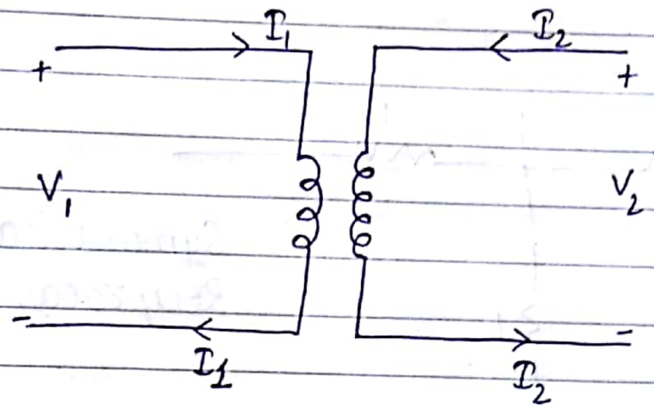
After Internals

25/09/17

Two Port Network

① Port - Pair of terminal from which current can enter or leave the n/w.

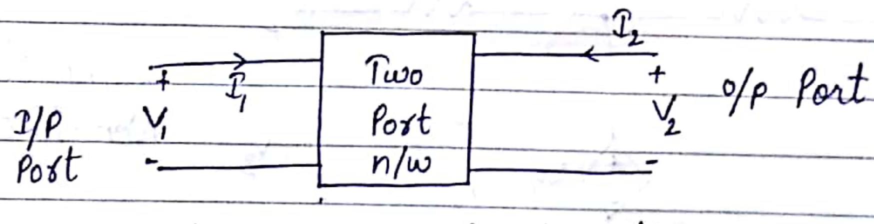


Transformer

Any system can be modeled using 2-port n/w.

I/p Port - V_1, I_1

o/p Port - V_2, I_2



V_1, I_1, V_2, I_2 - 6 Combinations

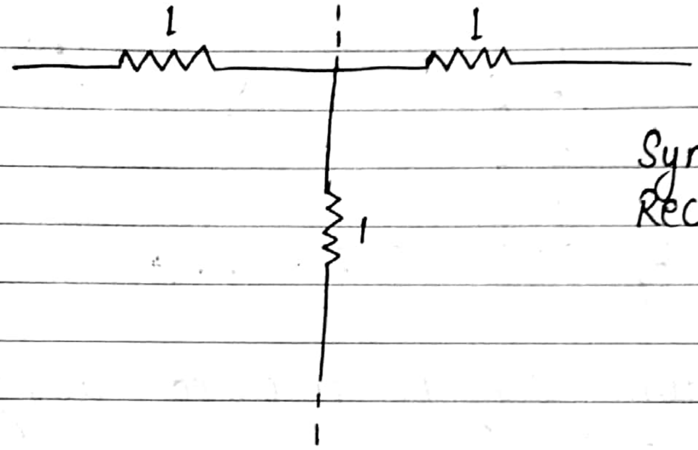
6 parameters - Z parameter
Y parameter
H parameter
G parameter
T(ABCD) parameter
T' parameter

→ Symmetrical N/w

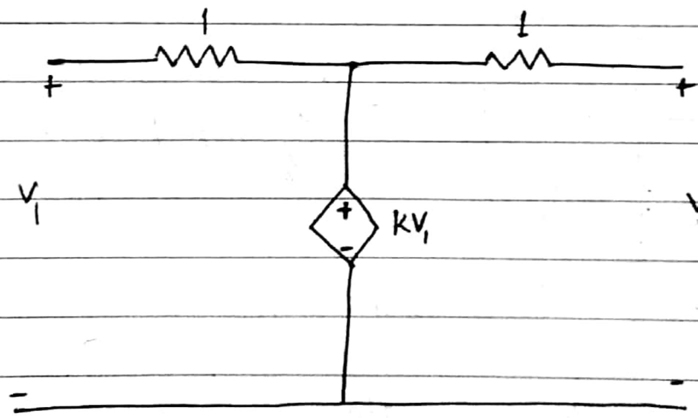
A n/w is said to be symmetrical if we divide the n/w in two ports then the one should be mirror image of other.

→ Reciprocal N/w

A n/w is said to be reciprocal which obeys reciprocity theorem. All ~~basic~~ ~~n/w's~~ passive n/w's are reciprocal.



Symmetrical.
Reciprocal



Symmetrical
Non-Reciprocal

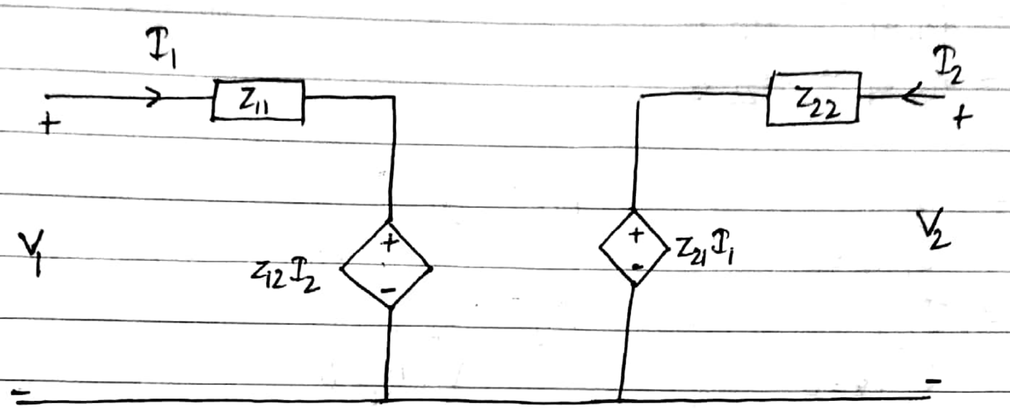
Z Parameter (Open ckt. parameter)

$$V_1 = Z_{11} I_1 + Z_{12} I_2$$
$$V_2 = Z_{21} I_1 + Z_{22} I_2$$

$$Z_{11} = \left.\frac{V_1}{I_1}\right|_{I_2=0} \qquad Z_{12} = \left.\frac{V_1}{I_2}\right|_{I_1=0}$$

$$Z_{21} = \left.\frac{V_2}{I_1}\right|_{I_2=0} \qquad Z_{22} = \left.\frac{V_2}{I_2}\right|_{I_1=0}$$

