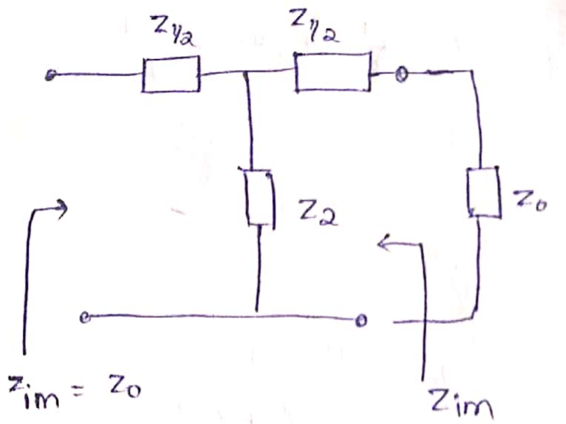
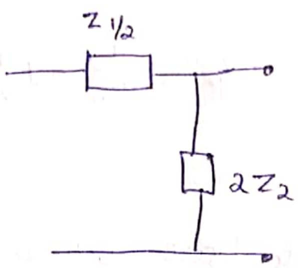
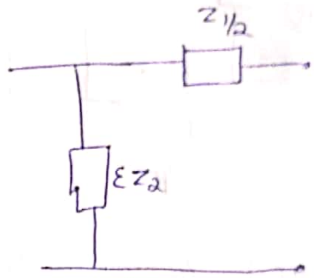
29-10-19

After Mid - 2

FILTER DESIGN







→ On cascading these two, we get a π type circuit

Now from the initial figure, we can write

$$\underbrace{Z_{in}}_{Z_0} = Z_{1/2} + Z_2 \,||\, [Z_0 + Z_{1/2}]$$

$$\therefore Z_{in} = \frac{Z_2[Z_0 + Z_{1/2}] + Z_{1/2}[Z_0 + Z_2 + Z_{1/2}]}{Z_0 + Z_2 + Z_{1/2}}$$

on solving keep $Z_{in} = Z_0$, we get $Z_0 = \sqrt{\frac{Z_1^2}{4} + Z_1 Z_2}$

Also, $$Z_{in}\Big|_{Z_2=\infty} = Z_{oc} = \frac{Z_1}{2} + Z_2$$

$$Z_{in}\Big|_{Z_2=0} = Z_{sc} = Z_{1/2} + [Z_{1/2} \,||\, Z_2]$$

$$Z_{oc} Z_{sc} = Z_0^2$$

$$= \frac{Z_1^2}{4} + Z_1 Z_2 \longrightarrow (1)$$

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Propogation constant (gamma)

$$\gamma = \ln\left[\frac{I_1}{I_2}\right]$$

here, I_1 = input current

I_2 = response current

γ = proportional cont

on applying KCL, we get

$$\frac{Z_1}{2} I_2 + Z_0 I_2 + (I_2 - I_1) Z_2 = 0$$

$$\underbrace{\frac{I_1}{I_2}}_{e^{\gamma}} = \frac{Z_1}{2Z_2} + \frac{Z_0}{Z_2} + 1$$

$$\Rightarrow Z_2 \cdot e^{\gamma} = \frac{Z_1}{2} + Z_2 + Z_0$$

$$Z_0^2 = \left[Z_2(e^{\gamma}-1) - \frac{Z_1}{2}\right]^2 \longrightarrow (2)$$

on solving (1) and (2), we get

$$0 = Z_2[e^{\gamma}-1]^2 - Z_1 e^{\gamma}$$

$$\cosh\gamma = 1 + \frac{Z_1}{2Z_2}$$

It can also be written as

$$\sinh\gamma = \sqrt{\cosh^2\gamma - 1}$$

$$\tanh\gamma = \frac{Z_0}{Z_2 + Z_1/2} = \frac{Z_0}{Z_{oc}}$$

$$\sinh\left(\frac{\gamma}{2}\right) = \sqrt{\frac{\cosh\gamma - 1}{2}}$$

$$\Rightarrow \sqrt{\frac{Z_1}{4Z_2}} = \sinh\left(\frac{\gamma}{2}\right)$$

In the side formula,

$\longrightarrow$ Z_1 and Z_2 are imaginary

if $\frac{Z_1}{4Z_2}$ = real

$\gamma = \alpha + j\beta$

So, $\sqrt{\frac{Z_1}{4Z_2}} = \sinh\left(\frac{\alpha}{2}\right)\cos\left(\frac{\beta}{2}\right) + j\sin\frac{\beta}{2}\cosh\frac{\alpha}{2}$

case-A

$\longrightarrow$ $Z_1 = jX_1$, $Z_2 = jX_2$

here, Z_1 and Z_2 are same type reactants

So, $\cosh\frac{\alpha}{2}\cdot\sin\frac{\beta}{2} = 0$

$\frac{\beta}{2} = 0, n\pi$

$\alpha = 2\sinh^{-1}\sqrt{\frac{Z_1}{4Z_2}}$ $\left\{\because \sinh\left(\frac{\alpha}{2}\right) = \sqrt{\frac{Z_1}{4Z_2}}\right\}$

where, $\left|\frac{Z_1}{4Z_2}\right| > 0$

case-B

$\longrightarrow$ $Z_1 = jX_1$, $Z_2 = -jX_2$

i) $\alpha = 0$

here, Z_1 and Z_2 are of diff type reactants

So, $\sinh\frac{\alpha}{2}\cos\frac{\beta}{2} = 0$

$\sin\frac{\beta}{2} = \sqrt{\frac{Z_1}{4Z_2}}$

$\beta = 2\sin^{-1}\sqrt{\frac{Z_1}{4Z_2}}$

where $-1 < \frac{Z_1}{4Z_2} < 0$

ii) $\beta = \pi$, $\cosh\frac{\alpha}{2} = \sqrt{\frac{Z_1}{4Z_2}}$

$\alpha = 2\cosh^{-1}\sqrt{\frac{Z_1}{4Z_2}}$ where $-\infty < \frac{Z_1}{4Z_2} < -1$

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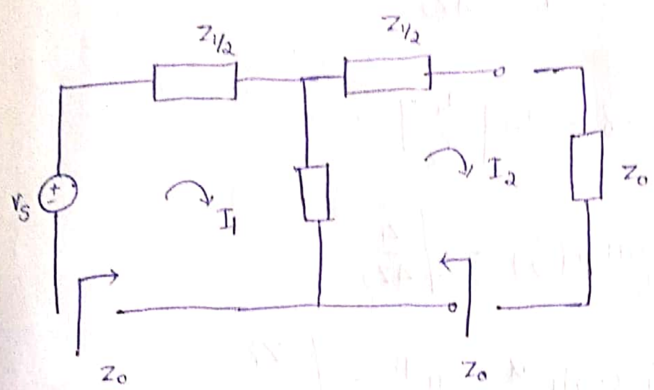
* These filter designs are mostly prepared by these reactive elements



T type model

Also, $\gamma = \ln\left[\frac{I_1}{I_2}\right]$

WKT, $Z_0 = \sqrt{\frac{Z_1^2}{4} + Z_1 Z_2}$

$= \sqrt{Z_1 Z_2}\sqrt{1 + \frac{Z_1}{4Z_2}}$

$= \sqrt{Z_1 Z_2\left[1 + \frac{Z_1}{4Z_2}\right]}$

$\Rightarrow \sinh\left(\frac{\gamma}{2}\right) = \sqrt{\frac{Z_1}{4Z_2}}$

$\downarrow$

$\alpha + j\beta$

So, $\sinh\frac{\alpha}{2}\cos\frac{\beta}{2} + j\cosh\frac{\alpha}{2}\sin\frac{\beta}{2} = \sqrt{\frac{Z_1}{4Z_2}}$

$Z_1 = jX_1$, $Z_2 = jX_2$

case (A)

$\frac{Z_1}{4Z_2} = \frac{X_1}{4X_2} > 0$

at $\beta = 0$

$\sinh\frac{\alpha}{2} = \sqrt{\frac{Z_1}{4Z_2}}$

$\alpha = 2\sinh^{-1}\sqrt{\frac{Z_1}{4Z_2}}$

case (B)

$Z_1 = jX_1$, $Z_2 = -jX_2$

$\frac{Z_1}{4Z_2} = \frac{jX_1}{-4jX_2} = -\frac{X_1}{4X_2}$

1) $\alpha = 0$

$\sin\frac{\beta}{2} = \sqrt{\frac{Z_1}{4Z_2}}$

$\beta = 2\sin^{-1}\sqrt{\frac{Z_1}{4Z_2}}$

$-1 < \frac{Z_1}{4Z_2} < 0$

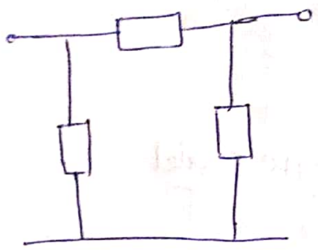
2) $\beta = \pi$

$\cosh\frac{\alpha}{2} = \sqrt{\frac{Z_1}{4Z_2}}$

$\alpha = 2\cosh^{-1}\sqrt{\frac{Z_1}{4Z_2}}$

$-\infty < \frac{Z_1}{4Z_2} < -1$

For π type



$$Z_0 = \frac{\sqrt{Z_1 Z_2}}{\sqrt{1 + \frac{Z_1}{4Z_2}}}$$

$$\gamma = \ln\left[\frac{I_1}{I_2}\right]$$

$$\Rightarrow \sinh\left(\frac{\gamma}{2}\right) = \sqrt{\frac{Z_1}{4Z_2}}$$

$$\sinh\frac{\alpha}{2}\cos\frac{\beta}{2} + j\cosh\frac{\alpha}{2}\cdot\sin\frac{\beta}{2} = \sqrt{\frac{Z_1}{4Z_2}}$$

Remaining all are just same like T type..

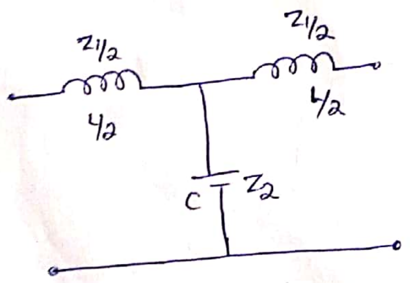
K-type Filters

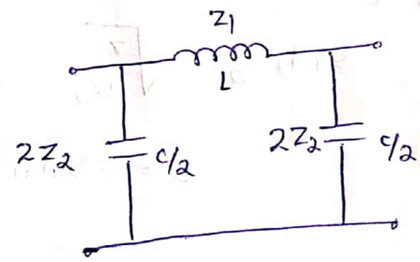
* It is product of impedences

$$Z_1 = j\omega L \quad , \quad Z_2 = \frac{1}{j\omega C}$$

$$Z_1 Z_2 = \frac{L}{C} = K^2$$

$$K = \sqrt{\frac{L}{C}} \ \Omega$$





$$\frac{Z_1}{4Z_2} = 0 \quad , \quad \omega = 0$$

$$Z_1 = -4Z_2$$

$$j\omega_c L = \frac{-4}{j\omega_c C}$$

$$\Rightarrow \omega_c^2 LC = 4 \Rightarrow f_c = \frac{1}{\pi\sqrt{LC}}$$

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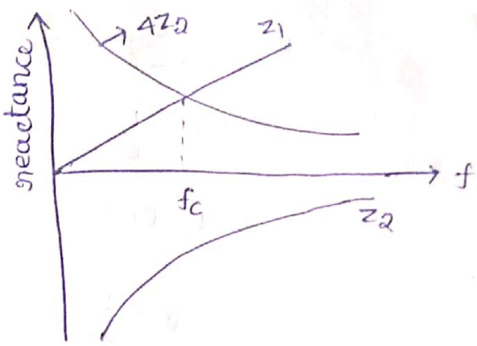
The graph can be drawn as



