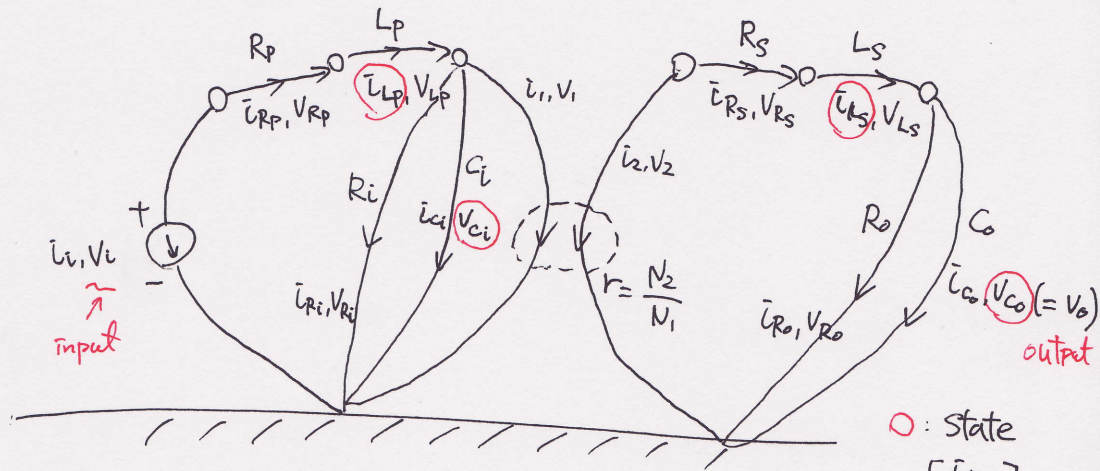


2. Linear graph



Constitutive eq.

$$V_{Rp} = R_p \bar{i}_{Rp}$$

$$V_{Ri} = R_i \bar{i}_{Ri}$$

$$V_{Rs} = R_s \bar{i}_{Rs}$$

$$V_{Ro} = R_o \bar{i}_{Ro}$$

$$L_p \dot{\bar{i}}_{LP} = V_{LP}$$

$$L_s \dot{\bar{i}}_{LS} = V_{LS}$$

$$C_i \dot{V}_{Ci} = \bar{i}_{Ci}$$

$$C_o \dot{V}_{Co} = \bar{i}_{Co}$$

Transformer

$$V_2 = r V_1$$

$$\bar{i}_2 = -\frac{1}{r} \bar{i}_1$$

Loop eq.

$$V_i = V_{Rp} + V_{LP} + V_{Ri}$$

$$V_{Ri} = V_{Ci} = V_1$$

$$V_2 = V_{Rs} + V_{Ls} + V_{Ro}$$

$$V_{Ro} = V_{Co} (= V_o)$$

Node eq.

$$\bar{i}_i = \bar{i}_{Rp} = \bar{i}_{LP} = \bar{i}_{Ri} + \bar{i}_{Ci} + \bar{i}_1$$

$$\bar{i}_2 + \bar{i}_{Rs} = 0$$

$$\bar{i}_{Rs} = \bar{i}_{Ls} = \bar{i}_{Ro} + \bar{i}_{Co}$$

$$\left\{ \begin{aligned} \dot{\bar{i}}_{LP} &= \frac{1}{L_p} V_{LP} = \frac{1}{L_p} (\underbrace{V_i}_{=u} - \underbrace{V_{Rp}}_{=V_{Ci}} - \underbrace{V_{Ri}}_{=X_2}) = \frac{1}{L_p} (u - R_p \bar{i}_{Rp} - \underbrace{R_i \bar{i}_{Ri}}_{=X_1}) \\ \dot{V}_{Ci} &= \frac{1}{C_i} \bar{i}_{Ci} = \frac{1}{C_i} (\bar{i}_{LP} - \bar{i}_{Ri} - \bar{i}_1) = \frac{1}{C_i} (\underbrace{\bar{i}_{LP}}_{=X_1} - \underbrace{\bar{i}_{Ri}}_{=V_{Ci}=X_2} + r \bar{i}_2) \\ \dot{\bar{i}}_{Ls} &= \frac{1}{L_s} V_{Ls} = \frac{1}{L_s} (\underbrace{V_2}_{=X_4} - \underbrace{V_{Rs}}_{=V_{Ci}=X_2} - \underbrace{V_{Co}}_{=V_{Co}=X_4}) = \frac{1}{L_s} (r V_1 - R_s \bar{i}_{Rs} - X_4) \\ \dot{V}_{Co} &= \frac{1}{C_o} \bar{i}_{Co} = \frac{1}{C_o} (\bar{i}_{Ls} - \bar{i}_{Ro}) = \frac{1}{C_o} (X_3 - \underbrace{\frac{1}{R_o} V_{Ro}}_{=V_{Co}=X_4}) \end{aligned} \right.$$

$$\left\{ \begin{aligned} \begin{bmatrix} \dot{\bar{i}}_{LP} \\ \dot{V}_{Ci} \\ \dot{\bar{i}}_{Ls} \\ \dot{V}_{Co} \end{bmatrix} &= \begin{bmatrix} -R_p/L_p & -1/L_p & 0 & 0 \\ 1/C_i & -1/C_i R_i & -r/C_i & 0 \\ 0 & r/L_s & -R_s/L_s & -1/L_s \\ 0 & 0 & 1/C_o & -1/C_o R_o \end{bmatrix} \begin{bmatrix} \bar{i}_{LP} \\ V_{Ci} \\ \bar{i}_{Ls} \\ V_{Co} \end{bmatrix} + \begin{bmatrix} 1/L_p \\ 0 \\ 0 \\ 0 \end{bmatrix} V_i \\ V_o &= \begin{bmatrix} 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \bar{i}_{LP} \\ V_{Ci} \\ \bar{i}_{Ls} \\ V_{Co} \end{bmatrix} \end{aligned} \right.$$