Dependent → V_1, V_2
Independent → I_1, I_2



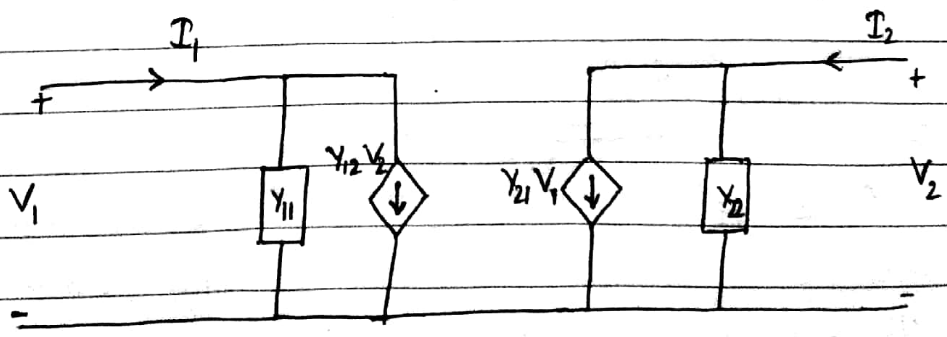
Y Parameter (Short ckt parameter)

$$I_1 = Y_{11}V_1 + Y_{12}V_2$$
$$I_2 = Y_{21}V_1 + Y_{22}V_2$$

$$Y_{11} = \left.\frac{I_1}{V_1}\right|_{V_2=0} \qquad Y_{12} = \left.\frac{I_1}{V_2}\right|_{V_1=0}$$

$$Y_{21} = \left.\frac{I_2}{V_1}\right|_{V_2=0} \qquad Y_{22} = \left.\frac{I_2}{V_2}\right|_{V_1=0}$$

Dependent → I_1, I_2
Independent → V_1, V_2



Y_{11}, Y_{22} → Admittance

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H parameter (Hybrid Parameter)

O/P Port - short circuit
I/P Port - open circuit

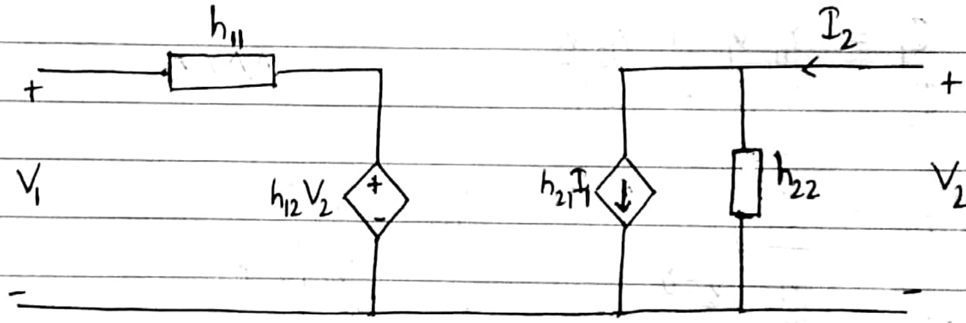
$$V_1 = h_{11} I_1 + h_{12} V_2$$
$$I_2 = h_{21} I_1 + h_{22} V_2$$

$$h_{11} = \frac{V_1}{I_1}\Big|_{V_2=0} \qquad h_{12} = \frac{V_1}{V_2}\Big|_{I_1=0}$$

$$h_{21} = \frac{I_2}{I_1}\Big|_{V_2=0} \qquad h_{22} = \frac{I_2}{V_2}\Big|_{I_1=0}$$

h_{11} - I/P Impedance
h_{22} - O/P Admittance

h_{21} - Forward current gain
h_{12} - Reverse voltage gain



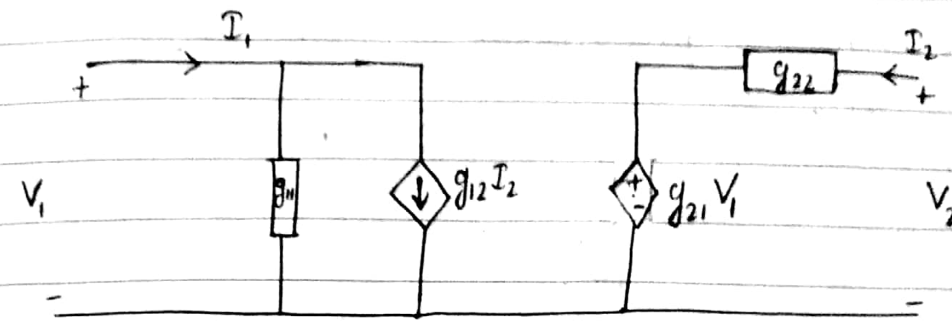
H-parameter is used to model the BJT
Dependent → V_1, I_2
Independent → V_2, I_1

G parameter

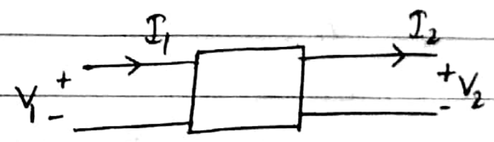
$$G = H^{-1}$$

O/P Port → open circuit
I/P Port → short circuit

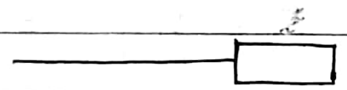
$$I_1 = g_{11} V_1 + g_{12} I_2$$
$$V_2 = g_{21} V_1 + g_{22} I_2$$