Now,

$$\frac{Z_1}{4Z_2} = \frac{-\omega^2 LC}{4} = \frac{-4\pi^2 f^2 LC}{4} = \frac{-f^2}{f_c^2}$$

So, $-1 \le \frac{-f^2}{f_c^2} \le 0 \rightarrow \alpha = 0 ;\ \beta = 2\sin^{-1}\left[\frac{f}{f_c}\right]$

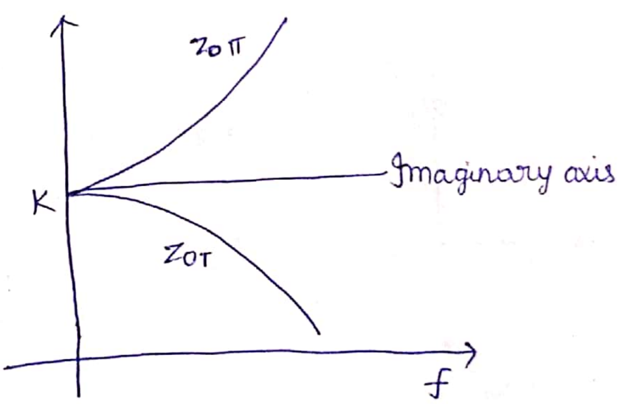
$-\infty < \frac{-f^2}{f_c^2} < -1 \quad \boxed{\frac{f}{f_c} > 1} \rightarrow \beta = \pi ;\ \alpha = 2\cosh^{-1}\left[\frac{f}{f_c}\right]$

~~$Z_1 = -4Z_2 \Rightarrow j\omega_c L = \frac{-4}{j\omega_c C} \Rightarrow \omega_c^2 LC = 4$~~

not there ~~$\Rightarrow f_c = \frac{1}{\pi\sqrt{LC}}$~~

$$Z_{0T} = \sqrt{Z_1 Z_2\left[1 + \frac{Z_1}{4Z_2}\right]} = K\sqrt{\left[1 - \left(\frac{f}{f_c}\right)^2\right]}$$

$$Z_{0\pi} = \frac{\sqrt{Z_1 Z_2}}{\sqrt{1 + \frac{Z_1}{4Z_2}}} = \frac{K}{\sqrt{1 - \left(\frac{f}{f_c}\right)^2}}$$



$$f_c^2 = \frac{1}{\pi^2 L C}$$

$$K = \sqrt{\frac{L}{C}}$$

$$f_c^2 = \frac{1}{\pi^2 K^2 C^2}$$

$$K^2 = \frac{L}{C}$$

$$L = CK^2$$

$$C = \frac{1}{\pi f_c K}$$

$$C = \frac{L}{K^2}$$

$$L = \frac{K}{\pi f_c}$$

$$f_c^2 = \frac{K^2}{\pi^2 L^2}$$

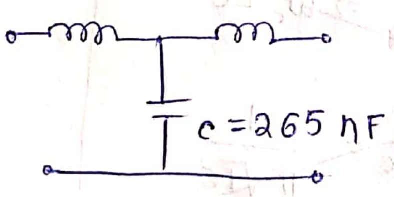
→ Using the given information build a high and low pass filters.

$$f_c = 2\,Khz$$

$$R_0 = K = 600\,\Omega$$

on solving $L = 95.4\ mH$

$$L/2 = 47.7\ mH$$



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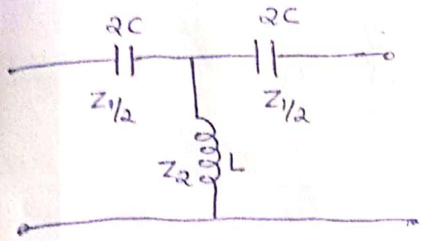
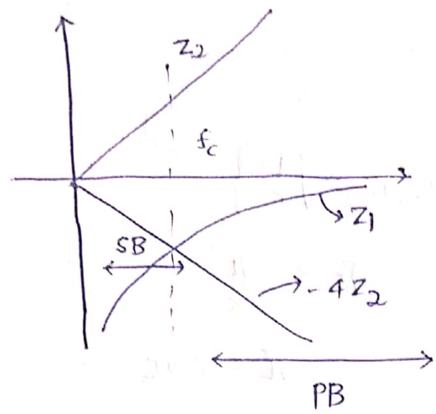


$$-1 < \frac{Z_1}{4Z_2} < 0$$

$$Z_1 = 0 \qquad \frac{1}{j\omega C} = 0$$

$$Z_1 = -4Z_2 \Rightarrow \frac{1}{j\omega C} = -4j\omega L$$

$$4\omega^2 = \frac{1}{LC} \Rightarrow f_c = \frac{1}{4\pi\sqrt{LC}}$$



$$Z_1 = \frac{1}{j\omega C} = \frac{-j}{\omega C}$$

$$Z_2 = j\omega L$$

WKT, $$Z_0 = \sqrt{Z_1 Z_2\left[1 + \frac{Z_1}{4Z_2}\right]}$$

$$\sinh(\gamma/2) = \sqrt{\frac{Z_1}{4Z_2}}$$

$$\sinh(\beta/2) = j\frac{f_c}{f}$$

$$\frac{Z_1}{4Z_2} = \frac{1}{j\omega C \cdot 4j\omega L} = \frac{-1}{4\omega^2 LC}$$

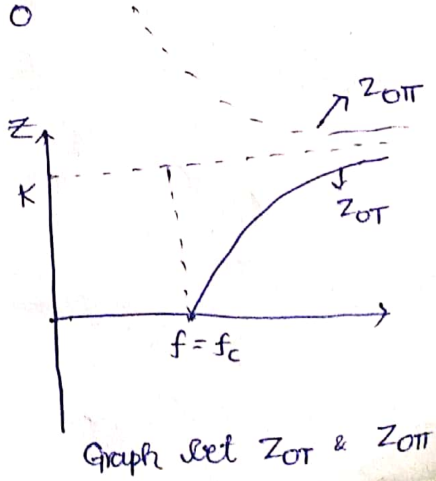
$$\frac{Z_1}{4Z_2} = \frac{-f_c^2}{f^2}$$

$$SB \Rightarrow \alpha = 2\cosh^{-1}\left[\frac{f_c}{f}\right], \quad \beta = \pi$$

$$PB \Rightarrow \beta = 2\sin^{-1}\left[\frac{f_c}{f}\right], \quad \alpha = 0$$

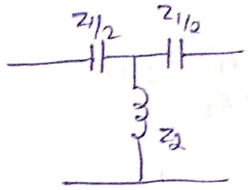
$$Z_{0T} = K\sqrt{1 + \frac{Z_1}{4Z_2}} = K\sqrt{1 - \left(\frac{f_c}{f}\right)^2}$$

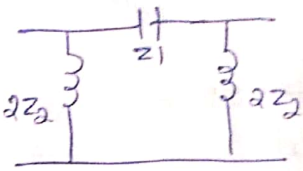
$$Z_{0\pi} = \frac{K}{\sqrt{1 + \frac{Z_1}{4Z_2}}} = \frac{K}{\sqrt{1 - \left(\frac{f_c}{f}\right)^2}}$$



Graph bet Z_{0T} & $Z_{0\pi}$

Ex:





$K = 600\,\Omega$

$f_c = 1\,kHz$

Ans Now, $f_c = \dfrac{1}{4\pi\sqrt{LC}}$

$$f_c = \frac{K}{4\pi L} \qquad \left\{ \because K = \sqrt{\frac{L}{C}} \right\}$$

$$\sqrt{C} = \frac{\sqrt{L}}{K}$$

$$\sqrt{L} = K\sqrt{C}$$

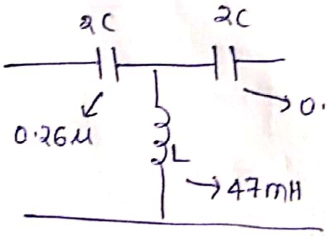
$$L = \frac{K}{4\pi f_c}$$

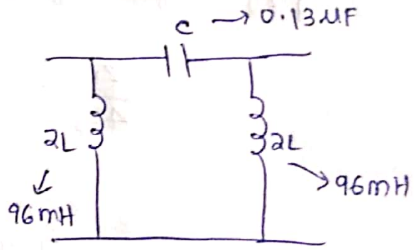
also, $f_c = \dfrac{1}{4\pi K C}$

$$C = \frac{1}{4\pi K f_c}$$

on solving we get $L = 47\,mH$

$C = 0.13\,\mu F$





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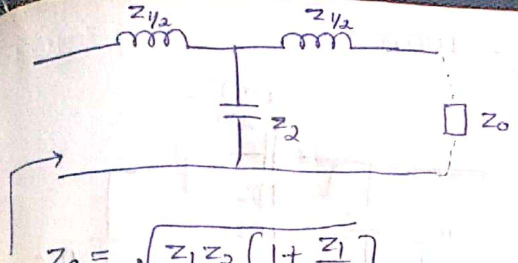
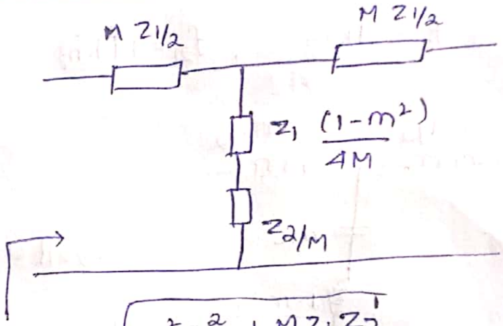




$$Z_0 = \sqrt{Z_1 Z_2 \left[1 + \frac{Z_1}{4Z_2}\right]}$$

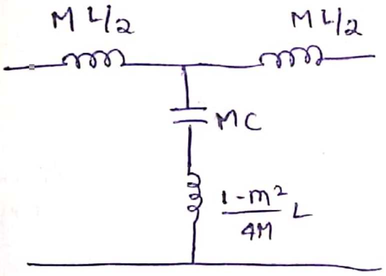
$$= \sqrt{\frac{Z_1^2}{4} + Z_1 Z_2}$$

$$Z_0 = \sqrt{\frac{M^2 Z_1^2}{4} + M Z_1 Z_2'}$$

$$Z_1^2 + Z_1 Z_2 = \frac{M^2 Z_1^2}{4} + M Z_1 Z_2'$$

here $Z_2' = \frac{Z_1}{4M}(1-M^2) + \frac{Z_2}{M}$

$\boxed{\text{Low pass filter}}$



$$\frac{1}{M\omega_r C} = \frac{1-M^2}{4M}\omega_r L$$

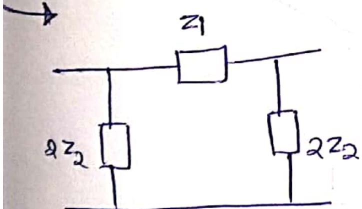
$$\omega_r^2 = \frac{4}{(1-M^2)LC}$$

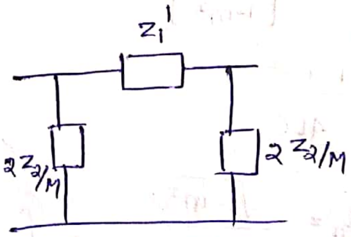
$$f_r = \frac{f_c}{\sqrt{1-M^2}}$$

$$f_r = \frac{1}{\pi\sqrt{LC(1-m^2)}}$$

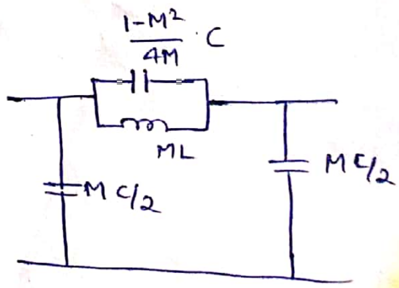
$$\boxed{\therefore M = \sqrt{1-\left(\frac{f_c}{f_r}\right)^2}}$$

here f_r = attenuation





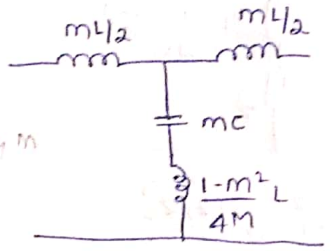
$$Z_1' = \frac{M Z_1 Z_2\left[\frac{4M}{1-M^2}\right]}{M Z_1 + Z_2\left[\frac{4M}{1-M^2}\right]}$$



