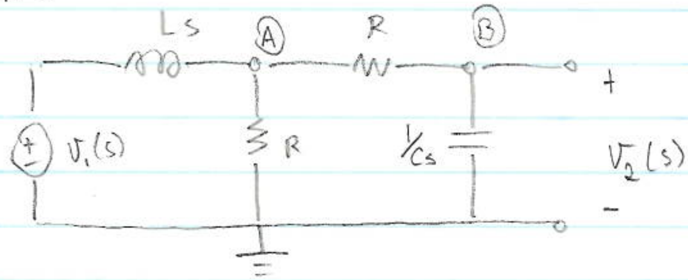
11/5



$$V_B(s) = V_2(s)$$

KCL A:

$$\frac{1}{Ls}\left(V_A(s) - V_1(s)\right) + \frac{1}{R} V_A(s) + \frac{1}{R}\left(V_A(s) - V_2(s)\right) = 0$$

KCL B:

$$\frac{1}{R}\left(V_2(s) - V_A(s)\right) + Cs\, V_2(s) = 0$$

$$\therefore \quad V_2(s)\left(\frac{1}{R} + sC\right) = \frac{1}{R} V_A(s)$$

$$V_A(s) = V_2(s)(1 + sRC)$$

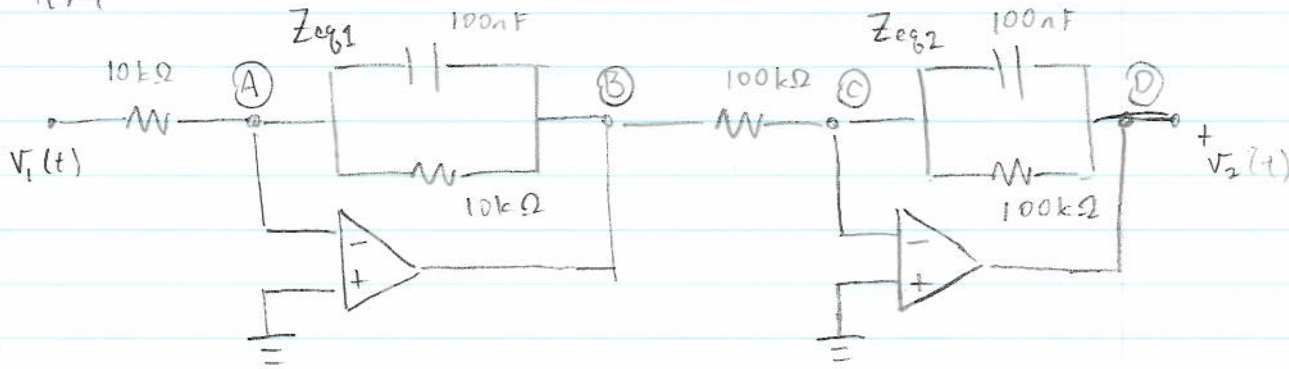
KCL A $\Rightarrow$ $$V_A(s)\left(\frac{1}{Ls} + \frac{2}{R}\right) - \frac{V_2(s)}{R} = \frac{V_1(s)}{Ls}$$

$$V_2(s)\left[(1+sRC)\left(\frac{1}{Ls} + \frac{2}{R}\right) - \frac{1}{R}\right] = \frac{V_1(s)}{Ls}$$

$$V_2(s)\left[\frac{R(1+sRC) + 2Ls(1+sRC) - Ls}{sRL}\right] = \frac{V_1(s)}{sL}$$

$$V_2(s) = V_1(s) \cdot \underbrace{\frac{R}{s^2(2RLC) + s(R^2C + L) + R}}_{= T(s)}$$

11/9



10 kΩ || 100 nF

$$\Rightarrow Z_{eq1} = \frac{10^4 \times \frac{1}{10^{-7}s}}{10^4 + \frac{1}{10^{-7}s}} = \frac{10^{11}}{10^4 s + 10^7} = \frac{10^7}{s + 1000}$$