T Parameter (ABCD)



$$V_1 = AV_2 - BI_2$$
$$I_1 = CV_2 - DI_2$$



T' Parameter

$$T' = [T]^{-1}$$
$$V_2 = A'V_1 - B'I_1$$
$$I_2 = C'V_1 - D'I_1$$

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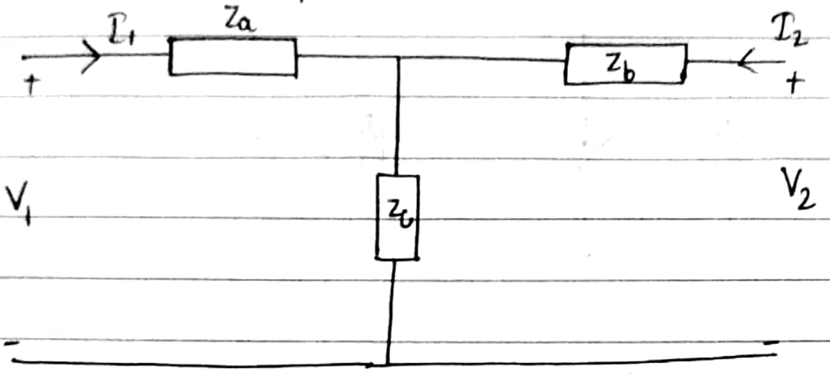
Q. Find the z parameter



$$Z_{11} = \frac{V_1}{I_1}\bigg|_{I_2=0}$$

Apply KVL ~~to~~ i/p

$$V_1 = Z_a I_1 + Z_c I_1$$

$$\frac{V_1}{I_1} = Z_a + Z_c$$

$$\Rightarrow Z_{11} = Z_a + Z_c$$

$$Z_{21} = \frac{V_2}{I_1}\bigg|_{I_2=0} = Z_c$$

Similarly

$$Z_{22} = \frac{V_2}{I_2}\bigg|_{I_1=0}$$

Apply KVL

$$V_2 = Z_b I_2 + Z_c I_2$$

$$\frac{V_2}{I_2} = Z_b + Z_c$$

$$\Rightarrow Z_{22} = Z_b + Z_c$$

$$Z_{12} = \frac{V_1}{I_2}\bigg|_{I_1=0} = Z_c$$

Method 2:

Apply KVL

$$V_1 = Z_a I_1 + Z_c(I_1 + I_2)$$

$$= (Z_a + Z_c) I_1 + Z_c I_2$$

$$V_1 = Z_{11} I_1 + Z_{12} I_2$$

Compare : $Z_{11} = Z_a + Z_c$ $Z_{12} = Z_c$

Similarly

$\Rightarrow V_2 = Z_b I_2 + Z_c(I_1 + I_2)$ $\qquad V_2 = Z_{21} I_1 + Z_{22} I_2$

$= Z_c I_1 + (Z_b + Z_c) I_2$

Compare : $Z_{21} = Z_c$

$Z_{22} = Z_b + Z_c$

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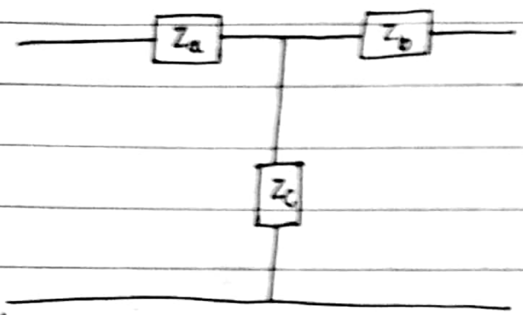
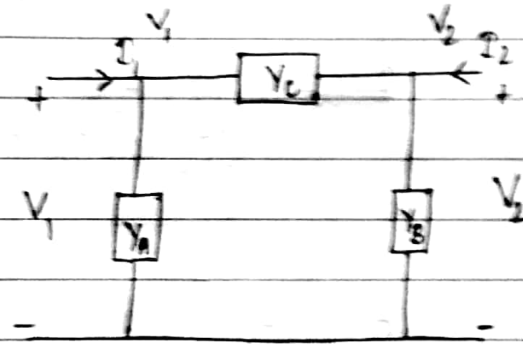


$$[Z] = \begin{bmatrix} Z_a + Z_c & Z_c \\ Z_c & Z_b + Z_c \end{bmatrix}$$

Very Important *



$V_1 Y_A + Y_c(V_1 - V_2) = I_1$

$(Y_A + Y_c)V_1 - Y_c V_2 = I_1$ — (I)

At V_2

$V_2 Y_B + Y_c(V_2 - V_1) = I_2$

$(Y_B + Y_c)V_2 - Y_c V_1 = I_2$ — (II)

Compare

$I_1 = Y_{11} V_1 + Y_{12} V_2$

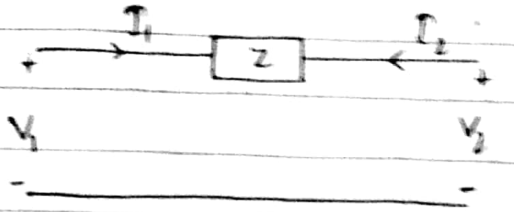
$I_2 = Y_{21} V_1 + Y_{22} V_2$

$\Rightarrow Y_{11} = Y_A + Y_c$ $\qquad Y_{21} = -Y_c$

$Y_{12} = -Y_c$ $\qquad Y_{22} = Y_B + Y_c$

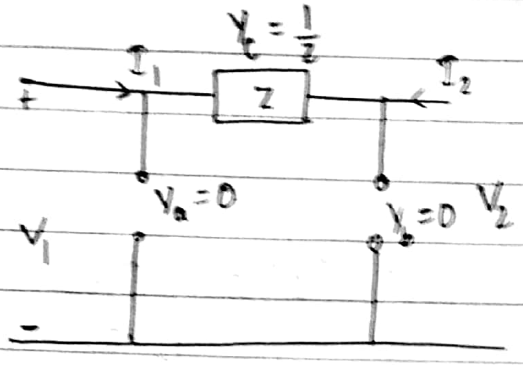
$$[Y] = \begin{bmatrix} Y_A + Y_c & -Y_c \\ -Y_c & Y_B + Y_c \end{bmatrix}$$

Q.