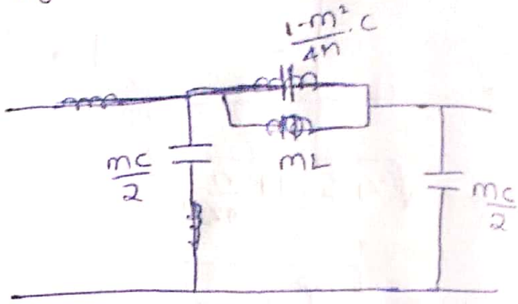
Ex: $f_c = 1\,kHz$, $f_r = 1.1\,kHz$, $R_0 = 400\,\Omega$

$\frac{L}{2}$

multiply m



vulta



We can use the same formulas to find L and C

$$L = \frac{K}{\pi f_c} \quad , \quad C = \frac{1}{\pi f_c K} \qquad \{\text{take } K = R_0\}$$

We get $L = 127\,mH$

$C = 0.79\,\mu F$

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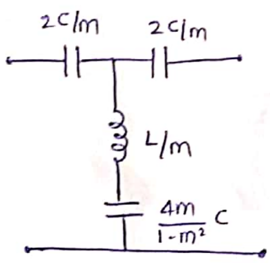
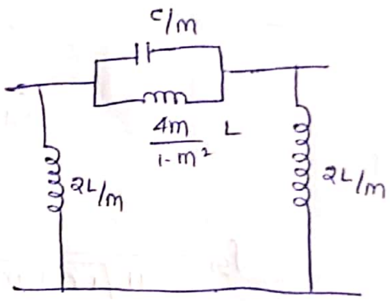
$\boxed{\text{High pass filter}}$

2C

divide m





$$W_r \frac{L}{M} = \frac{1}{w_r C\left[\frac{4m}{1-m^2}\right]}$$

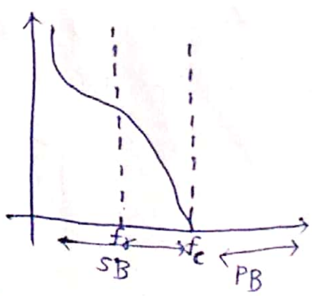
$$w_r^2 = \frac{1-m^2}{4LC}$$

$$\Rightarrow f_r = \frac{\sqrt{1-m^2}}{4\pi\sqrt{LC}} \quad , \quad f_c = \frac{1}{4\pi\sqrt{LC}}$$

$$f_r = f_c\sqrt{1-m^2}$$

$$\boxed{\therefore M = \sqrt{1-\left(\frac{f_r}{f_c}\right)^2}}$$

$$f_r < f_c$$



Ex: Given $f_c = 10\,Khz$

$R_0 = 5\,\Omega$

$M = 0.4$

Ans

$$L = \frac{K}{4\pi f_c} \quad , \quad C = \frac{1}{4\pi f_c K}$$

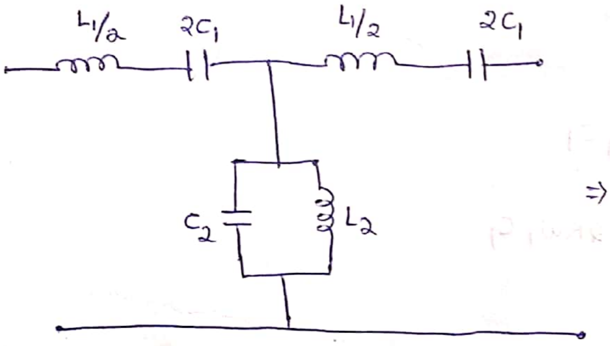
$$= \frac{5}{4\pi(10K)}$$

$L = 39.8\,\mu H$ and $C = 1.59\,\mu F$

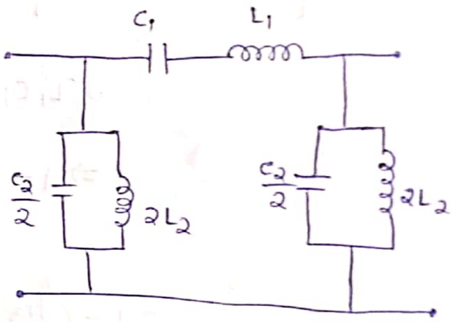
Now substitute these values in $\frac{2C}{m}$, $\frac{L}{m}$ and $\frac{4m}{1-m^2} \cdot C$

Resonance of Series = Resonance of parallel

$\boxed{\text{Band Pass filter}}$



$\Rightarrow$



$$Z_1 = \left[j\omega L_1 - \frac{j}{\omega C_1} \right] = j \left[\frac{\omega^2 L_1 C_1 - 1}{\omega C_1} \right]$$

$$Z_2 = \frac{j\omega L_2 \cdot \frac{1}{j\omega C_2}}{j\omega L_2 + \frac{1}{j\omega C_2}} = \frac{j\omega L_2}{1 - \omega^2 L_2 C_2}$$

$$Z_1 Z_2 = \frac{L_2}{C_1} = \frac{L_1}{C_2} = K^2$$

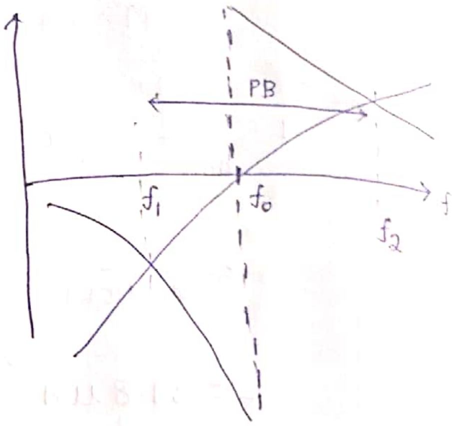
$$\omega_0 \frac{L_1}{2} = \frac{1}{2\omega_0 C_1}$$

$$\omega_0^2 = \frac{1}{L_1 C_1}$$

$$\omega_0^2 = \frac{1}{L_2 C_2}$$

$$L_1 C_1 = L_2 C_2 \Rightarrow \frac{L_1}{C_2} = \frac{L_2}{C_1}$$

$$-1 < \frac{Z_1}{4Z_2} < 0$$



$$Z_1 = 0 \longrightarrow \omega^2 = \frac{1}{L_1 L_2}$$

$$Z_1 = \pm j2K$$

$$\hookrightarrow z_1^2 = 4Z_1 Z_2 = -4K^2$$

$$Z_1 \omega_1 = -Z_1 \omega_2$$

$$\Rightarrow \omega_0 = \sqrt{\omega_1 \omega_2}$$

$$\Rightarrow f_0 = \sqrt{f_1 f_2}$$

$$\left[\frac{1}{j\omega_1 C_1} + j\omega_1 L_1\right] = -2jK$$

$$1 - \omega_1^2 L_1 C_1 = 2K\omega_1 C_1$$

$$\Rightarrow 1 - \frac{\omega_1^2}{\omega_0^2} = 2K\omega_1 C_1$$

$$1 - \left(\frac{f_1}{f_0}\right)^2 = 2K\omega_1 C_1$$

$$C_1 = \frac{f_2 - f_1}{4K\pi f_1 f_2}$$

$$L_1 = \frac{1}{\omega_0^2 C_1}$$

$$= \frac{4\pi K f_1 f_2}{\omega_0^2 (f_2 - f_1)} \Rightarrow L_1 = \frac{K}{\pi(f_2 - f_1)}$$

$$L_2 = C_1 K^2 = \frac{(f_2 - f_1)K}{4\pi f_1 f_2}$$

$$C_2 = \frac{L_1}{K^2} = \frac{1}{\pi(f_2 - f_1)K}$$

$$\left\{ \because \begin{array}{l} \omega_0 = 2\pi f_0 \\ f_0 = f_1 f_2 \end{array} \right\}$$

Ex: $K = 500\Omega$

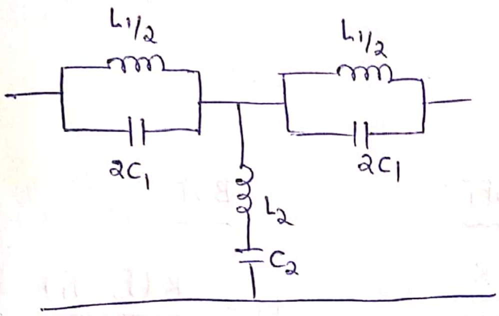
$f_1 = 1KHz$, $f_2 = 10KHz$

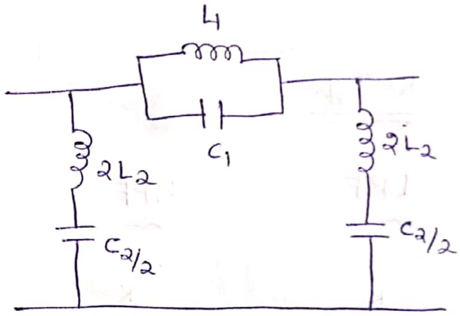
on solving we get

$C_1 = 143nF$ $\quad$ $C_2 = 69.6\ nF$

$L_1 = 17.4mH$ $\quad$ $L_2 = 35.7\ mH$

$\boxed{\text{Band Stop filter}}$



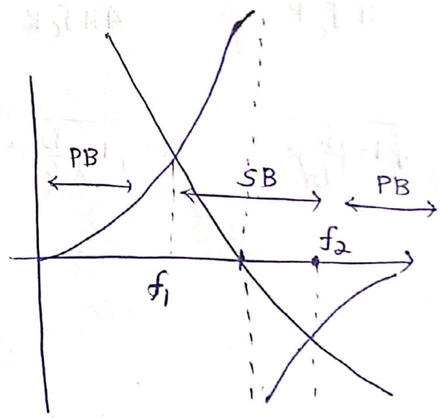


$$-1 < \frac{Z_1}{4Z_2} < 0$$

$$Z_1 Z_2 = K^2$$

$$L_1 C_1 = L_2 C_2$$

$$Z_1 Z_2 = \frac{L_1}{C_2} = \frac{L_2}{C_1} = K^2$$



$$Z_2 - j\left[\frac{1}{w_1 C_2} - w_1 L_2\right] = j\frac{K}{2}$$

$$Z_2 Z_1 = -4Z_2^2 = K^2$$

$$Z_2 = \pm j\frac{K}{2}$$

{∵ Series is more easier than parallel to solve. So we considered Z_2 other than Z_1 }

$$C_2 = \frac{1}{K\pi}\left[\frac{f_2 - f_1}{f_1 f_2}\right]$$

$$L_2 = \frac{1}{w_0^2 C_2} = \frac{K}{4\pi(f_2 - f_1)}$$

$$L_1 = C_2 K^2$$

$$= \frac{K}{\pi}\left[\frac{f_2 - f_1}{f_1 f_2}\right]$$

$$C_1 = \frac{L_2}{K^2}$$

$$= \frac{1}{4\pi K(f_2 - f_1)}$$

Scanned by CamScanner

Ex : $K = 600\Omega$

$f_1 = 2Khz$, $f_2 = 6khz$

on calculating we get $C_2 = 0.17\mu F$

$L_2 = 11.93 \, mH$

$L_1 = 63.66 \, mF$

$C_1 = \cancel{0.33 \mu F}$

$= 33nF$

K- Type

LPF	HPF	BPF	BSF
$L = \dfrac{K}{\pi f_c}$	$L = \dfrac{K}{4\pi f_c}$	$L_1 = \dfrac{K}{\pi (f_2 - f_1)}$	$L_1 = \dfrac{K(f_2 - f_1)}{\pi f_1 f_2}$
$C = \dfrac{1}{\pi f_c K}$	$C = \dfrac{1}{4\pi f_c K}$	$C_2 = \dfrac{1}{\pi K (f_2 - f_1)}$	$C_1 = \dfrac{1}{4\pi K (f_2 - f_1)}$
$M = \sqrt{1 - \left(\dfrac{f_c}{f_\infty}\right)^2}$	$M = \sqrt{1 - \left(\dfrac{f_\infty}{f_c}\right)^2}$	$L_2 = \dfrac{K(f_2 - f_1)}{4\pi f_1 f_2}$	$L_2 = \dfrac{K}{4\pi (f_2 - f_1)}$
		$C_1 = \dfrac{(f_2 - f_1)}{4\pi K f_1 f_2}$	$C_2 = \dfrac{1}{\pi K} \dfrac{(f_2 - f_1)}{f_1 f_2}$

