

2011.

$$\text{二、(2) 证明: } \dot{i}_C(t) = \frac{d\dot{q}}{dt} = \frac{U - U_C}{1} = U - U_C = \underline{\underline{q}} \quad U - f(q) \quad q(0)=0$$

$$U_L(t) = \frac{d\dot{u}}{dt} = U - 1 \cdot \dot{i}_L = U - \dot{i}_L = U - f(u) \quad u(0)=0$$

两式形式相同, 初始条件相同, 故必有 $q(t) = u(t)$.

$$\begin{aligned} U &= U_C + \dot{i} - \dot{i}_L = \frac{\dot{q}}{C} + \dot{i} - \frac{\dot{u}}{L} = \\ &= f(q(t)) + \dot{i} - f(u(t)) = \dot{i} \end{aligned}$$

从端口 $U - i$ 关系来看, 图中一端口网络等效为 β 的线性电阻, 故是端口型线性得证.

三、解: (1) 首先将 CCCS 变为 VCCS.

$$\dot{i}_{36} = \beta \dot{i} = \beta U_{23} G_1$$

$$\text{可知 VCCS 对不定导纳矩阵的贡献为: } 3 \begin{bmatrix} 2 & 3 \\ \beta G_1 & -1/G_1 \\ -1/G_1 & G_1 \end{bmatrix} = \begin{bmatrix} 2 & -2 \\ -2 & 2 \end{bmatrix}$$

写出所有二端元件对不定导纳矩阵的贡献:

$$Y_{iB} = \begin{bmatrix} 1 & SC_1 & -SC_1 & 0 & 0 & 0 & 0 \\ 2 & -SC_1 & SC_1 + SC_2 + G_1 & -G_1 & 0 & 0 & -SC_2 \\ 3 & 0 & \beta G_1 - G_1 & G_1 + G_2 + SG_1 - G_3 & 0 & -G_2 & 0 \\ 4 & 0 & 0 & -SG_3 & G_3 + G_4 + SG_3 & -G_4 & -G_3 \\ 5 & 0 & 0 & 0 & -G_4 & G_4 & 0 \\ 6 & 0 & -SG_2 + \beta G_1 & \beta G_1 - G_2 & -G_3 & 0 & G_2 + G_3 + SG_2 \end{bmatrix} = \begin{bmatrix} s & -s & 0 & 0 & 0 & 0 & 0 \\ -s & 2s+1 & -1 & 0 & 0 & 0 & s \\ 0 & 1 & s & -s & 0 & 0 & -1 \\ 0 & 0 & -s & 4+s & -2 & -2 & 0 \\ 0 & 0 & 0 & -2 & 2 & 0 & 0 \\ 0 & -s-2 & 1 & -2 & 0 & 0 & 3s+5 \end{bmatrix}$$

①先消第 2 行
②消掉保持原节点位置不变消!

(2) 设 6 为参考节点, 得不定导纳矩阵:

$$Y_{d(15)} = \begin{bmatrix} s & -s & 0 & 0 & 0 \\ -s & 2s+1 & 1 & 0 & 0 \\ 0 & 1 & s & -s & 0 \\ 0 & 0 & -s & 4+s & -2 \\ 0 & 0 & 0 & -2 & 2 \end{bmatrix} \xrightarrow{\text{消 } ③} \begin{bmatrix} s & -s & 0 & 0 & 0 \\ -s & 2s+1+\frac{1}{s} & -\frac{1}{s} & 0 & 0 \\ 0 & \frac{1}{s} & 4+s & -2 & 0 \\ 0 & 0 & 2 & 0 & 0 \end{bmatrix} \xrightarrow{\text{消 } ④} \begin{bmatrix} s & -s & 0 & 0 & 0 \\ -s & 2s+\frac{1}{s} & -\frac{1}{s} & 0 & 0 \\ 0 & \frac{1}{s} & 4+s & -2 & 0 \\ 0 & 0 & 2 & 0 & 0 \end{bmatrix} \xrightarrow{\text{消 } ②} \begin{bmatrix} s & -s^2 & 0 & 0 & 0 \\ -s & 2s+\frac{1}{s} & -\frac{1}{s} & 0 & 0 \\ 0 & \frac{1}{s} & 4+s & -2 & 0 \\ 0 & 0 & 2 & 0 & 0 \end{bmatrix}$$

$$\therefore \text{整理得 } Y_{SC}(s) = \begin{bmatrix} \frac{2s^3+2s^2+s}{4s^2+2s+1} & \frac{-s^2}{4s^2+2s+1} \\ \frac{s^2}{4s^2+2s+1} & \frac{2s^3+9s^2+5s+2}{4s^2+2s+1} \end{bmatrix} \xrightarrow{\frac{1}{8s^2+5s+4}} \begin{bmatrix} s - \frac{4s^3}{8s^2+5s+4} & -2s^2 \\ 2s^2 & 2 - \frac{8s^2+4s+4}{8s^2+5s+4} \end{bmatrix}$$