$Y = \frac{1}{Z}$

Find Y parameters



$Y_{11} = \frac{1}{Z}$ $\quad Y_{12} = \frac{-1}{Z}$ $\quad Y_{21} = \frac{-1}{Z}$ $\quad Y_{22} = \frac{1}{Z}$

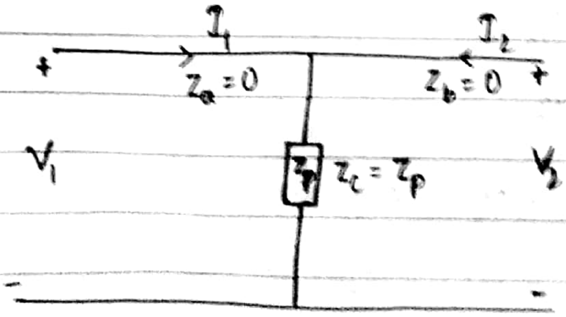
$[Y] = \begin{bmatrix} 1/Z & -1/Z \\ -1/Z & 1/Z \end{bmatrix}$ $\quad$ ~~Det~~ $|Y| = 0$

$[Z]$ doesn't exist

$[Z] = [Y]^{-1}$

$$\begin{bmatrix} a & b \\ c & d \end{bmatrix}^{-1} = \frac{1}{ad-bc}\begin{bmatrix} d & -b \\ -c & a \end{bmatrix}$$

Q.



Find Z and Y paramet

$Z_{11} = Z_p$ $\quad Z_{12} = Z_p$ $\quad Z_{21} = Z_p$ $\quad Z_{22} = Z_p$

$[Z] = \begin{bmatrix} Z_p & Z_p \\ Z_p & Z_p \end{bmatrix}$

$|Z| = 0$ $\Rightarrow$ Y parameter of this ckt. does not exist

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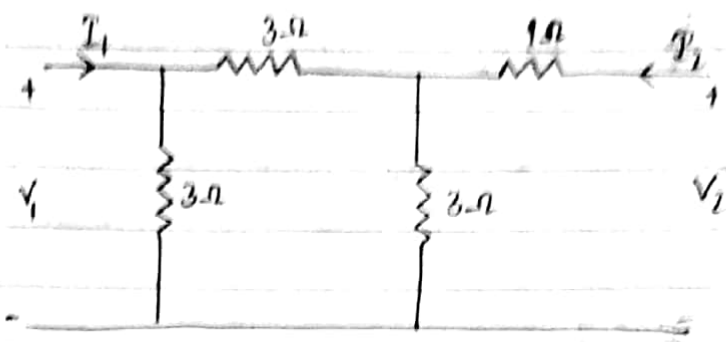

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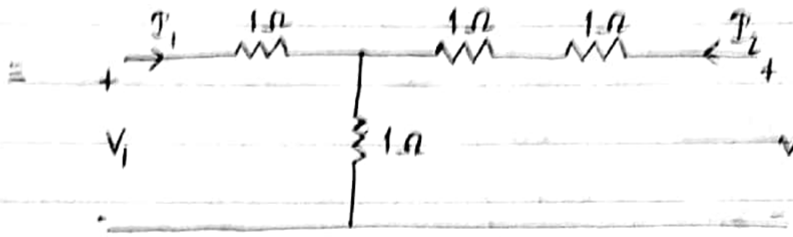


$Z_a = 1 \qquad Z_b = 2 \qquad Z_c = 1$

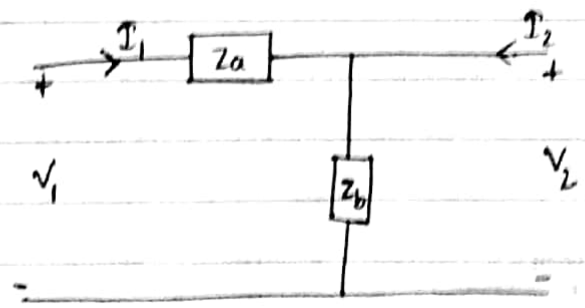
$Z_{11} = 2 \qquad Z_{12} = 1 \qquad Z_{21} = 1 \qquad Z_{22} = 3.$

$[Z] = \begin{bmatrix} 2 & 1 \\ 1 & 3 \end{bmatrix} \qquad |Z| = 5$

$[Y] = \frac{1}{5}\begin{bmatrix} 3 & -1 \\ -1 & 2 \end{bmatrix}$

$Y_{11} = \frac{3}{5} \qquad Y_{12} = \frac{-1}{5} \qquad Y_{21} = \frac{-1}{5} \qquad Y_{22} = \frac{2}{5}$

*



Find ABCD paramete

$V_1 = AV_2 - BI_2$

$I_1 = CV_2 - DI_2$

$V_1 = Z_a I_1 + Z_b(I_1 + I_2)$

$= (Z_a + Z_b) I_1 + Z_b I_2$

$V_2 = (I_1 + I_2) Z_b$

$V_2 = I_1 Z_b + I_2 Z_b$

$I_1 = \frac{V_2}{Z_b} - I_2 \quad -②$

$V_1 = (Z_a + Z_b)\left(\frac{V_2}{Z_b} - I_2\right) + Z_b I_2$

$= \frac{Z_a V_2}{Z_b} - Z_a I_2 + V_2 - Z_b I_2 + Z_b I_2$

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$$V_1 = \left(\frac{Z_a}{Z_b} + 1\right) V_2 - Z_a I_2 \quad -(1)$$

$$\Rightarrow A = \frac{Z_a + Z_b}{Z_b} \qquad B = Z_a$$

From (2)

$$C = \frac{1}{Z_b} \qquad D = 1$$

$$T = \begin{bmatrix} \frac{Z_a + Z_b}{Z_b} & Z_a \\ \frac{1}{Z_b} & 1 \end{bmatrix}$$

Condition for Symmetry

A two port n/w is said to be symmetrical if the ports can be interchanged w/o changing the port voltage and current.