100 kΩ || 100 nF

$$\Rightarrow Z_{eq2} = \frac{10^7}{s + 100}$$

$V_A = V_C = 0$

KCL @ A :

$$V_1(s) \times \frac{1}{10^4} + V_B(s) \times \left(\frac{10^7}{s+1000}\right)^{-1} = 0$$

$$\therefore V_B(s) = -V_1(s) \times \frac{10^3}{s + 1000}$$

KCL @ C :

$$\frac{1}{10^5} V_B(s) + V_2(s)\left(\frac{10^7}{s+100}\right)^{-1} = 0$$

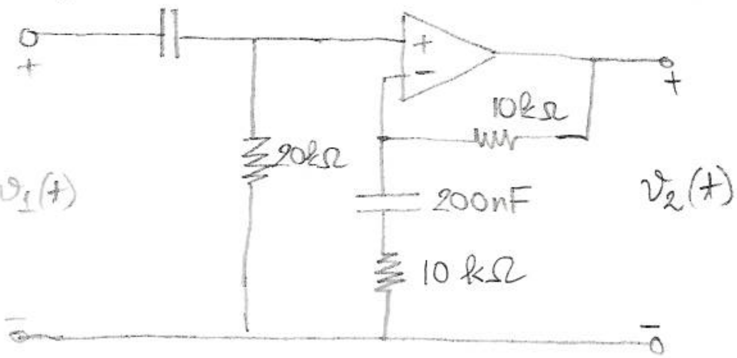
$$\Rightarrow V_2(s) = -\frac{V_B(s)}{10^5} \times \frac{10^7}{s+100}$$

$$= V_1(s) \times \underbrace{\frac{10^5}{(s+100)(s+1000)}}_{T(s)}$$

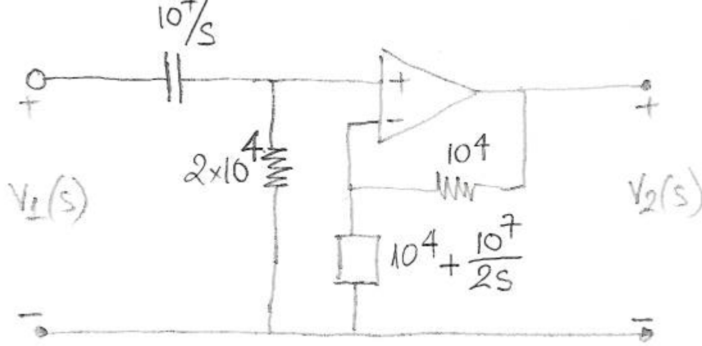
Zeroes : ϕ

Poles : $-100, -1000$

11-10,



→ transform into s-domain and simplify circuit



$$\rightarrow V_N = \frac{10^4+10^7/2s}{10^4+10^4+10^7/2s} V_2(s) = \frac{2s+10^3}{4s+10^3} V_2(s)$$

$$\rightarrow V_P = \frac{2\times10^4}{2\times10^4+10^7/s} V_1(s) = \frac{2s}{2s+10^3} V_1(s)$$

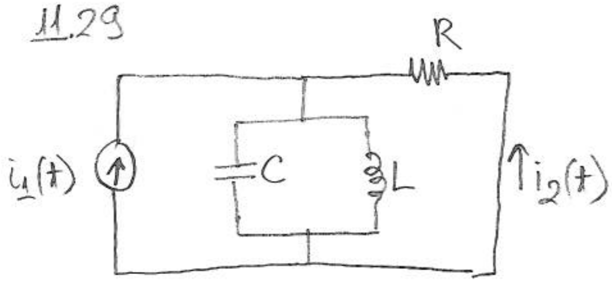
$$\rightarrow V_N = V_P \Rightarrow \frac{V_2(s)}{V_1(s)} = \frac{2s}{(2s+10^3)} \times \frac{4s+10^3}{(2s+10^3)} = \boxed{\frac{2s(4s+10^3)}{(2s+10^3)^2}}$$