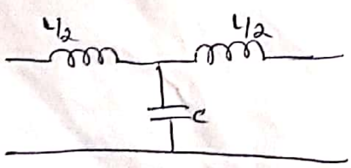
Ex : For an LPF, having $f_c = 2khz$, $R_0 = K = 600\Omega$ Find L, α

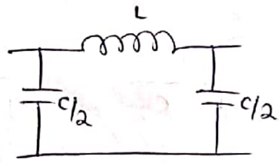
$$L = \frac{K}{\pi f_c} = 95.49 \, mH.$$

$$\alpha = 2 \cosh^{-1} \left(\frac{f}{f_c} \right)$$

$$= 3.143$$

Ex :





For an HPF , $f_c = 10 \, khz$, $K = 600\Omega$

find α at $f = 8khz$.

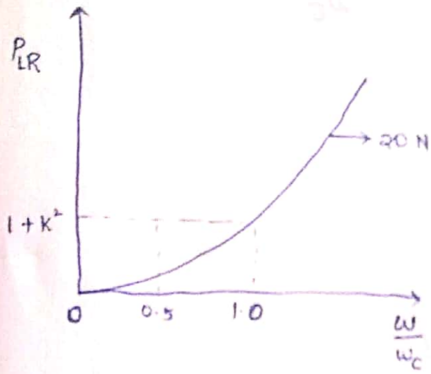
$L = 4.7mH$

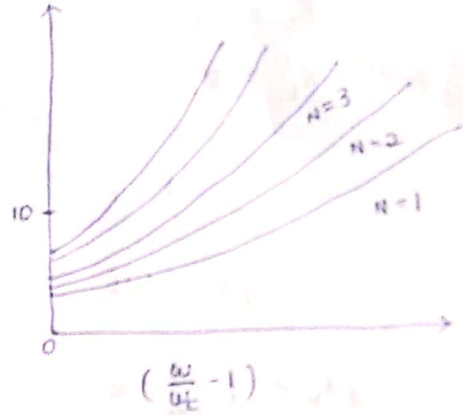
$C = 13.2 \, nF$

$\alpha = 1.38$

12-11-19

Power loss Ratio, $P_{LR} = 1 + K^2\left(\frac{W}{W_c}\right)^{2N}$





Equal Ripple [Chebbyshev]

$$P_{LR} = 1 + K^2 T_N^{2N}\left(\frac{W}{W_c}\right)$$

$$-1 \leq T_N(x) \leq 1$$

$$P_{LR} = \frac{K^2}{4}\left(\frac{2\omega}{\omega_c}\right)^{2N}$$

$$T_N(x) = \frac{1}{2}(2x)^N \qquad \omega >> \omega_c$$

Ex: Take $f_c = 2\ GHz$

$Z_0 = 50\,\Omega$

15 dB @ 3 GHz

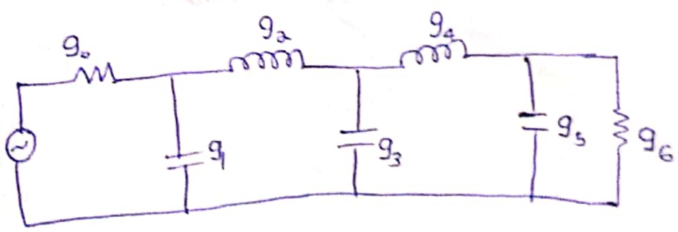
$\longrightarrow N = 5$

Also. $g_1 = 0.618$ $\quad g_4 = 1.618$

$g_2 = 1.618$ $\quad g_5 = 0.618$

$g_3 = 2.000$

Ans from the information given



Important substitutions are

$L' = R_0 L$ $\Rightarrow R_0 = 50\Omega$

$c' = \frac{c}{R_0}$

$w \leftarrow \frac{w}{w_c}$

$R_s' = R_0$

$R_L' = R_0 R_L$

<u>freq Scaling</u>

$jx = jwL$

$jX_K = j \frac{w}{w_c} L_K$

$= jw$

$jB_X = j \frac{w}{w_c} C_K = jwC_K'$ where $C_K' = \frac{C_K}{w_c}$

$$L_K' = \frac{R_0 L_K}{w_c}$$

$$C_K' = \frac{C_K}{R_0 w_c}$$

Now, $g_1 = C_1 \Rightarrow C_1' = \frac{C_1}{2\pi(50)(2\times10^9)} = \frac{0.618}{50\times2\times10^9}$

$g_2 = L_2 \Rightarrow L_2' = \frac{50\times1.618}{2\pi(2\times10^9)}$

$g_3 = C_3 \Rightarrow C_3' = \frac{C_3}{50(2\pi)(2\times10^9)}$

$g_4 = L_4 \Rightarrow L_4' = \frac{50\times1.618}{2\pi(2\times10^9)}$

$g_5 = C_5 \Rightarrow C_5' = \frac{0.618}{2\pi(50)(2\times10^9)}$

Now, $\omega \leftarrow \cancel{\frac{\omega}{\omega_c}} - \frac{\omega_c}{\omega}$

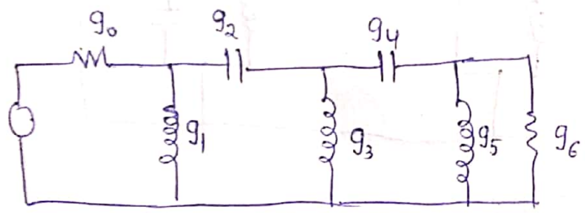
$$jX = j\omega L = -j\frac{\omega_c}{\omega} L = \frac{1}{j\omega C'}$$

$$C' = \frac{1}{\omega_c L R_0}$$

$$jB = j\omega C = -j\frac{\omega_c}{\omega} C = \frac{1}{j\omega L'}$$

$$L' = \frac{R_0}{\omega_0 C}$$

The circuit can be drawn as



$$L_1' = \frac{50}{2\pi(2\times10^9)(0.618)}$$

$$C_2' = \frac{1}{50(1.618)(2\pi\times10^9)}$$

$$L_3' = \frac{50}{2\pi\times2\times10^9\times2}$$

$C_4' =$

$L_5' =$

$$\Delta = \frac{\omega_2-\omega_1}{\omega_0} \qquad \omega_0 = \sqrt{\omega_1\omega_2}$$

$$\omega \leftarrow \frac{\omega_0}{(\omega_2-\omega_1)}\left[\frac{\omega}{\omega_0} - \frac{\omega_0}{\omega}\right] = \frac{1}{\Delta}\left[\frac{\omega}{\omega_0} - \frac{\omega_0}{\omega}\right]$$

$$jx = j\omega L = j\frac{1}{\Delta}\left[\frac{\omega}{\omega_0} - \frac{\omega_0}{\omega}\right] L_K = j\frac{\omega L_K}{\Delta\omega_0} - j\frac{\omega_0 L_K}{\Delta\omega}$$

$$= j\omega L_K' + \frac{1}{j\omega C_K'}$$

$$\boxed{L_K' = \frac{L_K R_0}{\Delta\omega_0} \qquad C_K' = \frac{\Delta}{\omega_0 L_K R}}$$

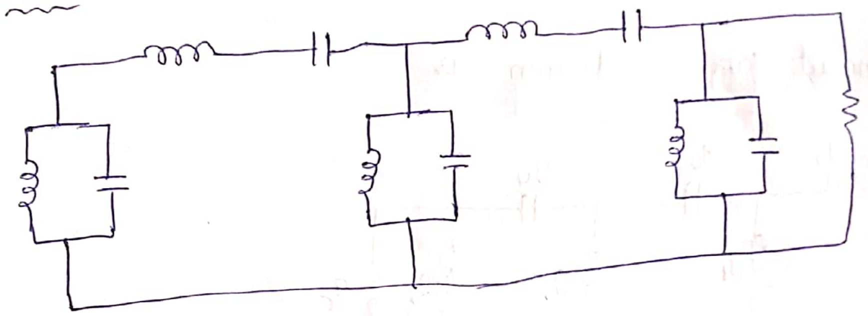
$$jB = j\omega c = j\frac{1}{\Delta}\left[\frac{\omega}{\omega_0} - \frac{\omega_0}{\omega}\right] c = \frac{j\omega C_K}{\Delta\omega_0} - j\frac{\omega_0 C_K}{\Delta\omega}$$

$$= j\omega C_K' - j\frac{1}{\omega L_K'}$$

$$\Rightarrow \quad C_K' = \frac{C_K}{\omega_0 R_0 \Delta}$$

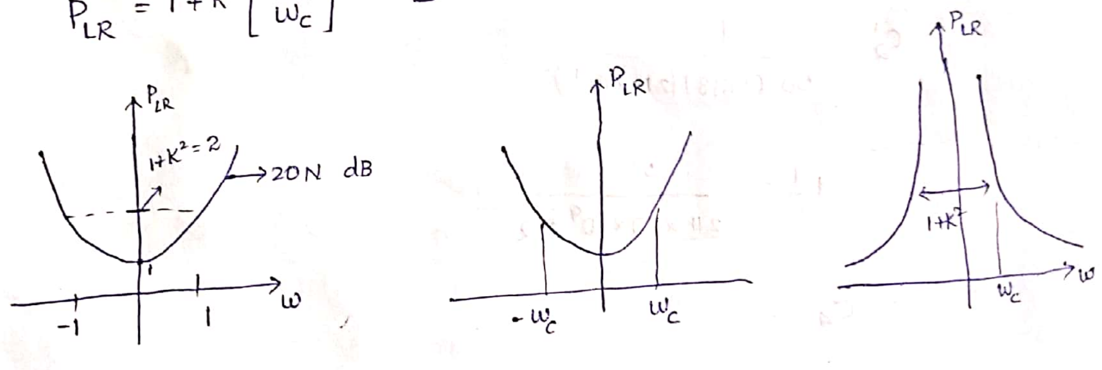
$$L_K' = \frac{\Delta R_0}{\omega_0 C_K}$$

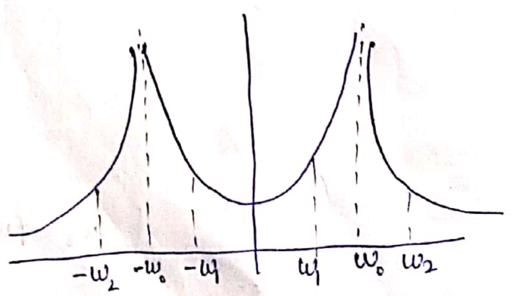
circuit



13-11-19

$$P_{LR} = 1 + K^2\left[\frac{\omega}{\omega_c}\right]^{2N} \rightarrow IL = 10 \log P_{LR}$$





$$\omega \leftarrow \Delta\left[\frac{\omega}{\omega_0} - \frac{\omega_0}{\omega}\right]^{-1}$$