→ $Z_{11} = Z_{22}$
→ $Y_{11} = Y_{22}$
→ $A = D$ → $A' = D'$
→ $h_{11} h_{22} - h_{12} h_{21} = 1$
→ $g_{11} g_{22} - g_{12} g_{21} = 1$

Condition for reciprocal

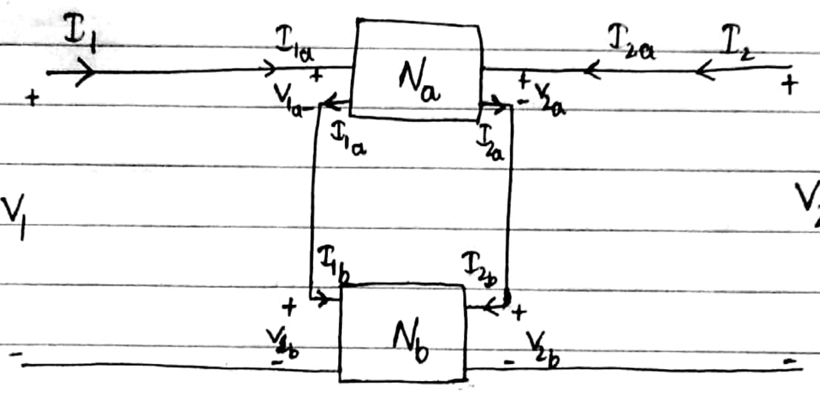
A two port n/w is said to be reciprocal if the ratio of excitation to the response is ~~it~~ invariant ~~and~~ to ~~and~~ an interchange of position of excitation and response in the n/w. N/w's containing passive elements are generally reciprocal.

$Z_{12} = Z_{21}$
$Y_{12} = Y_{21}$
$AD - BC = 1$
$A'D' - B'C' = 1$
$h_{12} = -h_{21}$
$h_{12} = -g_{21}$

Interconnection of two port n/w

1. Series Connection
2. Parallel Connection
3. Cascade connection
4. Series - Parallel connection

(1)



$I_1 = I_{1a} = I_{1b}$ $\qquad$ $V_1 = V_{1a} + V_{1b}$
$I_2 = I_{2a} = I_{2b}$ $\qquad$ $V_2 = V_{2a} + V_{2b}$

$$(1)\begin{cases} V_{1a} = Z_{11a} I_{1a} + Z_{12a} I_{2a} \\ V_{2a} = Z_{21a} I_{1a} + Z_{22a} I_{2a} \end{cases}$$

$$(2)\begin{cases} V_{1b} = Z_{11b} I_{1b} + Z_{12b} I_{2b} \\ V_{2b} = Z_{21b} I_{1b} + Z_{22b} I_{2b} \end{cases}$$

$V_1 = V_{1a} + V_{1b}$
$= Z_{11a} I_{1a} + Z_{12a} I_{2a} + Z_{11b} I_{1b} + Z_{12b} I_{2b}$

$$= (Z_{11a} + Z_{11b}) I_1 + (Z_{12a} + Z_{12b}) I_2 \quad - (A)$$

$$V_2 = V_{2a} + V_{2b}$$

$$= (Z_{21a} + Z_{21b}) I_1 + (Z_{22a} + Z_{22b}) I_2 \quad - (B)$$

$$Z_{11} = Z_{11a} + Z_{11b} \qquad Z_{12} = Z_{12a} + Z_{12b}$$

$$Z_{21} = Z_{21a} + Z_{21b} \qquad Z_{22} = Z_{22a} + Z_{22b}$$

$$[Z] = [Z_a] + [Z_b]$$

For stability
$t \to \infty$ graph $\to 0$

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Network ~~Analysis~~ Synthesis

→ Synthesize a n/w from a given n/w fn.

→ To realize the n/w as a physical passive n/w two important considerations are:
i) Possibility
ii) Stability

i) By posibility means the response of the n/w is zero for $t<0$.

ii) For ~~a~~ stability three cond^n's must be satisfied:
a) T(s) cannot ~~be~~ have poles in right half of s plane.
b) T(s) cannot have multiple poles in imaginery axis.
c) The degree of numerator of T(s) cannot exceed denominator by more than unity

Hurwitz Polynomial

Hurwitz polynomial is a denominator polynomial of n/w fn satisfying certain cond^n's. A polynomial P(s) is said to be Hurwitz if:
i) P(s) is real when s is real
ii) The roots of P(s) have real parts which are 0 or -ve.

Properties of Hurwitz
As a result of above two cond^n's P(s) have

following properties

i) All coefficients must be +ve & b/w highest order term in as and lowest order term, none of the coefficient may be 0 unless the polynomial is even or odd.

ii) Both odd & even part of $P(s)$ have roots on $J(\omega)$ axis only.

iii) Even part of $P(s)$ as $M(s)$ and odd part of $P(s)$ as $N(s)$

$P(s) = M(s) + N(s)$

iv) If $P(s)$ is either even or odd, all of its roots are on $J(\omega)$ axis

v) The continued fraction expansion of the ratio

$\psi(s) = \frac{M(s)}{N(s)}$ or $\frac{N(s)}{M(s)}$

deals all +ve coefficient terms

vi) If $P(s)$ is Hurwitz polynomial and $W(s)$ is multiplicative factor the $P_1(s) = P(s)\,W(s)$ is also ~~Hurwi~~ Hurwitz polynomial If $W(s)$ is also Hurwitz.

vii) In the case of the polynomial is either only even or only odd it is not possible to obtain ~~conta~~ continued fraction expansion then the polynomial $P(s)$ is Hurwitz if the ratio of $P(s)$ and its derivative gives continued fraction expression.

