微分电路与输入电压$u_1(t)$的波形，画出$u_2(t)$的波形。

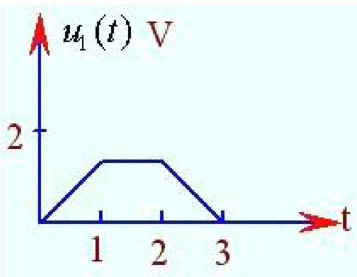
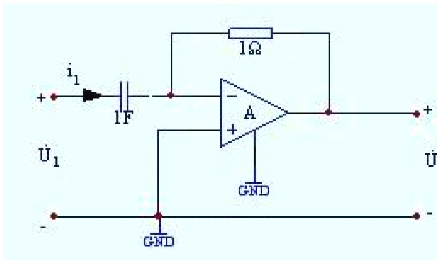


图　题12－5(a)



(b)

答案

解：$\because i_1(t)=\frac{du_1(t)}{dt}$

$u_2(t) = -i_1(t) = -\frac{du_1(t)}{dt}$

$\therefore u_2(t)$波形如图（c）所示。

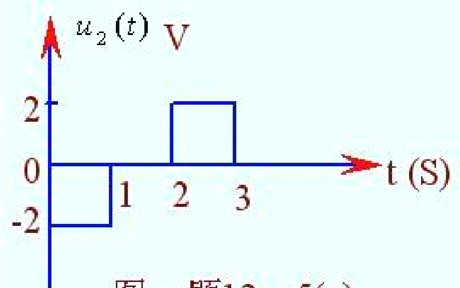
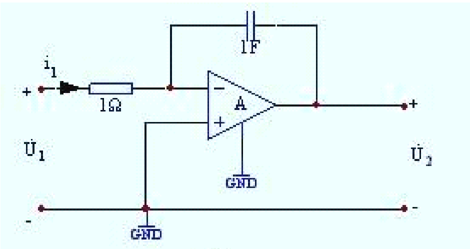


图 题12－5(c)

12-6 图题 12-6 所示积分电路与输入电压 $u_1(t)$的波形，画出 $u_2(t)$的波形。



(a)

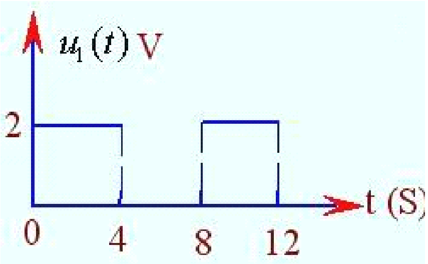


图 题12－6(b)

答案

解：$\because i_1(t) = u_1(t)$

$$u_2(t) = -\int_{-\infty}^{t} i_1(\tau)d\tau = -\int_{-\infty}^{t} u_1(\tau)d\tau$$

$\therefore u_2(t)$波形如图（c）所示。

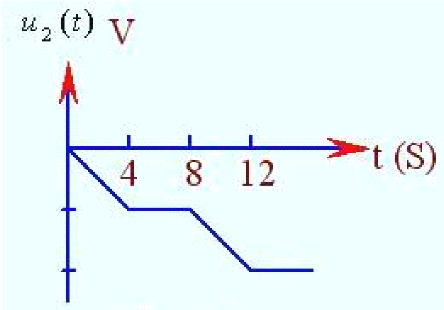
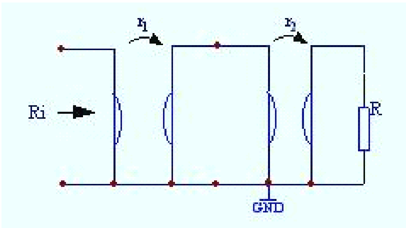


图　题12－6(c)

12-7　图题 12-7 所示电路，$r_1 = 2\Omega$，$r_2 = 1\Omega$，$R = 20\Omega$。求输入电阻。



图题 12-7

答案

解：

$$[A_1] = \begin{bmatrix} 0 & r_1 \\ \frac{1}{r_1} & 0 \end{bmatrix}$$

$$[A_2] = \begin{bmatrix} 0 & r_2 \\ \frac{1}{r_2} & 0 \end{bmatrix}$$

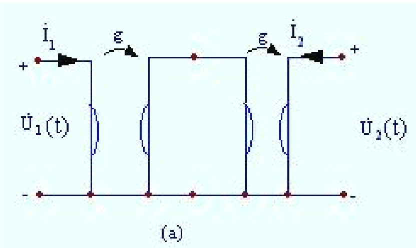
$$\therefore [A] = [A_1][A_2]$$

$$=\begin{bmatrix}\frac{r_1}{r_2} & r_2\\ 0 & \frac{r_2}{r_1}\end{bmatrix}=\begin{bmatrix}2 & 0\\ 0 & \frac{1}{2}\end{bmatrix}$$