→ poles: $2s+10^3=0 \Rightarrow \boxed{s=-500 \text{ (double)}}$

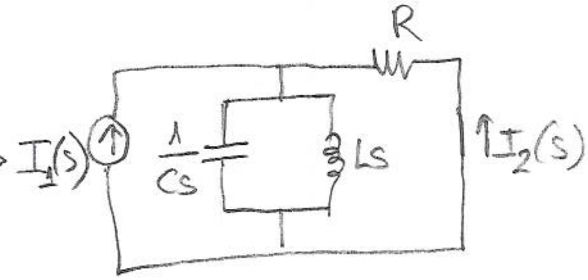
→ zeros: → $\boxed{s=0}$

→ $4s+10^3=0 \Rightarrow \boxed{s=-250}$

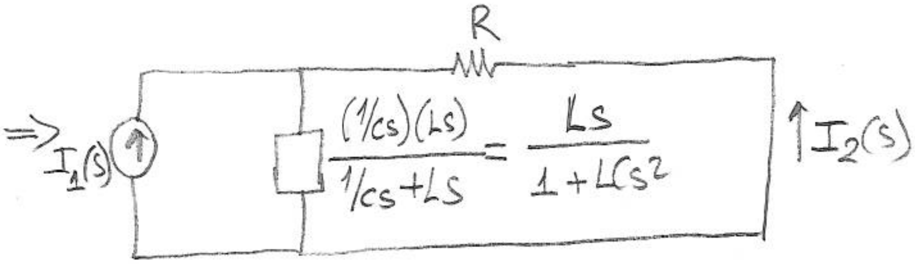
11.29



$\xrightarrow{\mathcal{L}}$



$\Rightarrow$

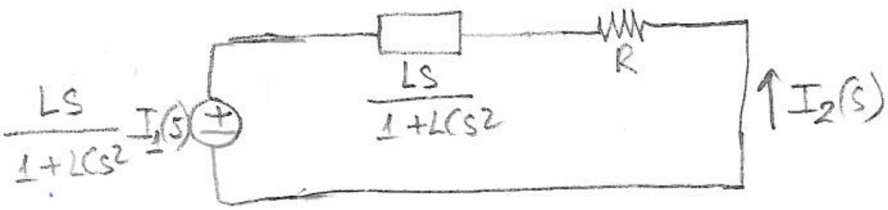


$\rightarrow i_1(t) = 5\cos(1000t)$ mA

$\rightarrow R = 10^3\,\Omega$

$\rightarrow L = 2H$

$\rightarrow C = 5\times10^{-7}F$



$$\Rightarrow I_2(s) = \frac{-\frac{Ls}{1+LCs^2}I_1(s)}{R+\frac{Ls}{1+LCs^2}} \Rightarrow T(s) = \frac{I_2(s)}{I_1(s)} = \frac{-s/RC}{s^2+s/RC+1/LC}$$

$$\Rightarrow T(j\omega) = \frac{-j\omega/RC}{-\omega^2+j\omega/RC+1/LC} \Rightarrow |T(j\omega)| = \frac{\omega/RC}{\sqrt{\left(\frac{1}{LC}-\omega^2\right)^2+\left(\frac{\omega}{RC}\right)^2}}$$

$\rightarrow$ for $i_1(t) = 5\cos(1000t) \Rightarrow \omega = 1000$ rad/s

$$\Rightarrow |T(1000j)| = 1.0 \text{ and } \angle T(1000j) = \frac{-\pi}{2} - \tan^{-1}\left[\frac{\omega/RC}{1/LC-\omega^2}\right] = -\pi \text{ rad}$$

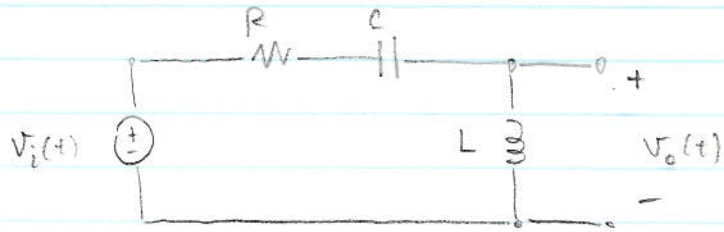
$$\Rightarrow i_2(t) = (5)(1)\cos[1000t-1.5708] = \boxed{1\ 5\cos[1000t+\pi]} \text{ mA}$$

$\rightarrow$ for $i_2(t) = 10\cos(2000t) \Rightarrow \omega = 2000$ rad/s

$$\Rightarrow |T(2000j)| = .8 \quad \text{and } \angle T(2000j) = -3.79 \text{ rad}$$

$$\Rightarrow i_2(t) = (10)(.8)\cos[2000t-1.7296] = \boxed{8\cos[2000t+3.79]} \text{ mA}$$