四解：(1) 复杂性所教 4-1-1=2
 按 U_{C1} 所在电容集 KCL 和电感 L_2 所在回路 KVL 列方程如下：

$$-i_s - i_{L2} - i_{R2} + i_{C2} + i_{C1} = 0 \Rightarrow C_1 \frac{du_{C1}}{dt} = C_2 \frac{du_{C2}}{dt} - i_{R2} - i_{L2} - i_s$$

$$U_{C1} + U_{R1} = U_s + U_{L1} + U_{L2} \Rightarrow L_2 \frac{di_{L2}}{dt} = -L_1 \frac{di_{L1}}{dt} + i_{R1} R_1 + U_{C1} - U_s$$

$$i_{R1} = \frac{U_s - U_{C1} - R_2 i_{L2}}{R_1 + R_2} \quad i_{R2} = \frac{-U_s + U_{C1} - R_1 i_{L2}}{R_1 + R_2}$$

$$\dot{U}_{C2} = \dot{U}_s - \dot{U}_{C1} \quad \dot{i}_{L1} = \dot{i}_s + \dot{i}_{L2}$$

整理得：
 $\dot{U}_{C1} = -U_{C1} - 0.5 \dot{i}_{L2} + 0.5 \dot{U}_s + U_s - \dot{i}_s$
 $\dot{i}_{L2} = +0.5 U_{C1} - 0.5 \dot{i}_{L2} - 0.5 U_s - 0.5 \dot{i}_s$

(2) 拉氏变换得：

$$sU_{C1}(s) = -U_{C1}(s) - 0.5 I_{L2}(s) + 0.5 sU_s(s) + U_s(s) - I_s(s) + U_{C1}(0-)$$

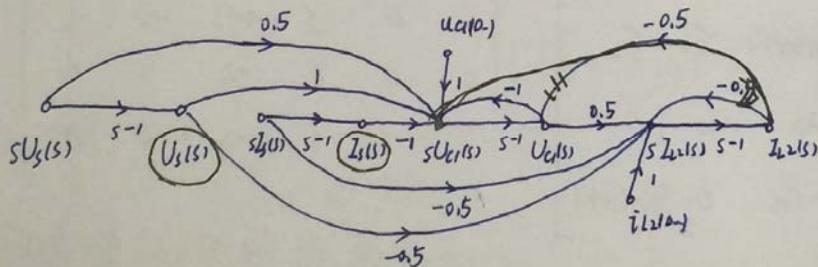
$$sI_{L2}(s) = 0.5 U_{C1}(s) - 0.5 I_{L2}(s) - 0.5 U_s(s) - 0.5 sI_s(s) + i_{L2}(0-)$$

式中： $U_s(s) = \frac{2}{s+1}$ $I_s(s) = \frac{1}{s+1}$

$$\mathcal{L}[e^{-t}] = e^{at} = \frac{1}{s-a}$$

$$= \frac{1}{s+1}$$

画状态转移图：



(3) 四行三列式 $\Delta = 1 - [(-s-1) + (-0.25s-1) + (-0.25s-2)] + (-s-1)(-0.25s-1) = 1 + 1.25s^{-1} + 0.5s^{-2}$

由 $U_{C1}(0-)$ 至 $U_{C1}(s)$ 的前向路径： $P_{1(11)} = s^{-1}$ $\Delta_{1(11)} = 1 + 0.25s^{-1}$ $\bar{P}_{11} = \frac{s^{-1} + 0.25s^{-2}}{1 + 1.25s^{-1} + 0.5s^{-2}}$

由 $U_{C1}(0-)$ 至 $I_{L2}(s)$ 的前向路径： $P_{1(21)} = 0.5s^{-2}$ $\Delta_{1(21)} = 1$ $\bar{P}_{21} = \frac{0.5s^{-2}}{1 + 1.25s^{-1} + 0.5s^{-2}}$

由 $I_{L2}(0-)$ 至 $U_{C1}(s)$ 的前向路径： $P_{1(12)} = -0.5s^{-2}$ $\Delta_{1(12)} = 1$ $\bar{P}_{12} = \frac{-0.5s^{-2}}{1 + 1.25s^{-1} + 0.5s^{-2}}$

由 $I_{L2}(0-)$ 至 $I_{L2}(s)$ 的前向路径： $P_{1(22)} = s^{-1}$ $\Delta_{1(22)} = 1 + s^{-1}$ $\bar{P}_{22} = \frac{s^{-1} + s^{-2}}{1 + 1.25s^{-1} + 0.5s^{-2}}$

