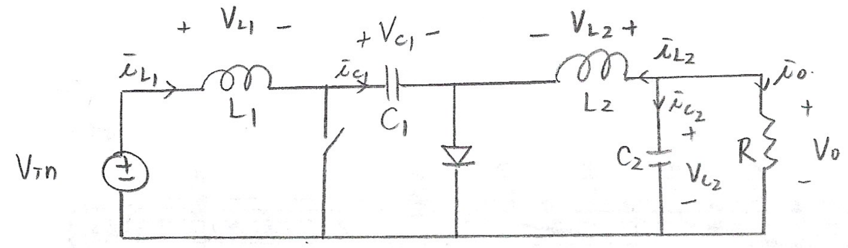
A Cùk converter is used with the following parameters:

$$V = 12v\ in$$
$$D = 0.6$$
$$L_1 = 1\ mH$$
$$L_2 = 2\ mH$$
$$C_1 = 25\ \mu F$$
$$C_2 = 5\ \mu F$$
$$f = 50kHz\ s$$
$$P = 40\ w$$

Find the output voltage, the inductor current ripples (for both L_1 & L_2) and the capacitor Assuming ideal components, voltage ripples (for both C_1 & C_2).



$V_{in} = 12V.$

$D = 0.6$

$L_1 = 1mH \quad C_1 = 25\mu F$

$L_2 = 2mH \quad C_2 = 5\mu F$

$f_s = 50kHz.$

$P = 40w.$

$$\frac{V_o}{V_i} = \frac{-D}{1-D} \Rightarrow V_o = \frac{-0.6}{(1-0.6)} \cdot 12 = \underline{\underline{-18V}}$$

$$\Delta i_{L_1} = \frac{V_i D}{f_s L_1} = \frac{12 \cdot 0.6}{(50\times10^3)(1\times10^{-3})} = \underline{\underline{0.144\ A}}.$$

$$\Delta i_{L_2} = \frac{V_i D}{f_s L_2} = \frac{12 \cdot 0.6}{(50\times10^3)(2\times10^{-3})} = \underline{\underline{0.072\ A}}.$$

$$\frac{\Delta V_{C2}}{V_o} = \frac{(1-D).}{8L_2 f_s^2 \cdot C_2} = \frac{(1-0.6)}{8\cdot(2\times10^{-3})(50\times10^3)^2\cdot(5\times10^{-6})} = \underline{\underline{2\times10^{-3}}}$$

$$\Delta Q_1 = C_1 \Delta V_{C_1} = \Delta t\ \Delta i_{C_1} = I_{L_1}(1-D)T.$$

$$I_{L_1} = I_i = \frac{-D}{1-D} \cdot I_o = \frac{-D}{1-D}\ \frac{P}{V_o} = 3.33$$

$$\Rightarrow \Delta V_{C_1} = \frac{I_{L_1}(1-D)T}{C_1} = \frac{3.33\ (1-0.6)}{(50\times10^3)\cdot(25\times10^{-6})} = \underline{\underline{1.0656\ V.}}$$