Q: $P(s) = s^4 + s^3 + 5s^2 + 3s + 4$

$M(s) = s^4 + 5s^2 + 4$

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

$$\psi(s) = \frac{M(s)}{N(s)} = \frac{s^4 + 5s^2 + 4}{s^3 + 3s}$$

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$$
\begin{array}{l}
s^3 + 3s \,)\, \cancel{s^4} + 5s^2 + 4 \,(\, s \\
\qquad\qquad \cancel{s^4} + 3s^2 \\
\qquad\qquad - \quad - \\
\hline
\qquad\qquad 2s^2 + 4 \,)\, \cancel{s^3} + 3s \,(\, \tfrac{1}{2}s \\
\qquad\qquad\qquad\qquad \cancel{s^3} + 2s \\
\qquad\qquad\qquad\qquad - \quad - \\
\hline
\qquad\qquad\qquad\qquad s \,)\, 2s^2 + 4 \,(\, 2s \\
\qquad\qquad\qquad\qquad\quad -2s^2 \\
\hline
\qquad\qquad\qquad\qquad\quad 4 \,)\, s \,(\, \tfrac{1}{4}s \\
\qquad\qquad\qquad\qquad\qquad -s \\
\hline
\qquad\qquad\qquad\qquad\qquad 0
\end{array}
$$

It is Hurwitz since all the coefficients are +ve.

Q. $P(s) = s^4 + s^3 + 2s^2 + 4s + 1$

Sol^n- $M(s) = s^4 + 2s^2 + 1$

$N(s) = s^3 + \cancel{2}\, 4s$

$\psi(s) = \dfrac{M(s)}{N(s)}$

$$
\begin{array}{l}
s^3 + 4s \,)\, \cancel{s^4} + 2s^2 + 1 \,(\, s \\
\qquad\qquad \cancel{s^4} + 4s^2 \\
\qquad\qquad - \quad - \\
\hline
\qquad\qquad -2s^2 + 1 \,)\, s^3 + 4s \,(\, -\tfrac{1}{2}s \\
\qquad\qquad\qquad\qquad s^3 - \tfrac{1}{2}s \\
\hline
\qquad\qquad\qquad\qquad \tfrac{5}{2}s
\end{array}
$$

Since the quotient is -ve it is not Hurwitz

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Q. $P(s) = s^3 + 2s^2 + 3s + 6$

$M(s) = 2s^2 + 6$

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

$\psi(s) = \dfrac{N(s)}{M(s)}$

$$2s^2+6 \overline{)\, s^3 + 3s \,}\left(\tfrac{1}{2}s\right.$$
$$\underline{s^3 + 3s}$$
$$\times$$

~~Hurwitz~~ — $w(s) = s^3 + 3s$

$w'(s) = 3s^2 + 3$

$$3s^2+3 \overline{)\, s^3 + 3s \,}\left(\tfrac{1}{3}s\right.$$
$$\underline{s^3 + s}$$
$$2s \overline{)\, 3s^2 + 3 \,}\left(\tfrac{3}{2}s\right.$$
$$\underline{3s^2}$$
$$3 \overline{)\, 2s \,}\left(\tfrac{2}{3}s\right.$$
$$\underline{2s}$$
$$\times$$

Hurwitz ✓

Positive real Functions

These fns are imp. b'coz they represent physically relizable passive driving pt. immitance.
A fn $T(s) = \dfrac{N(s)}{D(s)}$ is +ve real if the following cond^n's are satisfied :

i) $T(s)$ is real for s real

ii) $D(s)$ is Hurwitz polynomial.

The necessary & sufficient $cond^n$ for fn $T(s)$ to be +ve, real if following are satisfied:

→ Denominator of $T(s)$ should be Hurwitz polynomial. This $cond^n$ is checked only when the poles of $T(s)$ are on $J(w)$ axis otherwise not.

→ $T(s)$ may only have simple poles on $J(w)$ axis with real & +ve residue.

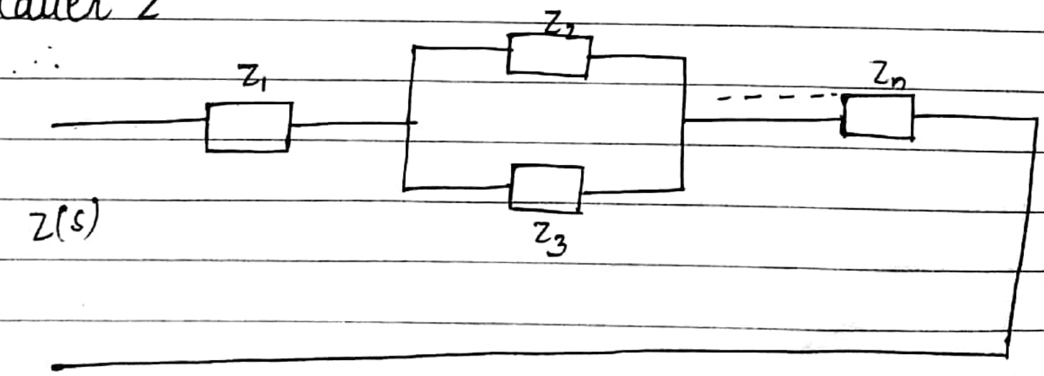
→ Real part of $T(jw) \geq 0$ for all w

Synthesis

→ Synthesizing the one port n/w with two kind of elements LC, RC, RL

→ There are various method for synthesizing one port n/w. We will focus on four basic form

i) Foster 1 ~~work~~ (Foster series form)
ii) Foster 2 (Foster parallel form)
iii) Cauer 1
iv) Cauer 2

i) 