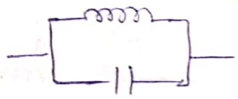
BSF:

$$jX = j\omega L = \frac{j\Delta L}{\left[\frac{\omega}{\omega_0} - \frac{\omega_0}{\omega}\right]}$$

$$\omega \leftarrow \Delta\left[\frac{\omega}{\omega_0} - \frac{\omega_0}{\omega}\right]^{-1}$$

$$\Rightarrow jB = j\omega\left[\frac{1}{\Delta L\omega_0}\right] + \frac{1}{j\omega\left(\frac{\Delta L}{\omega_0}\right)} \Rightarrow$$

$L' = \frac{\Delta L R_0}{\omega_0}$

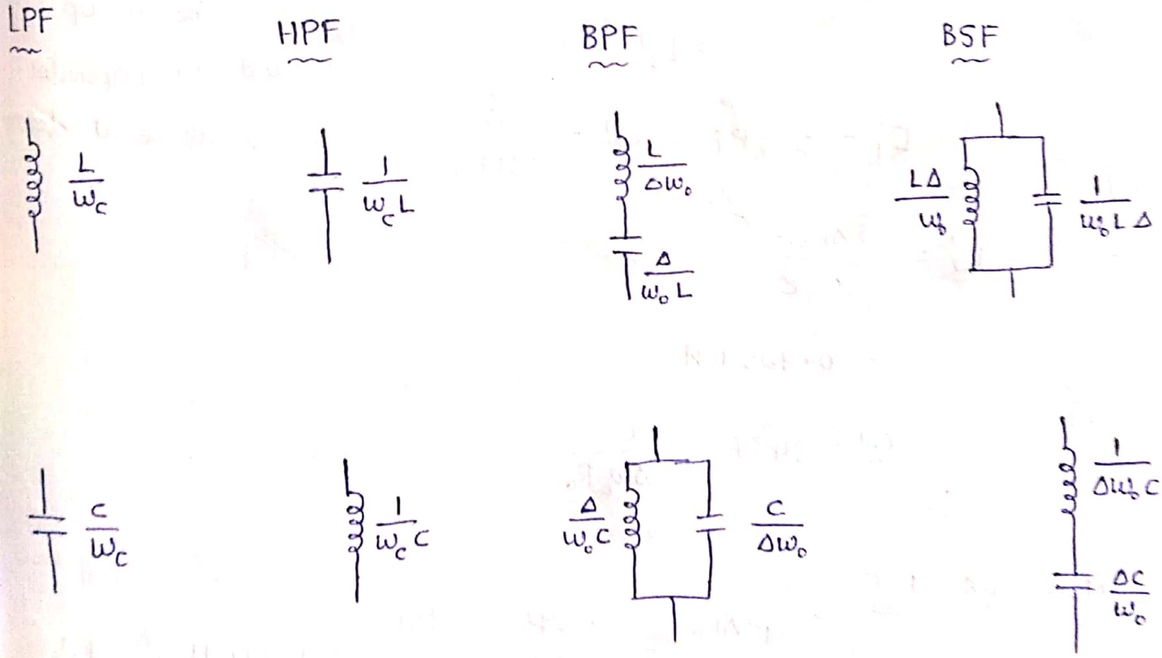


$\frac{1}{\Delta L \omega_0 R_0}$

$$jB = j\omega C = \frac{j\Delta C}{\left[\frac{\omega}{\omega_0} - \frac{\omega_0}{\omega}\right]} \Rightarrow jX = \frac{j\omega}{\omega_0 \Delta C} + \frac{1}{j\omega\left(\frac{\Delta C}{\omega_0}\right)}$$

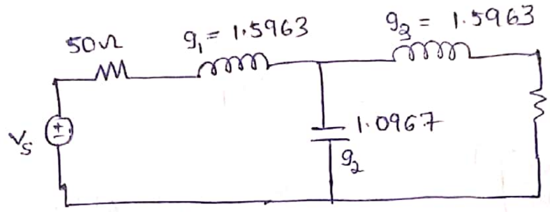
where $L = \frac{R_0}{\omega_0 \Delta C}$

$C = \frac{\Delta C}{\omega_0 R_0}$

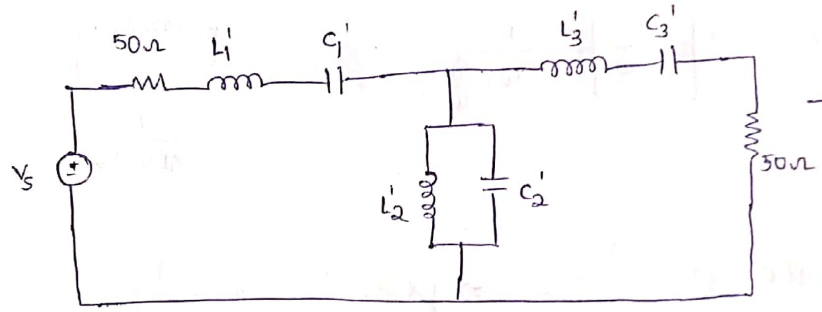


Ex: $R_o = 50\Omega$ 1 Ghz   } Giga $= 10^9$

$N = 3$ $\Delta = 10\%$



AM



Here $\omega_o = 2\pi f_o$

$= 2\pi (1 Ghz)$

This is BPF. so $L' = \dfrac{LR_o}{\Delta\omega_o}$

$= 0.127 \mu H$

$= L_3'$

{ for inductor R_o will be at up. and for capacitor R_o will be at down }

$C_1' = 0.2 PF = C_3' = \dfrac{\Delta}{\omega_o L R_o}$

$L_2' = \dfrac{\Delta R_o}{\omega_o C}$

$= 0.725 nH$

$C_2' = 34 PF = \dfrac{C}{\Delta\omega_o R_o}$

Now for BSF

$L_1' = \dfrac{L\Delta R_o}{\omega_o} = \dfrac{1.5963 (0.1) 50}{2\pi (10^9)} = 1.27 nH = L_3'$

$C_1' = \dfrac{1}{\Delta\omega_o L R_o} = 19.9 PF = C_3'$

$L_2' = 72.5 nH = \dfrac{R_o}{\Delta\omega_o C}$

$C_2' = 3.45 PF = \dfrac{C\Delta}{\omega_o R_o}$

14-11-19

Re-discussion of class

→ maximally flat (or) Butterworth

→ Equal ripple (or) chebbyshev

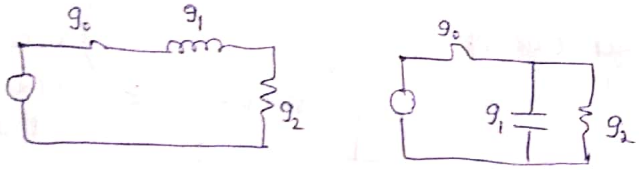
If $N = 1$

then we will have $N+1$ elements

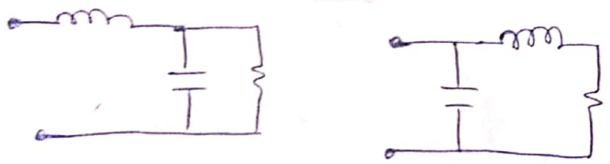
And the $(N+1)$th element will be load resistance.

If $N=1$ and he gave g_1 and g_2

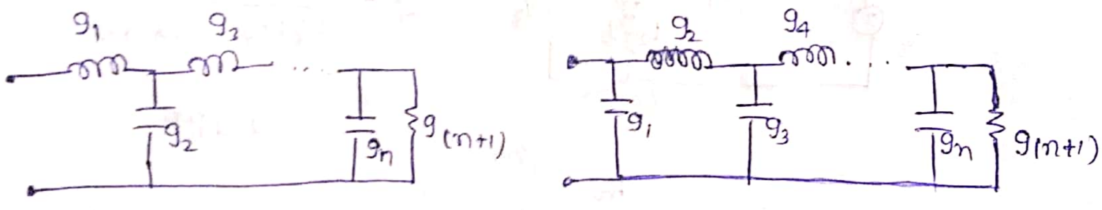
then g_2 is the $(N+1)$th element



→ $N = 1$



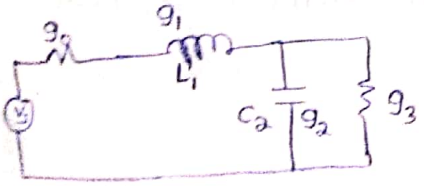
→ $N = 2$



If $N = n$

here n may be odd or even

→ lets take an example of $N = 2$



Important

$L' = LR_0 = g_1 R_0$

$C' = \frac{C}{R_0} = \frac{g_2}{R_0}$

$R_0' = g_0 R_0$

$R_L' = g_3 R_0$

Now for the side example, lets take $g_1 = 1.414$, $g_2 = 1.414$, $g_3 = 1.0$ } $N = 2$

$f_c = 1\,Ghz$

$R_o = 50\Omega$

↓

If it is given rad/sec then it is ω_c

LPF

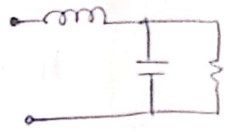
So, now $L_1' = \frac{L_1 R_o}{\omega_c}$

$= \frac{1.414(50)}{2\pi \times 10^9}$

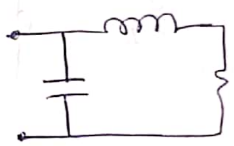
$= 11.25\,nH$

$C_2' = \frac{C_2}{R_o \omega_c} = \frac{1.414}{50(2\pi \times 10^9)}$

$= 4.4\,PF$

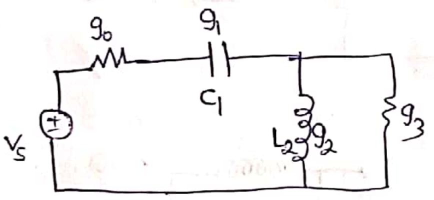


Now we can design for case of capacitor first



Take any one of these

HPF



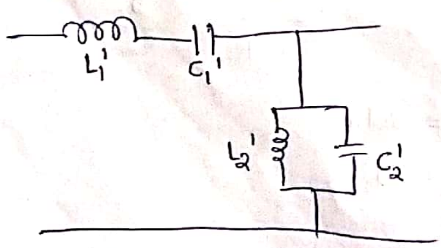
$C_1' = \frac{1}{\omega_c L R_o} = \frac{1}{(2\pi \times 10^9)(1.414)(50)}$

$= 2.2\,PF$

$L_2' = \frac{R_o}{\omega_c C} = \frac{50}{2\pi \times 10^9 (1.414)} = 5.63 \times 10^{-9}$

$= 5.63\,nH$

BPF here we will show a single element as both inductor and capacitor.



$$L_2' = \frac{\Delta R_0}{\omega_0 C_2}$$

$$= \frac{0.1(50)}{2\pi\times10^9\times 1.414} = 563\ PH$$

$$C_2' = \frac{C_2}{\Delta \omega_0 R_0} = \frac{1.414}{(0.1)\,2\pi\times10^9\times 50} = 45\ PF$$

BSF

Same like BPF we do it but by replacing some of the elements.