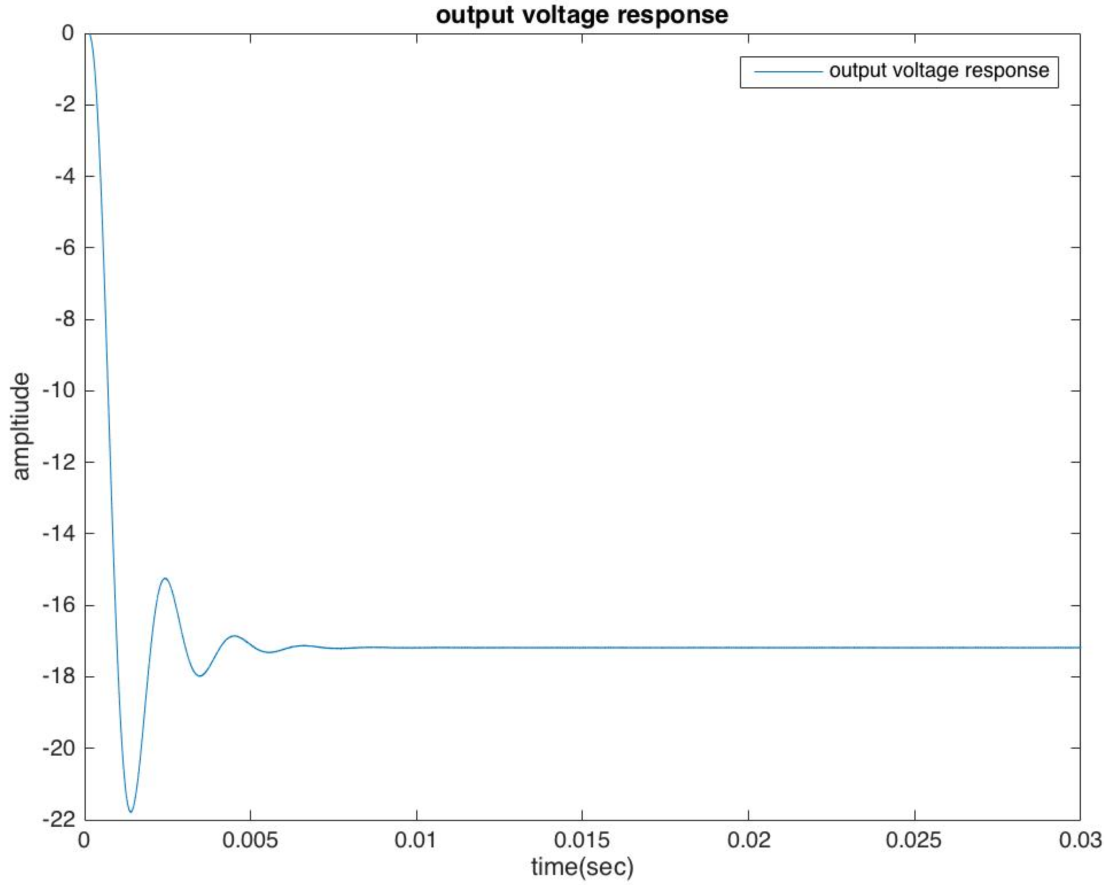


Figure 1. Output voltage waveform.