11/54 $T(s) = \dfrac{s^2}{(s+1000)(s+4000)} = \dfrac{s^2}{s^2 + 5000s + 4\times10^6}$



$$V_o(s) = \frac{sL}{R + \frac{1}{sC} + sL} V_i(s)$$

$$V_o(s) = \frac{s^2 LC}{s^2 LC + sRC + 1} = \frac{s^2}{s^2 + s\left(\frac{R}{L}\right) + \frac{1}{LC}}$$

$$\Rightarrow \frac{R}{L} = 5000$$

$$\frac{1}{LC} = 4\times10^6$$

$$\boxed{\begin{array}{l} L = 5\times10^{-2}\ H \\ \Rightarrow C = 5\times10^{-6}\ F \\ \Rightarrow R = 250\ \Omega \end{array}}$$

11/59 a) In the first circuit:

This is an inverting amp

$\therefore T(s) = -\frac{Z_2}{Z_1}$

where $Z_2 = \frac{10^4 \times 10^7 s^{-1}}{10^4 + 10^7 s^{-1}} = \frac{10^7}{s + 10^3}$

$Z_1 = 10^4 + \frac{1}{25} \times 10^9 s^{-1} = 10^4 + 4 \times 10^7 s^{-1}$

$-\frac{Z_2}{Z_1} = T(s) = \frac{-10^3}{s + 10^3} \times \frac{1}{1 + 4000 s^{-1}}$

$= \frac{-1000 s}{(s+1000)(s+4000)}$

In the 2nd circuit, voltage division

$$V_2(s) = V_1(s) \frac{\frac{10^4 \times \frac{1}{5} \times 10^8 s^{-1}}{10^4 + \frac{1}{5} \times 10^8 s^{-1}}}{\frac{2 \cdot 10^7}{s + 2 \cdot 10^7} + 2 \cdot 10^4 + 4 \cdot 10^7 s^{-1}}$$

$$= V_1(s) \frac{\frac{10^3}{s + 2 \times 10^3}}{\frac{10^3}{s + 2 \cdot 10^3} + \frac{2000}{s} + 1}$$

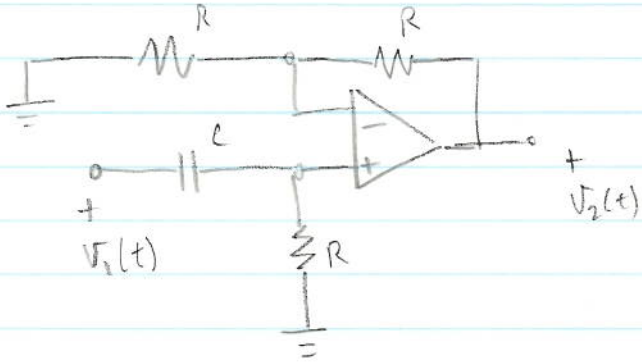
$$= V_1(s) \frac{10^3}{10^3 s + 2 \times 10^3 s + 4 \cdot 10^6 + s^2 + s(2 \times 10^3)}$$

$$= V_1(s) \frac{10^3}{s^2 + 5000 s + 4 \times 10^6} = \frac{1000}{(s+1000)(s+4000)}$$

part b and c: cct 1 is better for both cases. For load resistance ~ 1000 kOhms, the transfer function off cct 2 will alter.

part d: disagree. Cct 2 is analyzed assuming no current drawn from the load. If cct 2 is put in front of cct 1, a current will be drawn.

12/6



$$v_p(s) = v_1(s) \times \frac{R}{R + \frac{1}{sC}} = v_1(s) \times \frac{s}{s + \frac{1}{RC}}$$

$$v_2(s) = \frac{2R}{R} v_n(s)$$

$$= \frac{2s}{s + \frac{1}{RC}} v_1(s) \quad \boxed{\text{High-pass filter}}$$

pass band gain $\Leftrightarrow$ $s \to \infty$

$$\boxed{T(s) \to 2}$$

choose RC ST $f_c = 5 \text{ kHz}$

$\Leftrightarrow \omega_c = 10^4 \pi$

$$|T(j\omega_c)| = \frac{2\omega_c}{\sqrt{\omega_c^2 + \left(\frac{1}{RC}\right)^2}} \Rightarrow \omega_c = \frac{1}{RC}$$

$\therefore$ $RC = \pi^{-1} \times 10^{-4}$ Choose whatever values you like.

