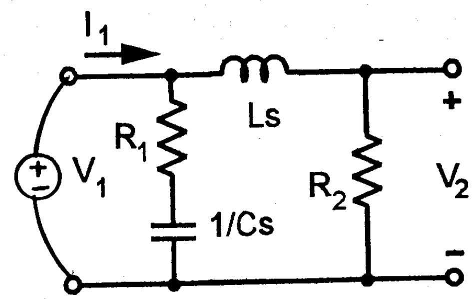
CHAPTER 11

11-1 (a) $Z(s) = \dfrac{1}{\left(R_1 + \dfrac{1}{C \cdot s}\right)^{-1} + (L \cdot s + R_2)^{-1}}$

$$Z(s) = \frac{(L \cdot s + R_2) \cdot (R_1 \cdot C \cdot s + 1)}{L \cdot C \cdot s^2 + (R_2 + R_1) \cdot C \cdot s + 1}$$

By voltage division: $T_V(s) = \dfrac{R_2}{L \cdot s + R_2}$



(b) $R_1 := 2000 \quad R_2 := R_1$

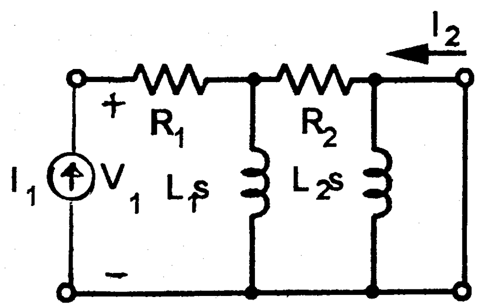
$L := 0.1 \quad C := 0.25 \cdot 10^{-6}$

$\text{polyroots}\left(\begin{bmatrix} R_2 \\ L \end{bmatrix}\right) = -2 \cdot 10^4 \qquad \text{polyroots}\left(\begin{bmatrix} 1 \\ (R_1 + R_2) \cdot C \\ L \cdot C \end{bmatrix}\right) = \begin{bmatrix} -3.897 \cdot 10^4 \\ -1.026 \cdot 10^3 \end{bmatrix}$

Z(s) has zeros at $s = R_2/L = -20000$ & $s = 1/R_1C = -2000$ and poles at s = -1026 and -38970
$T_V(s)$ has a pole at s = -20000

11-4 (a) $Z(s) = R_1 + \dfrac{1}{\dfrac{1}{L_1 \cdot s} + \dfrac{1}{R_2}}$

$$Z(s) = \frac{[R_1 \cdot R_2 + (R_1 + R_2) \cdot L_1 \cdot s]}{(R_2 + L_1 \cdot s)}$$



By current division: $I_2(s) = \dfrac{-L_1 \cdot s}{L_1 \cdot s + R_2} \cdot I_1(s)$

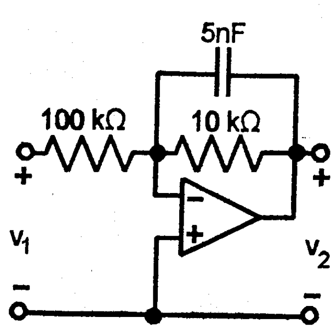
Hence $T_I(s) = \dfrac{I_2(s)}{I_1(s)} = \dfrac{-L_1 \cdot s}{L_1 \cdot s + R_2}$

(b) $R_1 := 500 \quad R_2 := 2000 \; L_1 := 0.4$

$\text{polyroots}\left(\begin{bmatrix} R_2 \\ L_1 \end{bmatrix}\right) = -5 \cdot 10^3 \qquad \text{polyroots}\left(\begin{bmatrix} R_1 \cdot R_2 \\ (R_1 + R_2) \cdot L_1 \end{bmatrix}\right) = -1 \cdot 10^3$

Z(s) has a zero at s = -1000 and a pole at s = -5000.
Tz(s) has a zero at s = 0 and a pole at s = -5000.

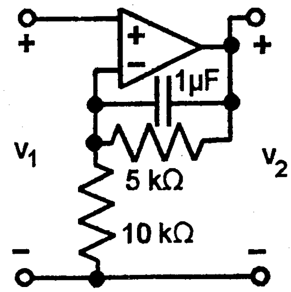
11-7 $Z_2(s) = \dfrac{1}{5 \cdot 10^{-9} \cdot s + \dfrac{1}{10^4}} = \dfrac{2000 \cdot 10^5}{(s + 20000)} \qquad Z_1(s) = 10^5$