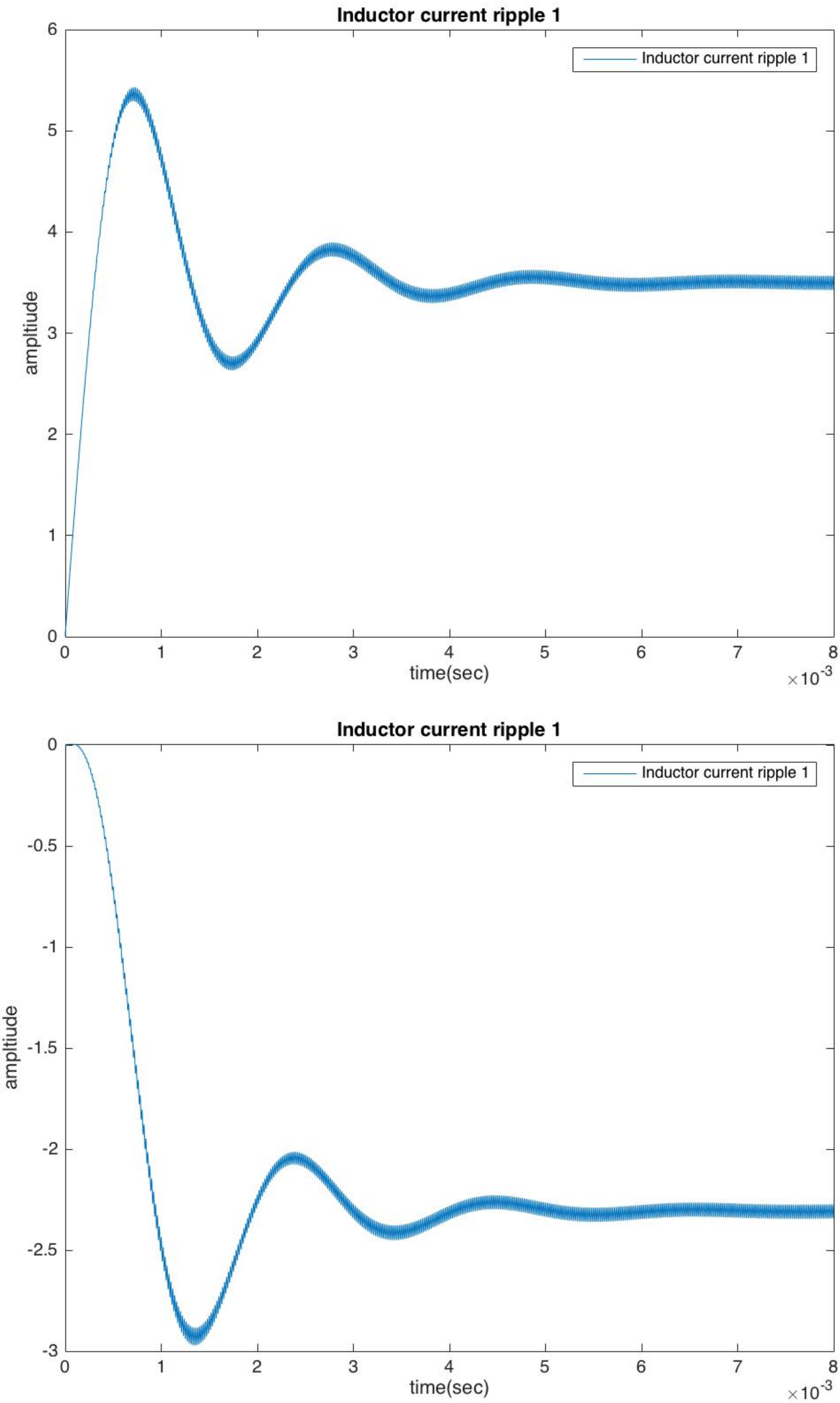


Figure 2. Inductor current waveform.