12-9,

$$T(s) = \frac{2}{10^{-2} + 20/s} = \frac{200\,s}{s + 2000} \Rightarrow T(jw) = \frac{200\,jw}{jw + 2000}$$

→ high pass filter $\Rightarrow |T(jw)| = \dfrac{200\,w}{\sqrt{w^2 + 4\times10^6}}$

→ pass band gain = 200

→ cut off frequency w_c occurs when $|T(jw_c)| = \dfrac{200}{\sqrt{2}}$

$$\Rightarrow \frac{w_c}{\sqrt{w_c^2 + 4\times10^6}} = \frac{1}{\sqrt{2}} \Rightarrow w_c = 2000 \text{ rad/s}$$

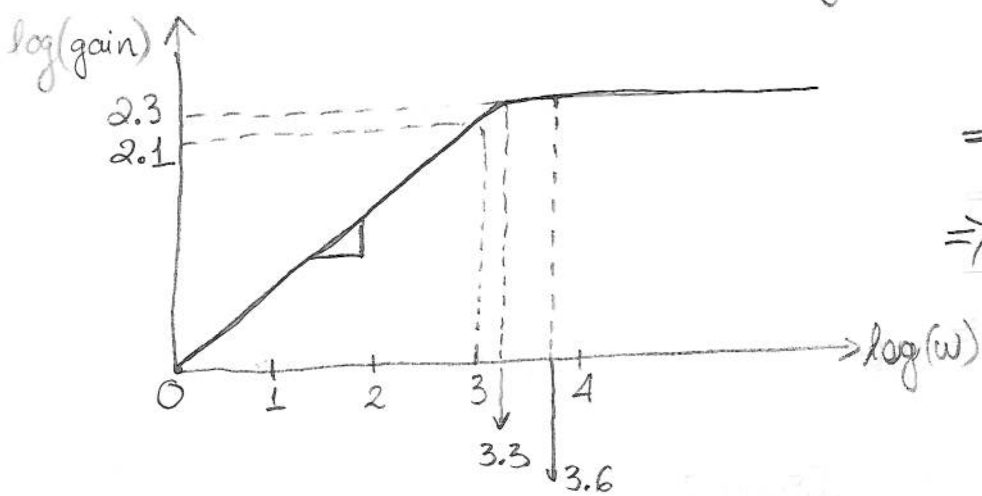
→ Bode-plot In log-log coordinate:

→ $w_c = 2000$ rad/s $\Rightarrow \log_{10}(w_c) = 3.3$

→ gain = 200 $\Rightarrow \log_{10}(\text{gain}) = 2.3$

→ $w = 0.5\,w_c = 1000$ rad/s $\Rightarrow \log_{10}(w) = 3$

→ $w = 2\,w_c = 4000$ rad/s $\Rightarrow \log_{10}(w) = 3.6$



$\Rightarrow$ slope $= 2.3/3.3 = 0.7$

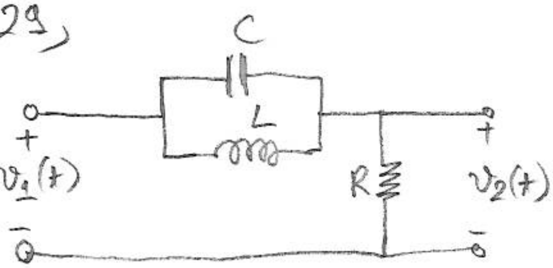
$\Rightarrow \log(\text{gain}) = 0.7 \times \log(w)$

→ for $w = 0.5 w_c$, $\log(\text{gain}) = 0.7 \times 3 = 2.1 \Rightarrow \text{gain} = 125.9$

→ for $w = w_c$, $\log(\text{gain}) = 2.3 \Rightarrow \text{gain} = 200$

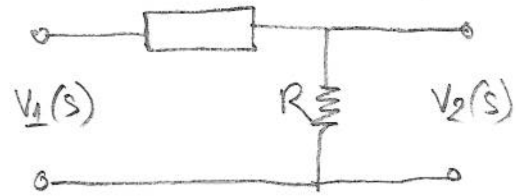
→ for $w = 2w_c$, $\log(\text{gain}) = 2.3 \Rightarrow \text{gain} = 200$

12-29)