$$R_i=\frac{A_{11}R+A_{12}}{A_{21}R+A_{22}}=80\Omega$$ 或

$$R_i=r_1^2\frac{1}{r_2^2\frac{1}{R}}=80\Omega$$

12-8　　证明图题 12-8 所示 （a）与（b）两个电路等效。



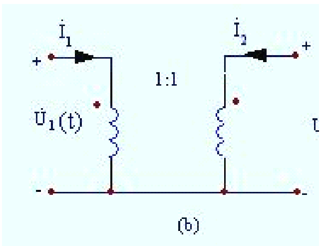


图　题 12-8

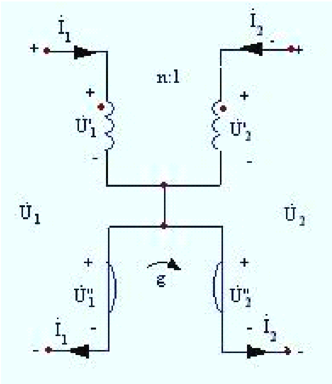
答案

证明：（a） $$[A_a]=[A_1][A_2]=\begin{bmatrix}0 & \frac{1}{g}\\ g & 0\end{bmatrix}\begin{bmatrix}0 & \frac{1}{g}\\ g & 0\end{bmatrix}=\begin{bmatrix}1 & 0\\ 0 & 1\end{bmatrix}$$

（b） $$[A_b]=\begin{bmatrix}1 & 0\\ 0 & 1\end{bmatrix}$$

$$[A_a]=[A_b]$$ ∴（a）（b）两个电路等效。

12-9　　求图题 12-9 所示网络的 H 参数矩阵。



图题 12-9

答案

解：

$$\because \dot{U}_1' = n\dot{U}_2' = n(\dot{U}_2 - \dot{U}_2'')$$

$$\dot{U}_2'' = \frac{1}{g}\dot{I}_1$$

$$U_1'' = -\frac{1}{g}\dot{I}_2$$

$$\dot{U}_1 = \dot{U}_1' + \dot{U}_1'' = n(\dot{U}_2 - \frac{1}{g}\dot{I}_1) - \frac{1}{g}\dot{I}_2$$

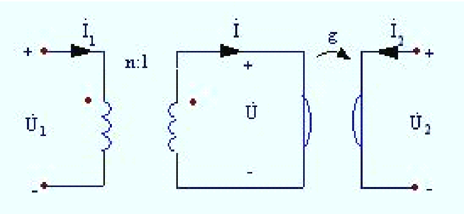
$$= n\dot{U}_2 - \frac{n}{g}\dot{I}_1 - \frac{1}{g}\dot{I}_2$$

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

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

$$\dot{I}_2 = -n\dot{I}_1 \text{ 即 } [H] = \begin{bmatrix} 0 & n \\ -n & 0 \end{bmatrix}$$

12-10　　求图题12-10所示二端口网络的Z矩阵。



图题 12-10

答案

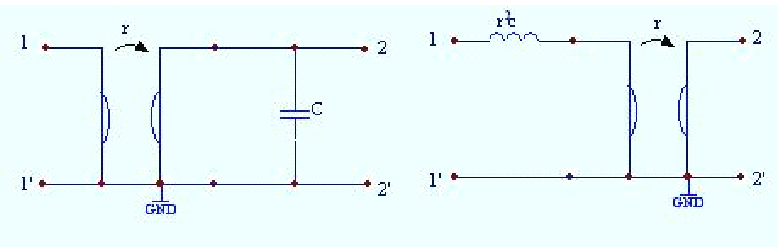
解：$\because \dot{U}_1 = n\dot{U}$

$$= n\left(-\frac{1}{g}\dot{I}_2\right)$$

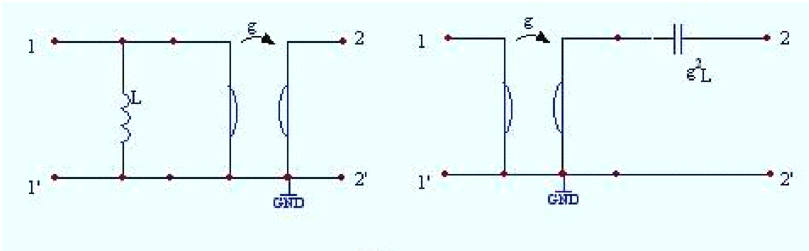
$$\dot{U}_2 = \frac{1}{g}\dot{I} = \frac{1}{g}n\dot{I}_1$$

$$[Z] = \begin{bmatrix} 0 & -\frac{n}{g} \\ -\frac{n}{g} & 0 \end{bmatrix}$$

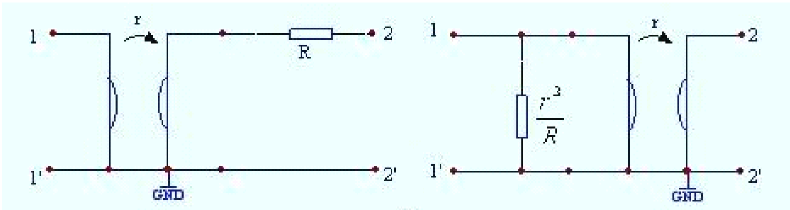
12-11　　证明图题 12-11 中各对电路是等效的。



(a)