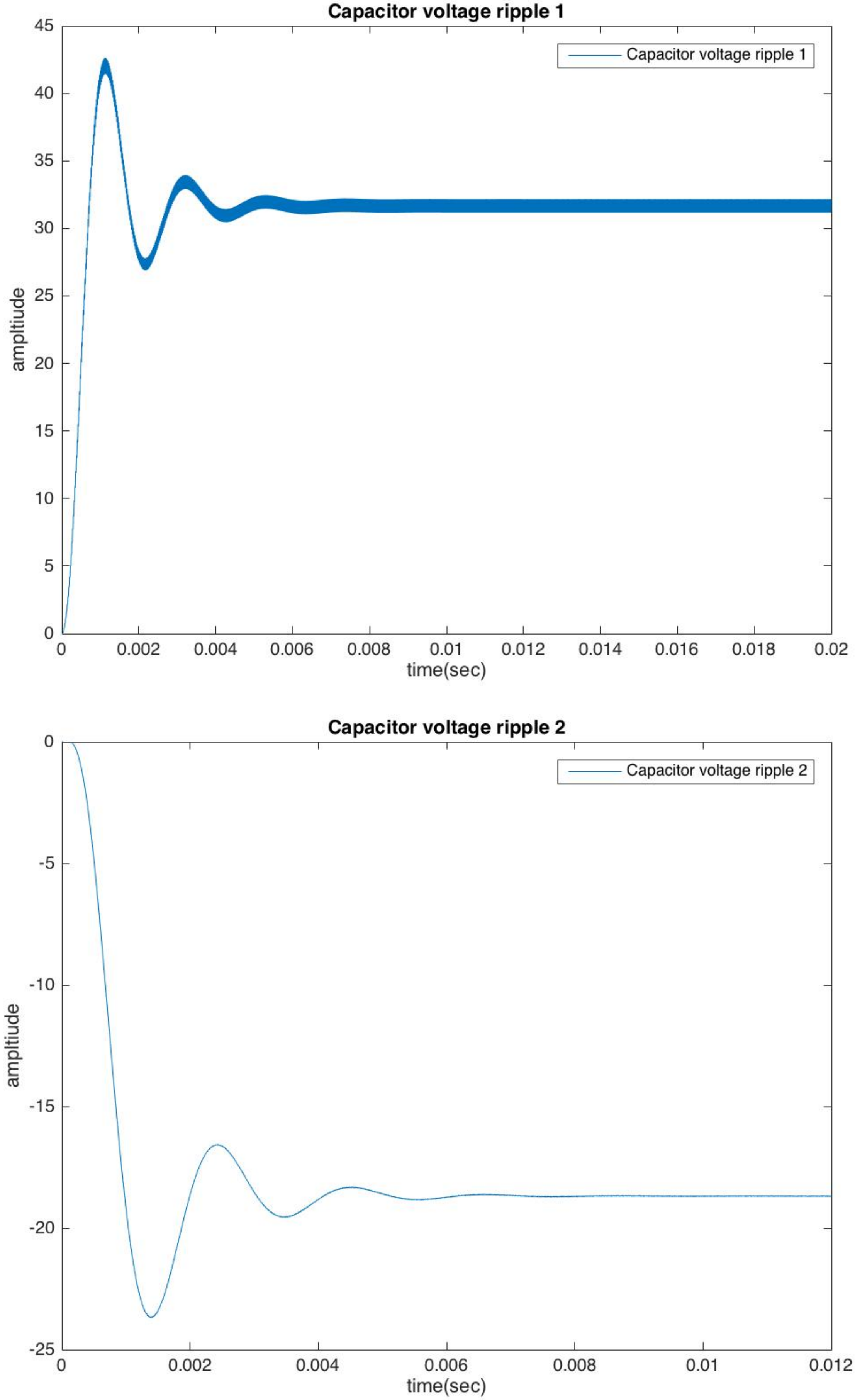


Figure 3. Capacitor voltage waveform.

(c)

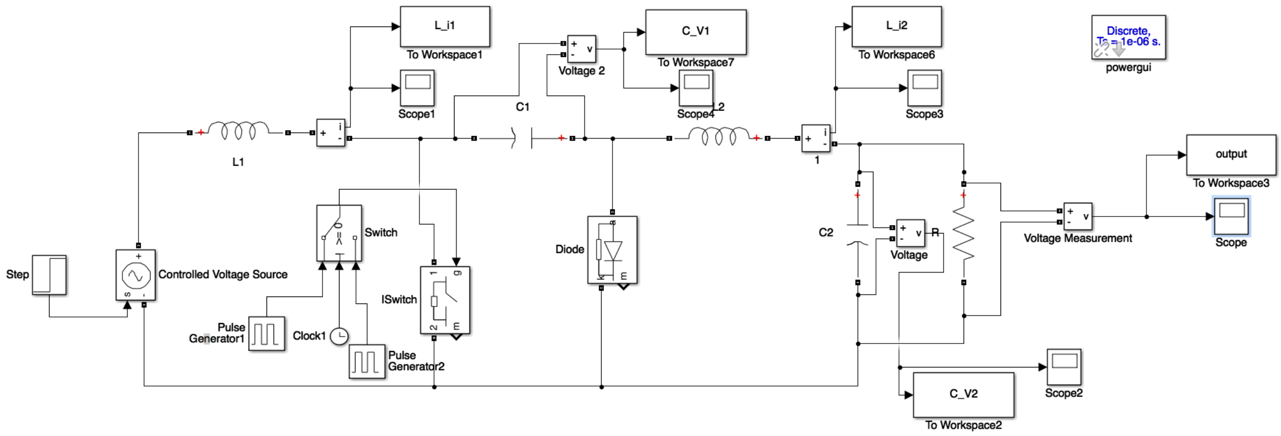


Figure 4.MATLAB Simulink model.