$T_V(s) = -\dfrac{Z_2}{Z_1} = -\left[\dfrac{2000}{(s + 20000)}\right]$

Tv(s) has a pole at s = -20000 and a zero at infinity

11-8 $Z_1(s) = \dfrac{1}{10^{-6}\cdot s + \dfrac{1}{5000}} = \dfrac{10^6}{(s+200)}$

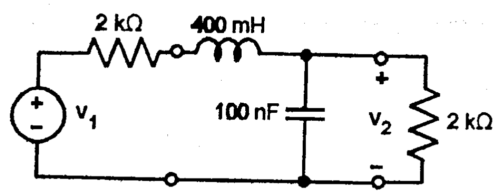


$Z_2(s) = 10^4$

$$T_V(s) = \frac{Z_1 + Z_2}{Z_2} = \frac{10^4 + \dfrac{10^6}{s+200}}{10^4} = \frac{(s+300)}{(s+200)}$$

Tv(s) has a zero at s = -300 and a pole at s = -200

11-13 By voltage division:

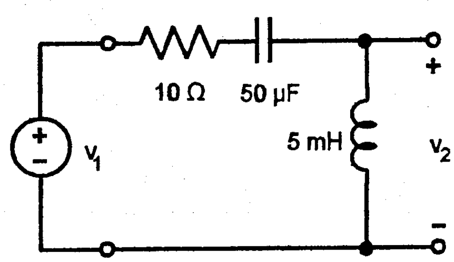


$$T_V(s) = \frac{\dfrac{1}{10^{-7}\cdot s + 5\cdot 10^{-4}}}{\dfrac{1}{10^{-7}\cdot s + 5\cdot 10^{-4}} + 0.4\cdot s + 2000}$$

$$T_V(s) = \frac{25000000}{\left(s^2 + 10000\cdot s + 50000000\right)}$$

$$h(t) = \mathcal{L}^{-1}\cdot\left[5000\cdot\left[\frac{5000}{(s+5000)^2 + 5000^2}\right]\right] = 5000\cdot e^{-5000t}\cdot \sin(5000\cdot t)\cdot u(t)$$

11-15 By voltage division:



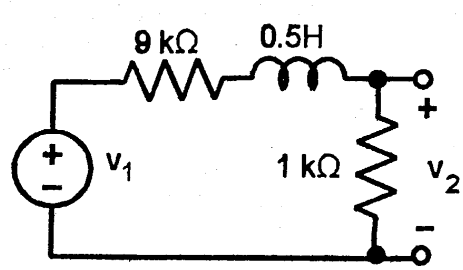
$$T_V(s) = \frac{5\cdot 10^{-3}\cdot s}{5\cdot 10^{-3}\cdot s + \left(50\cdot 10^{-6}\cdot s\right)^{-1} + 10}$$

$$T_V(s) = \frac{s^2}{s^2 + 2000\cdot s + 4000000}$$

$$h(t) = \mathcal{L}^{-1}\cdot\left(\frac{s^2}{s^2 + 2000\cdot s + 4000000}\right) = \mathcal{L}^{-1}\cdot\left[1 - \frac{2000\cdot(s+1000)}{(s+1000)^2 + \left(1000\cdot\sqrt{3}\right)^2} - \frac{2000}{\sqrt{3}}\cdot\frac{1000\cdot\sqrt{3}}{(s+1000)^2 + \left(1000\cdot\sqrt{3}\right)^2}\right]$$

$$h(t) = \delta(t) - \left(\frac{2000}{\sqrt{3}}\cdot \exp(-1000\cdot t)\cdot \sin\left(1000\cdot\sqrt{3}\cdot t\right) + 2000\cdot \exp(-1000\cdot t)\cdot \cos\left(1000\cdot\sqrt{3}\cdot t\right)\right)\cdot u(t)$$

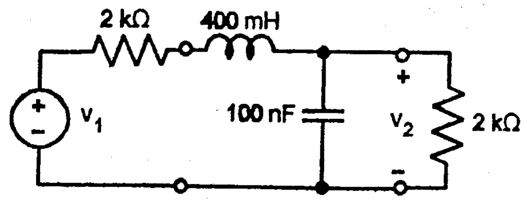
11-21 By voltage division:



$$T_V(s) = \frac{1000}{1000 + 0.5\cdot s + 9000} = \frac{2000}{(s+20000)}$$

$$g(t) = \mathcal{L}^{-1}\cdot\left[\frac{2000}{(s+20000)}\cdot\frac{1}{s}\right] = 0.1\cdot\left(1 - e^{-20000\cdot t}\right)\cdot u(t)$$

11-23 By voltage division:



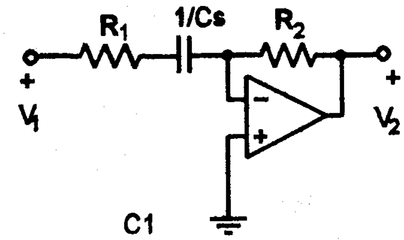
$$T_V(s)=\frac{\dfrac{1}{10^{-7}\cdot s+5\cdot 10^{-4}}}{\dfrac{1}{10^{-7}\cdot s+5\cdot 10^{-4}}+0.4\cdot s+2000}$$

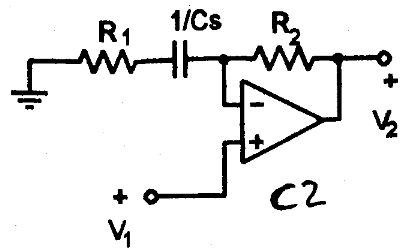
$$T_V(s)=\frac{25000000.}{\left(s^2+10000\cdot s+50000000\right)}$$

$$G(s)=\frac{T_V}{s}=\frac{25000000.}{(s+5000+j\cdot 5000)\cdot(s+5000-j\cdot 5000)}\cdot\frac{1}{s}=\frac{(-.25-.25\cdot j)}{(s+5000+5000\cdot j)}+\frac{(-.25+.25\cdot j)}{(s+5000-5000\cdot j)}+\frac{.5}{s}$$

$$g(t)=\left(0.5\cdot\sqrt{2}\cdot\exp(-5000\cdot t)\cdot\cos\left(5000\cdot t+3\cdot\frac{\pi}{4}\right)+0.5\right)\cdot u(t)$$

11-63(a) C1 is an inverting amplifier C2 is a noninverting amplifier





For both circuits: $Z_1 = R_1 + \frac{1}{C\cdot s} = \frac{R_1\cdot C\cdot s+1}{C\cdot s}$ and $Z_2 = R_2$

For C1: $T_V(s) = -\frac{Z_2}{Z_1} = \frac{-R_2\cdot C\cdot s}{R_1\cdot C\cdot s+1}$

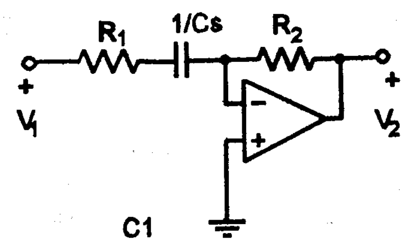
Pole at $s = -\frac{1}{R_1\cdot C}$, zero at $s=0$

For C2: $T_V = \frac{Z_1+Z_2}{Z_1} = \frac{(R_1+R_2)\cdot C\cdot s+1}{R_1\cdot C\cdot s+1}$

Pole at $s = \frac{-1}{R_1\cdot C}$, zero at $s = \frac{-1}{(R_1+R_2)\cdot C}$

(b) Use C1 in cascade with C2 $T(s) = \frac{-s\cdot(s+300)}{(s+200)\cdot(s+400)} = T_{C1}\cdot T_{C2} = \left[\frac{-\frac{3\cdot s}{800}}{\frac{s}{200}+1}\right]\cdot\left[\frac{\frac{s}{300}+1}{\frac{s}{400}+1}\right]$,

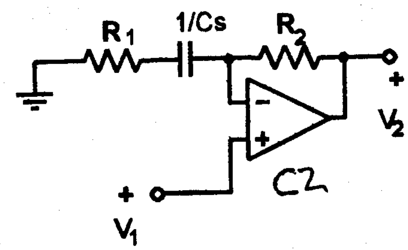
For C1: $T_{C1} = \frac{-R_2\cdot C\cdot s}{R_1\cdot C\cdot s+1} = \frac{-\frac{3\cdot s}{800}}{\frac{s}{200}+1}$



Let $C := 10^{-7}$ $R_1 := \frac{1}{200\cdot C}$ $R_2 := \frac{3}{800\cdot C}$

$R_1 = 5\cdot 10^4$ $R_2 = 3.75\cdot 10^4$

For C2: $T_{C2} = \frac{(R_1+R_2)\cdot C\cdot s+1}{R_1\cdot C\cdot s+1} = \frac{\frac{s}{300}+1}{\frac{s}{400}+1}$



Let $C := 10^{-7}$ $R_1 := \frac{1}{400\cdot C}$ $R_2 := \frac{1}{300\cdot C} - R_1$

$R_1 = 2.5\cdot 10^4$ $R_2 = 8.333\cdot 10^3$

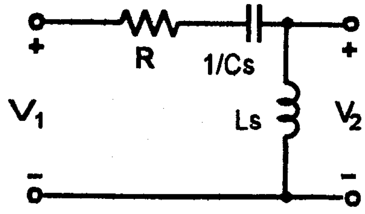
(c) C1 and C2 produce zeros closer to the s-plane origin than their poles. $T_3 = \frac{s(s+500)}{(s+200)\cdot(s+400)}$ can not be realized. It requires a zero at s = -500 which is further from the origin than either pole.