$\xrightarrow{\mathcal{L}}$

$$\frac{(1/cs)(Ls)}{1/cs + Ls} = \frac{s/c}{s^2 + 1/LC}$$



$$\Rightarrow V_2(s) = \frac{R}{R + \frac{s/C}{s^2 + 1/LC}} V_1(s) \Rightarrow T(s) = \frac{s^2 + 1/LC}{s^2 + s/RC + 1/LC}$$

$$\Rightarrow T(jw) = \frac{-w^2 + 1/LC}{-w^2 + wj/RC + 1/LC} \Rightarrow |T(jw)| = \frac{1/LC - w^2}{\left[(1/LC - w^2)^2 + \left(\frac{w}{RC}\right)^2\right]^{1/2}}$$

$\Rightarrow$ as $w \to \frac{1}{\sqrt{LC}}$, $|T(jw)| \to 0 \Rightarrow$ bandstop filter

$\Rightarrow$ as $w \to 0$, $|T(jw)| \to 1$

$\Rightarrow$ as $w \to \infty$, $|T(jw)| \to 1$

$\Rightarrow$ gain $= 1$

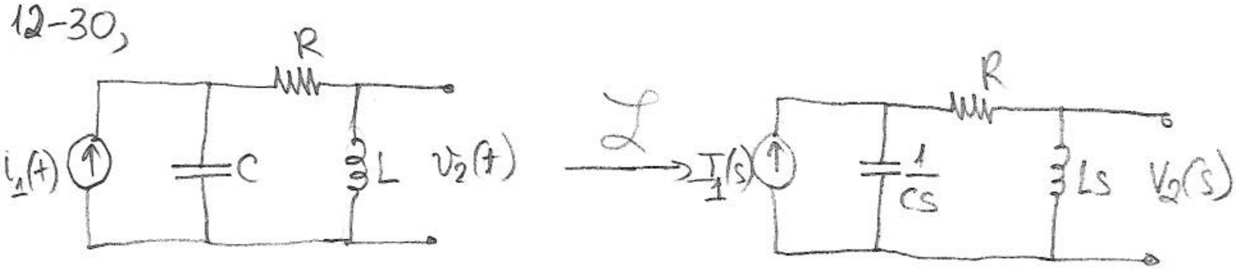
$\Rightarrow$ notch frequency $= 1/\sqrt{LC}$ rad/s

$\Rightarrow$ cutoff frequency w_c occurs when $|T(jw)| = \frac{1}{\sqrt{2}}$

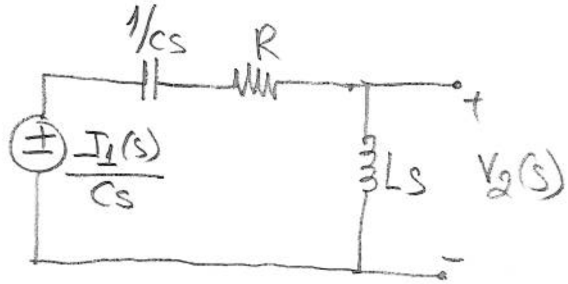
$$\Rightarrow \frac{1/LC - w_c^2}{\left[(1/LC - w_c^2)^2 + \left(\frac{w_c}{RC}\right)^2\right]^{1/2}} = \frac{1}{\sqrt{2}} \Rightarrow w_c^2 + \frac{w_c}{RC} - \frac{1}{LC} = 0$$

$$\Rightarrow \boxed{w_c = \frac{1}{2RC}\left[-1 \pm \sqrt{1 + 4 RC/L}\right]}$$

12-30,



$\Rightarrow$



$$\rightarrow V_2(s) = \frac{Ls}{1/Cs + R + Ls} \, \frac{I_1(s)}{Cs} = \frac{s/C}{s^2 + \frac{R}{L}s + \frac{1}{LC}} I_1(s)$$

$$\Rightarrow V_2(j\omega) = \frac{j\omega/C}{-\omega^2 + \frac{R}{L}\omega j + \frac{1}{LC}} I_1(j\omega)$$

$\rightarrow$ as $\omega \rightarrow 0$, $|V_2(j\omega)| \rightarrow 0$

$\rightarrow$ as $\omega \rightarrow \infty$, $|V_2(j\omega)| \rightarrow 0$

$\rightarrow$ when $\omega = 1/\sqrt{LC}$, $|V_2(j\omega)| = \frac{L}{CR} |I_1(j\omega)|$

$\Rightarrow$ this is a bandpass filter