19-11-19

$$P(S) = s^4 + 6s^3 + 2s^2 + s + 1 \Big\}$$ Divide this into odd and even powers.

$$M(S) = s^4 + 2s^2 + 1$$

$$N(S) = 6s^3 + s$$

Now,

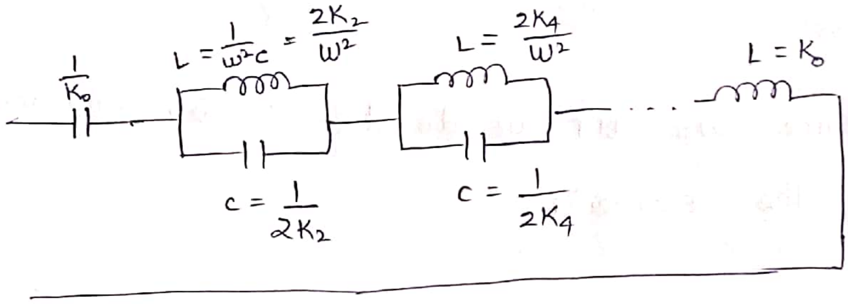
$$6s^3+s \,\big)\, s^4 + 2s^2 + 1 \,\big(\, \frac{s}{6}$$
$$s^4 + \frac{s^2}{6}$$
$$\frac{11}{6}s^2 + 1 \,\big)\, 6s^3 + s \,\big(\, \frac{36}{11}s$$
$$6s^3 + \frac{36s}{11}$$
$$-\frac{25}{11}s \,\big)\, \frac{11}{6}s^2 + 1 \,\big(\, \frac{-121}{150}s$$
$$\frac{11}{6}s^2$$
$$1 \,\big)\, \frac{-25}{11}s \,\big(\, \frac{-25}{11}s$$
$$\frac{-25}{11}s$$
$$0$$

Since on obtaining 0 as remainder we got $-\frac{25}{11}s$ as a quotient which is $-$ve.

$\therefore$ The given P(s) is not a Horwitch polynomial.

Foster's I^{st} method

$$z(s) = \frac{K_0}{s} + \frac{2K_2 s}{s^2+\omega_2^2} + \frac{2K_1 s}{s^2+\omega_1^2} \cdots + K_\infty s$$

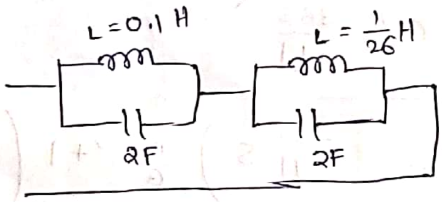


Now, $$z(s) = \frac{s(s^2+9)}{(s^2+5)(s^2+13)}$$

$$= \frac{2K_2 s}{(s^2+5)} + \frac{2K_4 s}{(s^2+13)}$$

$$2K_2 s = \left[(s^2+5)\, z(s)\right]\Big|_{s^2=-5}$$

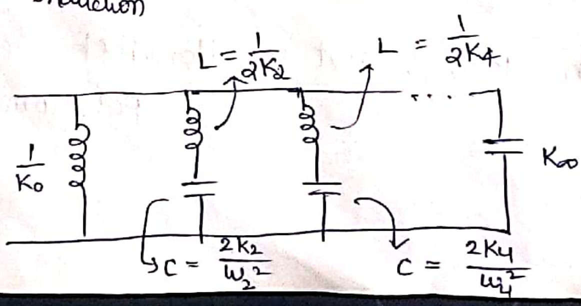
$$2K_2 \cancel{s} = \frac{\cancel{s}\,(s^2+9)}{s^2+13} = \frac{4}{8} = \frac{1}{2}$$



$$L = \frac{1}{10} = 0.1\ H$$

Foster's II nd method

$$y(s) = \underbrace{\frac{K_0}{s}}_{\text{Induction}} + \frac{2K_2 s}{s^2+\omega_2^2} + \cdots \frac{2K_4 s}{s^2+\omega_4^2} + \cdots + \frac{K_\infty s}{C}$$



Now, $Y(s) = \dfrac{(s^2+5)(s^2+13)}{s(s^2+9)}$

here we want to do one division as the numerator power is greater than denominator.

$$s^3+9s \,\overline{)\, s^4+18s^2+65 \,}\,(s$$
$$s^4+9s^2$$
$$\overline{\qquad 9s^2+65 \qquad}$$

So, $Y(s) = s + \dfrac{9s^2+65}{s^3+9s}$

$= s + \dfrac{K_0}{s} + \dfrac{2K_2 s}{s^2+9} \Rightarrow 2K_2 = \dfrac{16}{9}$

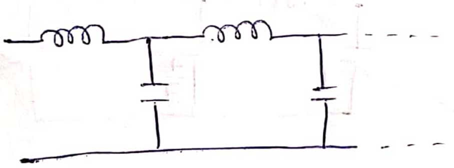
$K_0 = \dfrac{65}{9}$

20-11-19

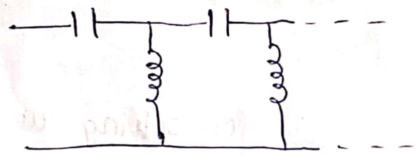
Cauer's form

There are 2 forms in it.

I/



II/



Ex $\quad Z(s) = \dfrac{s(s^2+4)(s^2+6)}{(s^2+3)(s^2+5)}$ $\qquad$ I form

$= \dfrac{s^5+10s^3+24s}{s^4+8s^2+15}$

here numerator power is bigger than denominator.

So,

$s^4+8s^2+15 \,)\, s^5+10s^3+24s \,(s \longrightarrow Z_1$

s^5+8s^3+15s

$2s^3+9s \,)\, s^4+8s^2+15 \,(s/2 \longrightarrow Y_1$

$s^4+\frac{9}{2}s^2$

$\frac{7}{2}s^2+15 \,)\, 2s^3+9s \,(\frac{4}{7}s \longrightarrow Z_2$

$2s^3+\frac{60}{7}s$

$\frac{3}{7}s \,)\, \frac{7}{2}s^2+15 \,(\frac{49}{6}s \longrightarrow Y_2$

$\frac{7}{2}s^2$

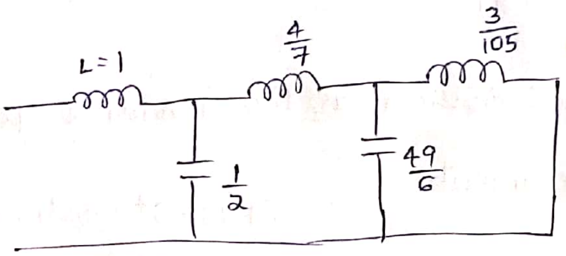
$15 \,)\, \frac{3}{7}s \,(\frac{3}{105}s \longrightarrow Z_3$

$\frac{3}{7}s$

0

Scanned by CamScanner

Now the circuit will be based on those quotients



as the question is Z(S)

1st quotient is Z_1 then Y_1

so 1st inductor than capacitor

Ex: $$Z(S) = \frac{(S^2+3)(S^2+5)}{S(S^2+4)(S^2+6)}$$

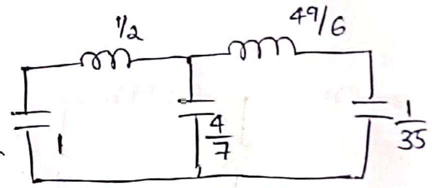
here denominator has more power than numerator

so reverse it. so, $$Y(S) = \frac{S(S^2+4)(S^2+6)}{(S^2+3)(S^2+5)}$$

Now do the same process as earlier.

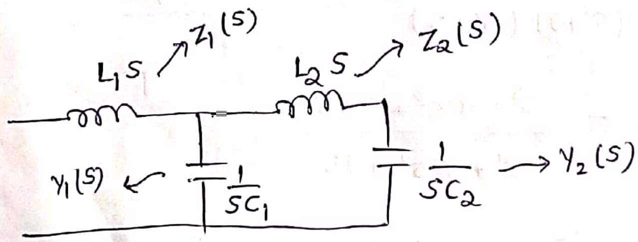
And the 1st quotient is considered as Y_1 than Z_1

and the circuit will be



on solving we can get those values.

Formula:



We can get the real eqn by

$$Z(S) = Z_1(S) + \cfrac{1}{Y_1(S) + \cfrac{1}{Z_2(S) + \cfrac{1}{Y_2(S)}}}$$

power of num < denominator

II form

$$Y(s) = \frac{(s^2+3)(s^2+5)}{s(s^2+4)(s^2+6)}$$

$$= \frac{s^4+8s^2+15}{s^5+10s^3+24s} = \frac{15+8s^2+s^4}{24s+10s^3+s^5}$$

$24s+10s^3+s^5 \,)\, 15+8s^2+s^4 \,(\frac{15}{24s} \longrightarrow Y_1$

$15+\frac{150}{24}s^2+\frac{15}{24}s^4$

$\frac{7}{4}s^2+\frac{3}{8}s^4 \,)\, 24s+10s^3+s^5 \,(\frac{576}{42s} \longrightarrow Z_1$; $\frac{96}{7s}$

$24s+\frac{36}{7}s^3$

$\frac{34}{7}s^3+s^5 \,)\, \frac{7}{4}s^2+\frac{3}{8}s^4 \,(\frac{1764}{4896s}$; Y_2

$\frac{7}{4}s^2+\frac{49}{136}s^4$

$\frac{1}{68}s^4 \,)\, \frac{34}{7}s^3+s^5 \,(\frac{41616}{126s}$

$\frac{34}{7}s^3$

$s^5 \,)\, \frac{s^4}{68} \,(\frac{72}{4896s}$

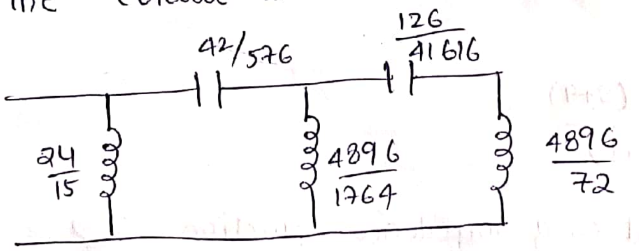
$\frac{s^4}{68}$

0

on solving we get

$$Y_2 = \frac{1764}{4896s} \rightarrow \frac{49}{136s}, \quad Z_2 = \frac{41616}{126s} \rightarrow \frac{2312}{7s}, \quad Y_3 = \frac{72}{4896s} \rightarrow \frac{1}{68s}$$

So the circuit is

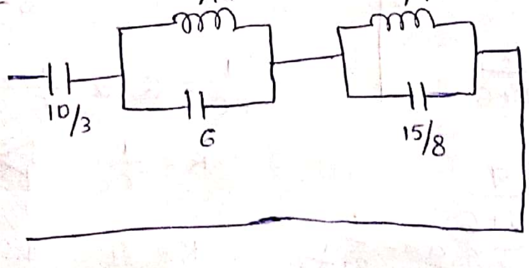


Example.

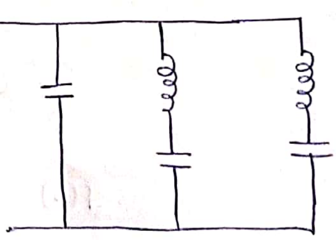
$$Z(s) = \frac{(s^2+1)(s^2+3)}{s(s^2+2)(s^2+5)}$$

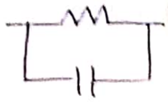
write all the foster forms and Cauer forms.