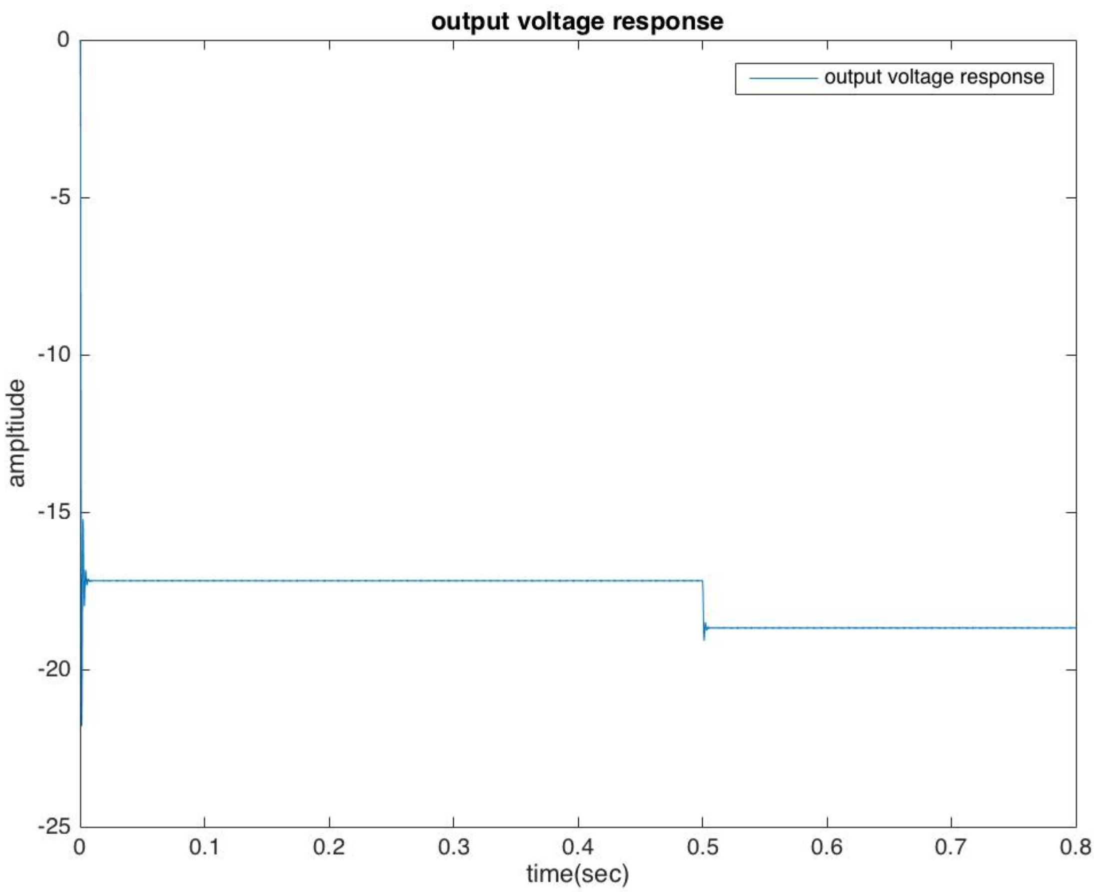
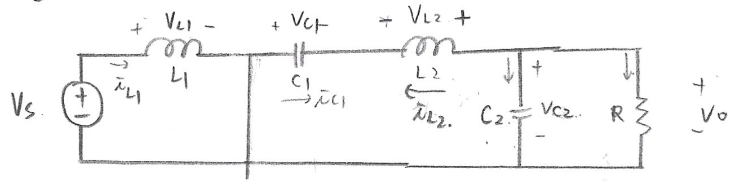


Figure 5. Output voltage response.

(d) Use state space.

$$x = \begin{bmatrix} i_{L1} \\ i_{L2} \\ V_{c1} \\ V_{c2} \end{bmatrix}$$

① ON.