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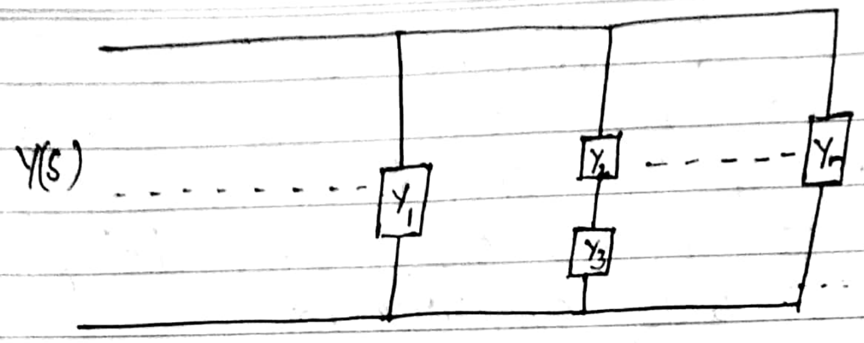

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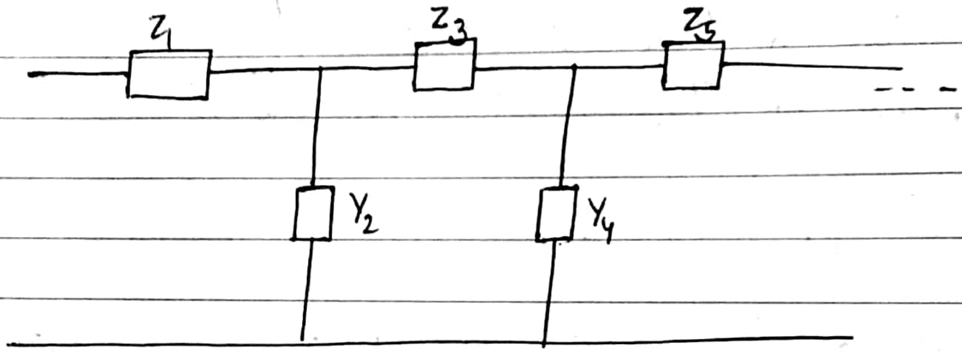

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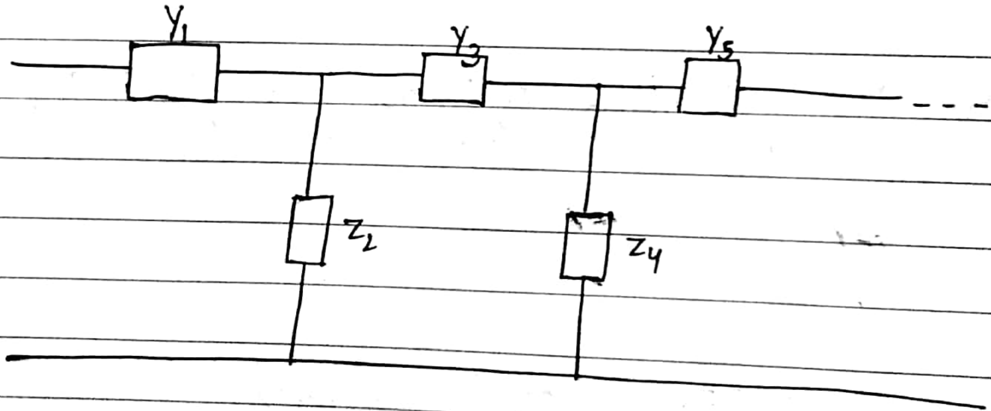

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Cauer 1

$$Z(s) = \frac{2(s^2+1)(s^2+9)}{s(s^2+4)} = \frac{2s^4+20s^2+18}{s^3+4s}$$

$$s^3+4s \;)\; 2s^4+20s^2+18 \;(\; \overset{L=2}{2s} \leftarrow Z_1$$

$$2s^4+8s^2$$

$$12s^2+18 \;)\; s^3+4s \;(\; \cancel{12s}\ s/12 \leftarrow Y_2$$

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

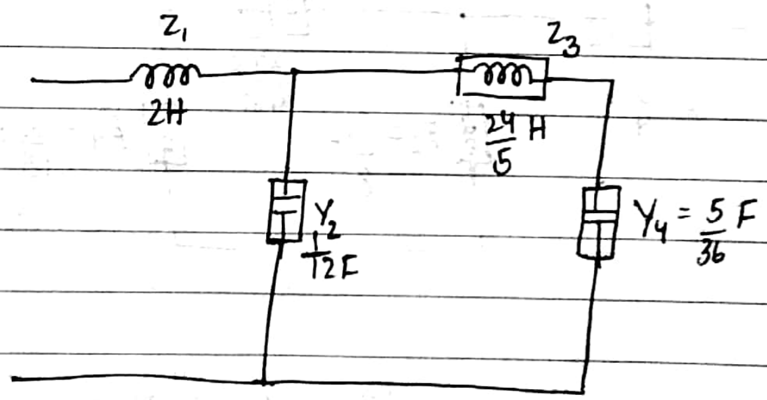
$$\frac{5}{2}s \;)\; 12s^2+18 \;(\; \frac{24}{5}s \leftarrow Z_3$$