F-I



F-II



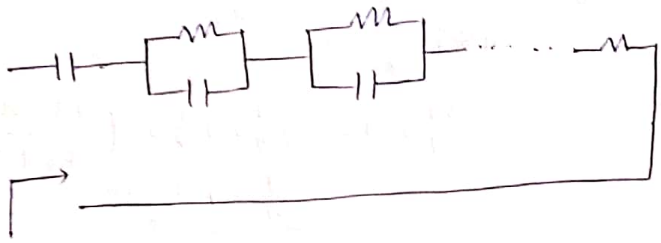
RC circuit  → Impedence

RL circuit  → Admitance

$$\{RC\}\quad Z(S) = \frac{Z_1(S)\cdot Z_2(S)}{Z_1(S)+Z_2(S)} = \frac{R/SC}{R+1/SC} = \frac{R}{SRC+1} = \frac{1/C}{S+\frac{1}{RC}}$$

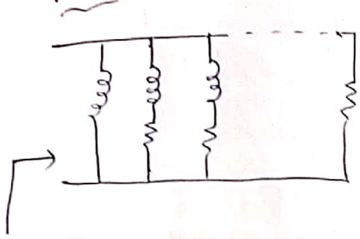
$$\{RL\}\quad Y(S) = \frac{1}{LS+R} = \frac{1/L}{S+(R/L)} \leftarrow \frac{a}{S+b}$$

F-I



Z(S)

F-II



Y(S)

* If $|Z(0)| > |Z(\infty)|$, then we have to follow F-I also the power of num $\leq$ power of denom in foster forms

21-11-19

Ex: $F(S) = \dfrac{6(S+3)(S+9)}{S(S+6)}$

Consider it as a impedence function

Also it is satisfying the above 2 conditions. (*)

$$S^2+6S\,)\,6S^2+72S+162\,(\,6$$
$$6S^2+36S$$
$$\overline{\quad 36S+162 \quad}$$

$$\therefore F(S) = 6 + \frac{36S+162}{S^2+6S}$$

$$= 6 + \frac{A}{S} + \frac{B}{S+6}$$

partial fraction ↑

$$A = S\left(\frac{36S+162}{S(S+6)}\right)\Bigg|_{S=0} = 27$$

$$B = (S+6)\left(\frac{36S+162}{S(S+6)}\right)\Bigg|_{S=-6} = 9$$

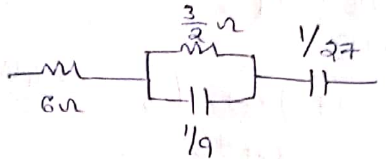
$$\therefore F(S) = 6 + \frac{27}{S} + \underbrace{\frac{9}{S+6}}_{\frac{a}{S+b} = \frac{1/C}{S+\frac{1}{RC}}}$$

$\frac{1}{RC} = 6$ & $\frac{1}{C} = 9$

$R = \frac{1}{6C}$

$R = \frac{9}{6} = \frac{3}{2}$

∴ Foster I form is

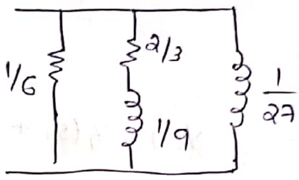


Now consider the example as Admitance function

$$\text{So}, \quad Y(S) = 6 + \frac{27}{S} + \frac{9}{S+6}$$

∴ Foster II form is

circuit is



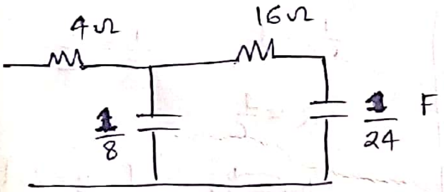
Ex: $$F(S) = \frac{4(S+1)(S+3)}{S(S+2)}$$

first we have to remove pole at infinity

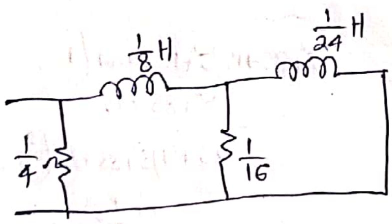
$$F(S) = \frac{4S^2+16S+12}{S^2+2S}$$

circuit is Causey I form

$S^2+2S)\,4S^2+16S+12\,(4 \rightarrow Z_1(S)$
$\quad 4S^2+8S+0$
$\quad\quad 8S+12)\,S^2+2S\,(S/8 \rightarrow Y_1(S)$
$\quad\quad\quad S^2+\frac{12}{8}S$
$\quad\quad\quad\quad \frac{4}{8}S)\,8S+12\,(16 \rightarrow Z_2(S)$
$\quad\quad\quad\quad\quad 8S$
$\quad\quad\quad\quad\quad 12)\,\frac{4}{8}S\,(\frac{S}{24} \rightarrow Y_2(S)$
$\quad\quad\quad\quad\quad\quad \frac{4}{8}S$
$\quad\quad\quad\quad\quad\quad 0$



another Causey II form



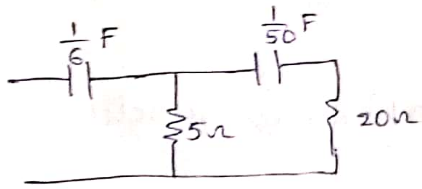
here the capacitor values wont be changed.

Causey form II

We write the function in ascending order

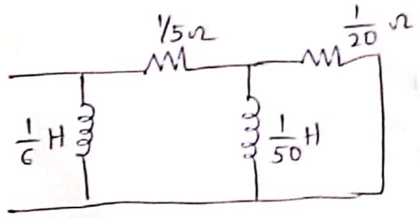
i.e. $$F(S) = \frac{12+16S+4S^2}{2S+S^2}$$

And the circuit is as Impedance func



$$25+s^2 \overline{)\,12+16s+4s^2\,} \left(\tfrac{6}{s} \longrightarrow Z_1(s)\right.$$
$$12+16s$$
$$10s+4s^2 \overline{)\,25+s^2\,} \left(\tfrac{1}{5} \longrightarrow Y_1(s)\right.$$
$$2s+\tfrac{4}{5}s^2$$
$$\tfrac{1}{5}s^2 \overline{)\,10s+4s^2\,} \left(\tfrac{50}{s} \longrightarrow Z_2(s)\right.$$
$$10s$$
$$4s^2 \overline{)\,\tfrac{1}{5}s^2\,} \left(\tfrac{1}{20} \longrightarrow Y_2(s)\right.$$
$$\tfrac{s^2}{5}$$
$$0$$

If we consider it as a Admitance func the circuit is



$$Y(s) = Y_1(s) + \cfrac{1}{Z_1(s) + \cfrac{1}{Y_2(s) + \cfrac{1}{Z_2(s)}}}$$

Ex: $Z(s) = \dfrac{(s+4)(s+6)}{(s+3)(s+5)}$

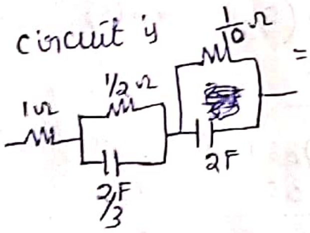
find Foster I and cauey I

$$Z(s) = \frac{s^2+10s+24}{s^2+8s+15}$$

$$s^2+8s+15 \overline{)\,s^2+10s+24\,} \left(1\right.$$
$$s^2+8s+15$$
$$2s+9$$

$$= 1 + \frac{2s+9}{s^2+8s+15}$$

circuit is



$$= 1 + \frac{A}{s+3} + \frac{B}{s+5}$$

$$= 1 + \frac{3/2}{\underbrace{s+3}_{\frac{1}{RC}}} + \frac{1/2}{s+5}$$

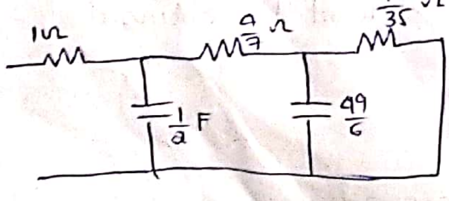
$\frac{1}{RC} = 3$ $\quad \frac{1}{C} = \frac{3}{2}$

$R = \frac{3}{C}$

$\{ \because B = \frac{1}{2} \}$

Now lets do cauey forms

circuit is



$$s^2+8s+15 \overline{)\,s^2+10s+24\,} \left(1\right.$$
$$s^2+8s+15$$
$$2s+9 \overline{)\,s^2+8s+15\,} \left(\tfrac{s}{2}\right.$$
$$s^2+\tfrac{9}{2}s$$
$$\tfrac{7}{2}s+15 \overline{)\,2s+9\,} \left(\tfrac{4}{7}\right.$$
$$2s+\tfrac{60}{7}$$
$$\tfrac{3}{7} \overline{)\,\tfrac{7}{2}s+15\,} \left(\tfrac{49}{6}s\right.$$
$$\tfrac{7}{2}s$$
$$15 \overline{)\,\tfrac{3}{7}\,} \left(\tfrac{1}{35}\right.$$
$$\tfrac{3}{7}$$
$$0$$

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$Z(s) = \frac{R(Ls)}{Ls+R} = \frac{Rs}{s+\frac{R}{L}} \leftarrow \frac{as}{s+b}$ so $\frac{Z(s)}{s} = \frac{R}{s+\frac{R}{L}}$

$Y(s) = \frac{1}{R+\frac{1}{Cs}} = \frac{Cs}{CsR+1} = \frac{s/R}{s+\frac{1}{RC}}$ $\frac{Y(s)}{s} = \frac{1/R}{s+1/RC}$

The condition is $Z(\infty) > Z(0)$

5. $F(s) = \frac{(s+1)(s+3)}{(s+2)(s+4)}$

Foster form I

$Z(s) = \frac{s^2+4s+3}{s^2+6s+8}$ on expanding this like before we will get negative terms. So we should do

$\frac{Z(s)}{s} = \frac{(s+1)(s+3)}{s(s+2)(s+4)}$

Now we will get +ve terms.

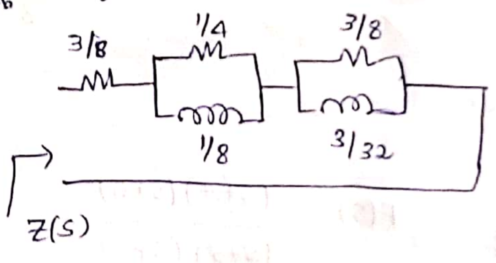
$\frac{Z(s)}{s} = \frac{s^2+4s+3}{s^3+6s^2+8s}$ apply partial fraction directly.

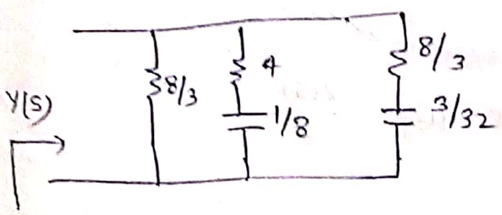
$\cancel{s^3+6s^2+8s \overline{) s^2+4s+3 } (\frac{1}{s}} \quad \cancel{s^2+6s+8}$

$= \frac{A}{s} + \frac{B}{s+2} + \frac{C}{s+4}$

on solving, we get $\frac{as}{s+b} = \frac{Rs}{s+\frac{R}{L}}$ → so $R = \frac{3}{8}$ and $\frac{R}{L} = 4$, $L = \frac{R}{4} = \frac{3}{32}$

$Z(s) = \frac{3}{8} + \frac{(1/4)s}{s+2} + \frac{(\frac{3}{8})s}{s+4}$



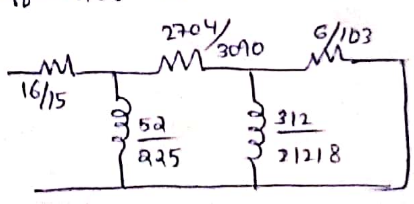


Cauer form I

$Z_{RC}(s) = \frac{2(s+2)(s+4)}{(s+3)(s+5)} = \frac{2s^2+12s+16}{s^2+8s+15}$

Here we will get coefficients as −ve. So we use II form

$\therefore Z(s) = \frac{16+12s+2s^2}{15+8s+s^2}$



Ex: $F(S) = \dfrac{3(S+3)(S+5)}{(S+4)(S+6)}$ } write foster form I and II

We have to see which is suitable whether R_L or R_C

If $Z(0) > Z(\infty) \longrightarrow R_C$

$Z(\infty) > Z(0) \longrightarrow R_L$

Here we got $Z(0) = \dfrac{15}{8}$ and $Z(\infty) = 3$

so we consider R_L circuit.