$u = [V_s]$

$y = [V_o]$.

$$V_s = V_{L1} = L\, \dot{i}_{L1}$$

$$V_{L2} = V_{C1} - V_{C2} = L_2\, \dot{i}_{L2}$$

$$i_{C1} = -i_{L2} = C_1 \dot{V}_{C1}$$

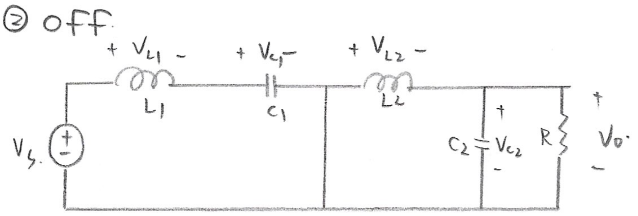
$$i_{C2} = C_2 \dot{V}_{C2} = i_{L2} - i_o = i_{L2} - \frac{V_{C2}}{R}$$

$$V_o = V_{C2}$$

$$\dot{x} = \begin{bmatrix} \dot{i}_{L1} \\ \dot{i}_{L2} \\ \dot{V}_{C1} \\ \dot{V}_{C2} \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & \frac{1}{L_2} & \frac{-1}{L_2} \\ 0 & -\frac{1}{C_1} & 0 & 0 \\ 0 & \frac{1}{C_2} & 0 & \frac{-1}{RC_2} \end{bmatrix} \begin{bmatrix} i_{L1} \\ i_{L2} \\ V_{C1} \\ V_{C2} \end{bmatrix} + \begin{bmatrix} \frac{1}{L_1} \\ 0 \\ 0 \\ 0 \end{bmatrix} [V_s]$$

$$y = [V_o] = \begin{bmatrix} 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} i_{L1} \\ i_{L2} \\ V_{C1} \\ V_{C2} \end{bmatrix}$$

② off



$$V_{L1} = V_s - V_{C1} = L_1 \dot{i}_{L1}$$

$$V_{L2} = -V_{C2} = L_2 \dot{i}_{L2}$$

$$i_{C1} = i_{L1} = C_1 \dot{V}_{C1}$$

$$i_{C2} = i_{L2} - i_o = i_{L2} - \frac{V_{C2}}{R} = C_2 \dot{V}_{C2}$$

$$V_o = V_{C2}$$

$$\dot{x} = \begin{bmatrix} 0 & 0 & \frac{-1}{L_1} & 0 \\ 0 & 0 & 0 & \frac{-1}{L_2} \\ \frac{1}{C_1} & 0 & 0 & 0 \\ 0 & \frac{1}{C_2} & 0 & \frac{-1}{RC_2} \end{bmatrix} \begin{bmatrix} i_{L1} \\ i_{L2} \\ V_{C1} \\ V_{C2} \end{bmatrix} + \begin{bmatrix} \frac{1}{L_1} \\ 0 \\ 0 \\ 0 \end{bmatrix} [V_s]$$

$$y = \begin{bmatrix} 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} i_{L1} \\ i_{L2} \\ V_{C1} \\ V_{C2} \end{bmatrix}$$

$$\begin{cases} \dot{\bar{x}} = (A_1 d + A_2 d')\,\bar{x} + (B_1 d + B_2 d')\,\bar{u} \\ \bar{y} = (C_1 d + C_2 d')\,\bar{x} + (D_1 d + D_2 d')\,\bar{u} \end{cases}$$

$$\Rightarrow A_v = \begin{bmatrix} 0 & 0 & \frac{-d'}{L_1} & 0 \\ 0 & 0 & \frac{d}{L_2} & \frac{-1}{L_2} \\ \frac{d'}{C_1} & -\frac{d}{C_1} & 0 & 0 \\ 0 & \frac{1}{C_2} & 0 & \frac{-1}{RC_2} \end{bmatrix} \qquad B_v = \begin{bmatrix} \frac{1}{L_1} \\ 0 \\ 0 \\ 0 \end{bmatrix}$$

$$C_v = \begin{bmatrix} 0 & 0 & 0 & 1 \end{bmatrix}$$

$$TF = C_v (S I - A_v)^{-1} B_v = \frac{10^{14} \times (-9.6)}{10^{14}(0.0034 S + 6.4)} = \underline{\underline{\frac{-9.6}{0.0034 S + 6.4}}}$$