解矩阵 $\begin{pmatrix} U_{C1} \\ I_{L2} \end{pmatrix} = \begin{pmatrix} \frac{s+0.25}{s^2+1.25s+0.5} & \frac{-0.5s}{s^2+1.25s+0.5} \\ \frac{0.5}{s^2+1.25s+0.5} & \frac{s+1}{s^2+1.25s+0.5} \end{pmatrix} \begin{pmatrix} 1 \\ \frac{s+0.25}{s^2+1.25s+0.5} \end{pmatrix}$

$$\begin{pmatrix} U_{C1} \\ I_{L2} \end{pmatrix} = \begin{pmatrix} 1 \\ \frac{s+0.25}{s^2+1.25s+0.5} \end{pmatrix} \begin{pmatrix} s+0.25 & -0.5 \\ 0.5 & s+1 \end{pmatrix}^{-1}$$

$$\begin{aligned}
 (14) \quad I_{L2(s)} &= \underline{I_{21} U_{11}(0)} + \underline{I_{22} U_{21}(0)} + \cancel{\underline{I_{11} U_{11}} + \underline{I_{12} U_{21}}} \frac{\underline{I_{21}(s)}}{\underline{I_{11} + I_{12}}} + \\
 &= \frac{s+1.5}{s^2+1.5s+0.5} \quad \underline{I_{13} Z_1} + \underline{I_{12} U_{21}} \\
 &= \frac{s+1.5 + s^2 \left[\frac{1}{s+1} \times (-0.55^{-2}) + 0.55^{-1} \right] \frac{(s+1)}{s+2}}{s^2+1.5s+0.5}
 \end{aligned}$$

Z_{L2}

五、解：(1)以节点③为参考节点，列网路节点方程：

$$(G_3 + G_1)U_{n1} - G_3 U_{n2} = i_s$$

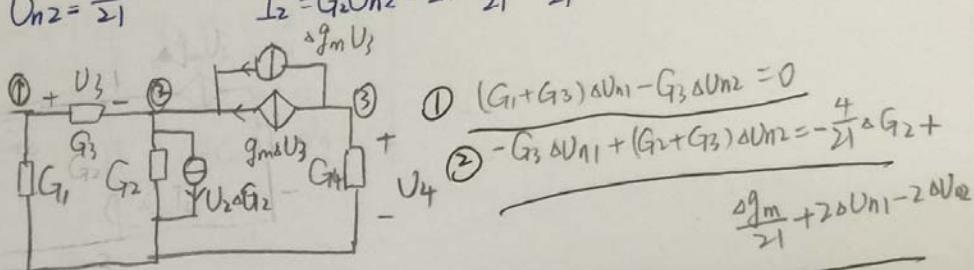
$$-G_3 U_{n1} + (G_3 + G_2) U_{n2} = g_m U_3$$

$$U_3 = U_{n1} - U_{n2}$$

$$\text{联立求解: } U_{n1} = \frac{5}{21} \quad U_{n2} = \frac{4}{21}$$

$$I_2 = G_2 U_{n2} = 2 \times \frac{4}{21} = \frac{8}{21}$$

(2) 增量网络如图。



列节点方程: $(G_1 + G_3 + G_2)\Delta U_{n2} = \Delta g_m U_3 + \Delta G_2 I_2 G_2$

$$U_3 = -\frac{R_3}{R_1 + R_3} \Delta U_{n2}$$

$$U_4 = -\Delta g_m U_3 G_4$$

$$③ \quad G_4 U_4 = -\Delta g_m \frac{1}{21} + 2 \Delta U_{n2} - 2 \Delta U_{n1}$$

$$\begin{aligned}
 U_4 &= -\frac{1}{147} \Delta g_m + \frac{4}{49} \left(-\frac{2}{21} \Delta G_2 + \frac{1}{42} \Delta g_m \right) + \frac{4}{147} \Delta G_2 \times \frac{3}{7} - \\
 &\quad - \frac{6}{1029} \Delta g_m - \frac{4}{1029} \Delta G_2
 \end{aligned}$$

$$\frac{6}{49} \times \frac{1}{42} \Delta g_m$$

$$\begin{aligned}
 &\quad - \frac{1}{147} \Delta g_m + \frac{4}{49} \times \frac{1}{42} \Delta g_m - \frac{8}{21 \times 49} \Delta G_2 + \frac{12}{147 \times 7} \Delta G_2 \\
 &\quad - \frac{1}{49 \times 7} \Delta g_m
 \end{aligned}$$

$$\begin{array}{c}
 \cancel{4} \\
 \cancel{1} + \cancel{5} \\
 \cancel{4} + \cancel{5} + \cancel{2} \\
 \cancel{1} + \cancel{5} + \cancel{2}
 \end{array}$$

$$-\frac{8}{1029} \Delta g_m + \frac{4}{1029} \Delta G_2$$