i.e.  $\Rightarrow \dfrac{Z(S)}{S} = \dfrac{R}{S + \frac{R}{L}}$

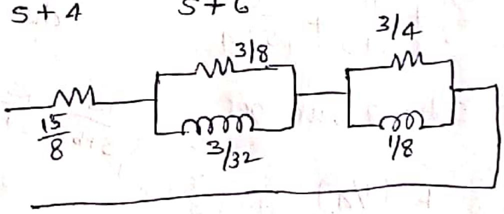
We get -ve terms. So we applied $\dfrac{Z(S)}{S}$

$$\Rightarrow \frac{Z(S)}{S} = \frac{3(S+3)(S+5)}{S(S+4)(S+6)}$$

$$\frac{Z(S)}{S} = \frac{A}{S} + \frac{B}{S+4} + \frac{C}{S+6}$$ { direct partial fraction }

$$\therefore Z(S) = \frac{15}{8} + \frac{\left(\frac{3}{8}\right)S}{S+4} + \frac{(3/4)S}{S+6}$$

and the circuit is



Ex: $F(S) = \dfrac{(S+4)(S+6)}{(S+5)(S+7)}$

we will get -ve values. So take $\dfrac{Z(S)}{S}$

$$\frac{Z(S)}{S} = \frac{A}{S} + \frac{B}{S+5} + \frac{C}{S+7}$$

$$\therefore Z(S) = \frac{24}{35} + \frac{(1/10)S}{S+5} + \frac{(3/14)S}{S+7}$$

30-10-19

After Mid-2

① A parallel RLC network with

$R = 5\Omega$, $L = 100 mH$, $C = 1mF$

a) Compute Quality factor (Q)

b) Determine at which freq the impedence magnitude drops to 90% of its max value

② A parallel RLC circuit with $L = 5mH$

$Q_0 = 6.5$, $\omega_0 = 1000$ rad/sec

Determine approximate values of input impedence at

a) 500 b) 750 c) 900 rad/sec

1-ans

a) Quality factor $(Q) = R\sqrt{\frac{C}{L}}$ { for parallel }

$$= 5\sqrt{\frac{1\times10^{-3}}{100\times10^{-3}}}$$

$$= \frac{5}{10} \Rightarrow 0.5$$

b) $Z_{max} = (0.9) R$

$$= 4.5\Omega$$

$$Y(\omega) = \frac{1}{Z_{max}} = \frac{1}{4.5}$$

$$|Y(\omega)| = \sqrt{\left(\frac{1}{R}\right)^2 + \left(\omega C - \frac{1}{\omega L}\right)^2}$$

$$\left|\frac{1}{4.5}\right|^2 = \frac{1}{5^2} + \left[\omega\times10^{-3} - \frac{1}{\omega\times10^{-1}}\right]^2$$

on solving, we get

$\omega_1 = 68.7$ rad/sec

$\omega_2 = 159.5$ rad/sec

2-ans

$$|Y| = \sqrt{\frac{1}{R^2} + \left(\omega C - \frac{1}{\omega L}\right)^2}$$

$$= \sqrt{\frac{1}{R^2} + \left(\frac{\omega Q_0}{R\omega_0} - \frac{\omega_0 Q_0}{\omega R}\right)^2}$$

$$= \sqrt{\frac{1}{R^2} + \frac{Q_0^2}{R^2}\left[\frac{\omega}{\omega_0} - \frac{\omega_0}{\omega}\right]^2}$$

$$Y(\omega) = \frac{1}{R}\sqrt{1 + Q_0^2\left(\frac{\omega}{\omega_0} - \frac{\omega_0}{\omega}\right)^2}$$

$$R = Q_0 \omega_0 L$$

$$R = 32.5\,\Omega$$

$$Y(500) = \frac{1}{325}\sqrt{1 + (6.5)^2\left[\frac{500}{1000} - \frac{1000}{500}\right]}$$

$$= 0.3016 \quad , \quad Z_{(500)} = 3.3156\,\Omega$$

$$Y(750) = 0.0551 \quad , \quad Z_{(750)} = 18.15\,\Omega$$

$$Y(900) = 0.0349 \quad , \quad Z_{(900)} = 28.65$$

(3) RLC circuit is connected in series with

$R = 5\Omega$, $L = 20mH$, $C = 1mF$

Calculate Q_0 , bandwidth , mag of impedence at $0.95\omega_0$

(4) If the freq is 40, 80 rad/sec find parallel equi of series combination of 2Ω resistor and

a) 100 mF capacitor

b) 3mH inductor

3-ans $Q_0 = \frac{1}{R}\sqrt{\frac{L}{C}}$ {for series}

↳ Just inverse of parallel

$\therefore Q_0 = 0.894$

$L = \frac{QR}{\omega_0}$, $C = \frac{1}{Q\omega_0 R}$

Here we have L and C. So, $\omega_0 = \frac{1}{\sqrt{LC}}$

$= 223.713$

Also, $Z = \sqrt{R^2 + \left(\frac{QR\omega}{\omega_0} - \frac{Q\omega_0 R}{\omega}\right)^2}$

$= R\sqrt{1+Q^2\left(0.95 - \frac{1}{0.95}\right)^2}$

$|Z| = 5\Omega$

$\beta = \frac{\omega_0}{Q_0}$

$= \frac{R}{L} \Rightarrow 250$

↓

bandwidth

$\boxed{7\text{-}11\text{-}19}$ Tutorial

① BPF

Given, $f_1 = 2.5K$ also, $K = 650\Omega$

$f_2 = 5.5K$

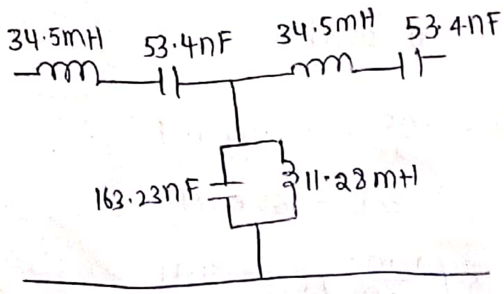
Now, $L_1 = \frac{K}{\pi(f_2 - f_1)} = \frac{650}{\pi\ (3K)} \Rightarrow 69\ mH$

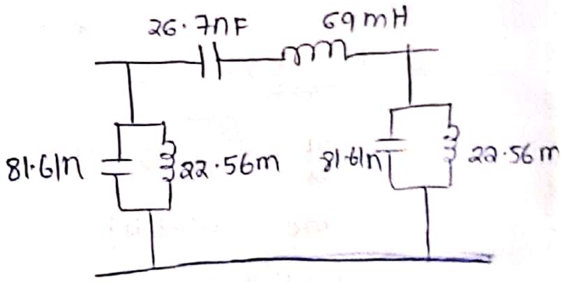
$C_2 = \frac{1}{\pi K(f_2 - f_1)} = \frac{1}{\pi\ 650\ (3K)} \Rightarrow 163.23nF$

$L_2 = \frac{K(f_2 - f_1)}{4\pi f_1 f_2} = \frac{650\ (3K)}{4\pi\ (13.75\ K^2)} \Rightarrow 11.28\ mH$

$C_1 = \frac{(f_2 - f_1)}{4\pi K f_1 f_2} = \frac{3K}{4\pi\ (650)\ (13.75\ K^2)} \Rightarrow 26.7\ nF$

Designing circuit





② BSF

Given $f_1 = 2.7K$ also $K = 650\Omega$

$f_2 = 5.7K$

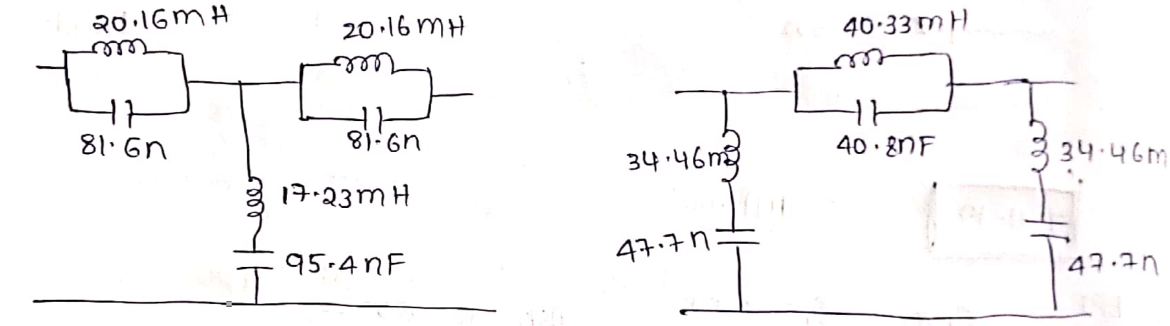
Now, $L_1 = \frac{K(f_2 - f_1)}{\pi f_1 f_2} = \frac{650(3K)}{\pi(15.39K^2)} = 40.33\ mH$

$C_1 = \frac{1}{4\pi K(f_2 - f_1)} = \frac{1}{4\pi(650)(3K)} = 40.8\ nF$

$L_2 = C_1 K^2 = (40.8n)(422.5K) = 17.23\ mH$

$C_2 = \frac{L_1}{K^2} = \frac{40.33m}{422.5K} = 95.4\ nF$

circuit



③ LPF

Given, $R_0 = 550\Omega$ and $f_\infty = 2.2k\ Hz$ → attenuation

$f_c = 1.7K\ Hz$

Now, $L = \frac{K}{\pi f_c} = \frac{550}{\pi(1.7K)} = 102.9\ mH$

$C = \frac{1}{\pi f_c K} = \frac{1}{\pi(1.7k)(550)} = 0.34\ \mu H$

$M = \sqrt{1 - \left(\frac{f_c}{f_r}\right)^2} = \sqrt{1 - \left(\frac{2.2k}{1.7k}\right)^2} = 0.638$

T-section

$\frac{mL}{2} = 32.68\ mH$

$mC = 0.21\ \mu F$

$\left[\frac{1-m^2}{4m}\right] L = 24.6\ mH$

π-section

$\frac{mC}{2} = 0.107\ \mu F$

$mL = 65\ mH$

$\left(\frac{1-m^2}{4m}\right) C = 79\ nF$

Scanned by CamScanner

(4) HPF Given $R_0 = 650\Omega$

$f_c = 5KHz$ $f_\infty = 3.8KHz$

Now, $L = \frac{K}{4\pi f_c} = \frac{650}{4\pi(5K)} = 10.3mH$

$C = \frac{1}{4\pi f_c K} = \frac{1}{4\pi(5K)(650)} = 24nF$

$M = \sqrt{1 - \left(\frac{f_\infty}{f_c}\right)^2} = \sqrt{1 - \left(\frac{3.8K}{5K}\right)^2} = 0.649$

T-section

$\frac{2C}{m} = 73.95nF$

$\frac{L}{m} = 15.87 mH$

$\left(\frac{4m}{1-m^2}\right) c = 107.3 mH$

π-section

$\frac{2L}{M} = 31.74 mH$

$\frac{C}{M} = 36.97nF$

$\left(\frac{4m}{1-m^2}\right) L = 46.19 mH$

12-11-19

1) Given $N = 4$ and $R_0 = 75\Omega$

$f_c = 3GHz$

$g_1 = 0.7654$ $g_3 = 1.8478$

$g_2 = 1.8478$ $g_4 = 0.7654$

Design LPF and HPF

LPF

$L' = \frac{LR_0}{\omega_c} = \frac{1.8478(75)}{2\pi \times 3 \times 10^9} = \frac{138.585}{18.849} \times 10^{-9} = 7.35nH$

$c' = \frac{C}{R_0\omega_c} = \frac{0.7654}{75(2\pi \times 10^9)} = 1.6PF$

HPF

$c' = \frac{1}{\omega_c L R_0} = \frac{1}{(2\pi \times 10^9)(75)(0.7654)} = 2.7PF$

$L' = \frac{R_0}{\omega_c C} = \frac{75}{(2\pi \times 10^9)(1.8478)} = 6.45nH$