(d) To be realizable using C1 and C2 it must be possible to partition T(s) into first order factors each of which has a zero closer to the origin than its pole.

11-65 (a) Using voltage division in the RLC ckt

$$T_V(s)=\frac{L\cdot s}{R+\frac{1}{C\cdot s}+L\cdot s}=\frac{L\cdot C\cdot s^2}{L\cdot C\cdot s^2+R\cdot C\cdot s+1}$$

$$\omega_0=\frac{1}{\sqrt{L\cdot C}} \qquad \text{and} \qquad \zeta=\frac{R}{2}\cdot\sqrt{\frac{C}{L}}$$



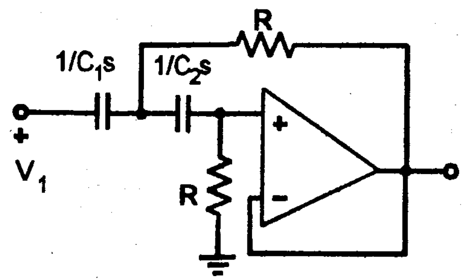
C1

Using node analysis in the RC OP AMP ckt

$$\begin{bmatrix} C_1\cdot s+C_2\cdot s+\frac{1}{R} & -\left(C_2\cdot s+\frac{1}{R}\right) \\ -C_2\cdot s & C_2\cdot s+\frac{1}{R} \end{bmatrix}\cdot\begin{bmatrix} V_A \\ V_B \end{bmatrix}=\begin{bmatrix} C_1\cdot s\cdot V_1 \\ 0 \end{bmatrix}$$

$$\Delta(s)=\frac{R^2\cdot C_1\cdot C_2\cdot s^2+\left(R\cdot C_1+R\cdot C_2\right)\cdot s+1}{R^2}$$

$$\Delta_B(s)=C_1\cdot C_2\cdot s^2\cdot V_1$$



C2

$$T_V(s)=\frac{R^2\cdot C_1\cdot C_2\cdot s^2}{R^2\cdot C_1\cdot C_2\cdot s^2+\left(R\cdot C_1+R\cdot C_2\right)\cdot s+1} \qquad \omega_0=\frac{1}{R\cdot\sqrt{C_1\cdot C_2}} \qquad \text{and} \qquad \zeta=\frac{1}{2}\cdot\left(\sqrt{\frac{C_1}{C_2}}+\sqrt{\frac{C_2}{C_1}}\right)$$

(b) For the RLC ckt $\quad L\cdot C=10^{-12} \quad R\cdot\sqrt{\frac{C}{L}}=1 \quad$ Let $\quad C=10^{-8} \quad$ Then $\quad L=10^{-4} \quad R=100$

For the RC OP AMP ckt $\quad C_1\cdot C_2\cdot R^2=10^{-12} \quad \sqrt{\frac{C_1}{C_2}}+\sqrt{\frac{C_2}{C_1}}=1$

The expression $\sqrt{\frac{C_1}{C_2}}+\sqrt{\frac{C_2}{C_1}}$, is of the form $f(x)=x+\frac{1}{x}$, whose minimum value is f(x)=2 at x = 1

Therefore the RC OP AMP circuit can not produce $\zeta = 0.5$.

Choose the RLC circuit since its element values are reasonable and it meets the specification.

(c) For the RLC ckt $\quad L\cdot C=10^{-4} \quad R\cdot\sqrt{\frac{C}{L}}=4 \quad$ Let $\quad C=10^{-6} \quad$ then $\quad L=100 \quad R=4\cdot 10^4$

For the RC OP AMP ckt: Let $R=10^4$, Assume: $\quad C_1:=10^{-6} \qquad C_2:=2\cdot C_1$

Given $\quad C_1\cdot C_2\cdot 10^8=10^{-4} \quad \sqrt{\frac{C_1}{C_2}}+\sqrt{\frac{C_2}{C_1}}=4 \quad \text{Find}\left(C_1,C_2\right)=\begin{bmatrix} 2.679\cdot 10^{-7} \\ 3.732\cdot 10^{-6} \end{bmatrix}$ many other solutions are possible

The RLC circuit requires L = 100 H which is too large to be practical. Choose the RC OP AMP circuit.