(b)



(c)

图　题 12-11

答案

（a）　证明

$$[A_1]=\begin{bmatrix}0 & r\\ \frac{1}{r} & 0\end{bmatrix}\begin{bmatrix}1 & 0\\ j\omega C & 1\end{bmatrix}=\begin{bmatrix}j\omega Cr & r\\ \frac{1}{r} & 0\end{bmatrix}$$

$$[A_2]=\begin{bmatrix}1 & j\omega r^2C\\ 0 & 1\end{bmatrix}\begin{bmatrix}0 & r\\ \frac{1}{r} & 0\end{bmatrix}=\begin{bmatrix}j\omega Cr & r\\ \frac{1}{r} & 0\end{bmatrix}$$

$\because [A_1]=[A_2]$　　$\therefore$ 两电路对应等效。

（b）

$$[A_1]=\begin{bmatrix}1 & 0\\ \frac{1}{j\omega L} & 1\end{bmatrix}\begin{bmatrix}0 & \frac{1}{g}\\ g & 0\end{bmatrix}=\begin{bmatrix}0 & \frac{1}{g}\\ g & \frac{1}{j\omega gL}\end{bmatrix}$$

$$[A_2]=\begin{bmatrix}0 & \frac{1}{g}\\ g & 0\end{bmatrix}\begin{bmatrix}1 & \frac{1}{j\omega g^2 L}\\ 0 & 1\end{bmatrix}=\begin{bmatrix}0 & \frac{1}{g}\\ g & \frac{1}{j\omega gL}\end{bmatrix}$$

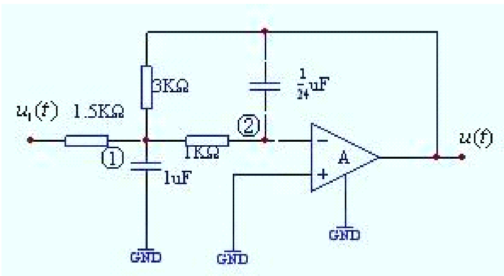
$\because [A_1]=[A_2]$ $\therefore$ 两电路对应等效。

（c）
$$[A_1]=\begin{bmatrix}0 & r\\ \frac{1}{r} & 0\end{bmatrix}\begin{bmatrix}1 & R\\ 0 & 1\end{bmatrix}=\begin{bmatrix}0 & r\\ \frac{1}{r} & \frac{R}{r}\end{bmatrix}$$

$$[A_2]=\begin{bmatrix}1 & 0\\ \frac{R}{r^2} & 1\end{bmatrix}\begin{bmatrix}0 & r\\ \frac{1}{r} & 0\end{bmatrix}=\begin{bmatrix}0 & r\\ \frac{1}{r} & \frac{R}{r}\end{bmatrix}$$

$\because [A_1]=[A_2]$ $\therefore$ 两电路对应等效。

12-12　图题 12-12 所示正弦稳态电路，$u_1(t)=2\cos 2000t V$，求 $u(t)$。



图题 12-12

答案

解：$\because \dot{U}_{1m} = 2\angle 0^\circ (V)$

根据频域分析法，有：

$$\begin{cases} \dot{U}_{n1}\left(\dfrac{1}{1500}+\dfrac{1}{1000}+\dfrac{1}{3000}+j2\times10^{-3}\right)-\dfrac{\dot{U}_{n2}}{1000}-\dfrac{\dot{U}}{3000}=\dfrac{\dot{U}_{1m}}{1500} \\ -\dfrac{\dot{U}_{n1}}{1000}+\left(\dfrac{1}{1000}+j\dfrac{1}{12}\times10^{-3}\right)\dot{U}_{n2}-j\dfrac{1}{12}\times10^{-3}\,\dot{U}=0 \\ \dot{U}_{n2}=0 \end{cases}$$

得：
$$\left.\begin{aligned} &\dot{U}_{n1} = -j\frac{\dot{U}}{12} \\ &\dot{U}_{n1}(2+j2)-\frac{\dot{U}}{3}=\frac{2\dot{U}_{1m}}{3} \end{aligned}\right\}$$

$$\therefore \dot{U}=\frac{8}{\sqrt{2}}\angle 135^\circ = 4\sqrt{2}\angle 135^\circ (V)$$

$$u(t)=4\sqrt{2}\cos(2000t+135^\circ)(V)$$