$$12s^2$$

$$18 \;)\; \frac{5}{2}s \;(\; \frac{5}{36}s \leftarrow Y_4$$

$$\frac{5}{2}s$$

$$\times$$



$Y = Cs$

$Z = \frac{1}{Cs}$

Cauer 2

$$Z(s) = \frac{18+20s^2+2s^4}{4s+s^3}$$

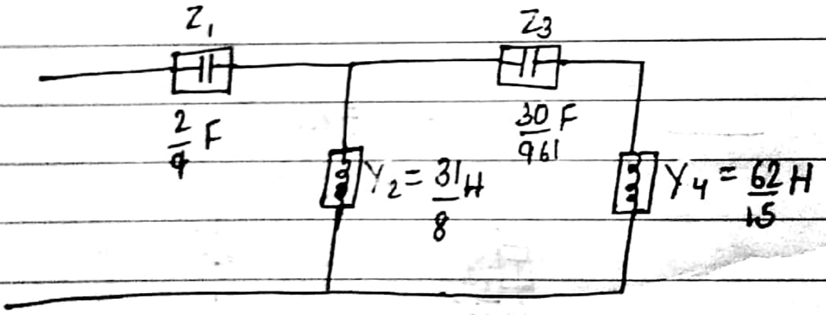
$$4s+s^3 \overline{)\, 18+20s^2+2s^4 \,}\left(\frac{9}{2s} \leftarrow Z_1\right.$$
$$18+\frac{9}{2}s^2$$

$$\frac{31}{2}s^2+2s^4 \overline{)\, 4s+s^3 \,}\left(\frac{8}{31s} \leftarrow Y_2\right.$$
$$4s+\frac{16}{31}s^3$$

$$\frac{15}{31}s^3 \overline{)\, \frac{31}{2}s^2+2s^4 \,}\left(\frac{961}{30s} \leftarrow Z_3\right.$$
$$\frac{31}{2}s^2$$

$$2s^4 \overline{)\, \frac{15}{31}s^3 \,}\left(\frac{15}{62s} \leftarrow Y_4\right.$$
$$\frac{15}{31}s^3$$

x



RC Impedance or RL admittance fn

The ~~false~~ poles & zeroes lie on -ve ~~zero~~ real axis including origin. of complex s plane.

The ~~false~~ poles & zeroes alternate along the -ve real axis

The residue of ~~false~~ poles ~~of Z(~~ Z_{RC} or Y_{RL} must be real & +ve

The singularity nearest to $-\infty$ must be zero. i.e fn of Z_{RC} or Y_{RL} is tends to 0 with s tends to ∞.

The singularity nearest to origin must be a pole

RL impedance or RC admittance fn

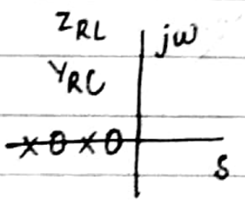
The poles & zeroes lie on -ve real axis including origin of complex s plane.

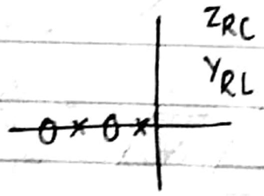
The poles & zeroes alternate along the -ve real axis.

The ~~reo~~ residue of the pole of ~~z~~ Y_{RC} or Z_{RL} must be real & +ve.

The singularity nearest to origin must be zero i.e. the fn Z_{RL} or Y_{RC} tends to 0 when $s \to 0$.

The singularity nearest to $-\infty$ must be a pole i.e fn Z_{RL} or Y_{RC} tends to ∞ when $s \to -\infty$





$$Z(s) = \frac{(s+1)(s+4)}{s(s+2)(s+5)}$$

Z_{RC}

Y_{RL}

Poles - 0, -2, -5

~~Origin~~ Zeroes -1, -4

HAPPY HALLOWEEN!

(2) $Z(s) = \dfrac{s(s+2)(s+5)}{(s+1)(s+4)}$ Z_{RC} Y_{RC}

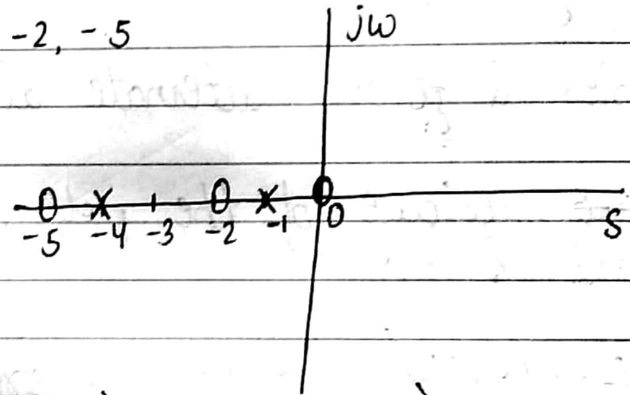
30/10/17

(1) $Z(s) = \dfrac{s(s+2)(s+5)}{(s+1)(s+4)}$

Solve
Foster 1
Foster 2

Sol^n- $P \Rightarrow -1, -4$

zeroes $\Rightarrow 0, -2, -5$



Z_{RL}

Y_{RC}

$$Z(s) = \frac{A(s+2)(s+1)(s+4) \; A - 4(s+2)}{(s+1)(s+4)}$$

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

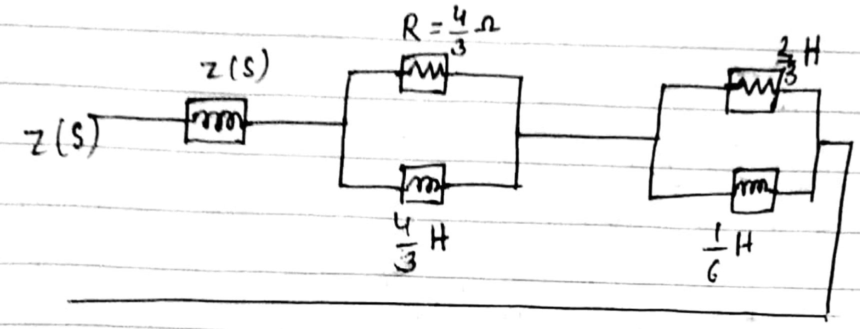
$$= s+2 - \frac{4}{3(s+1)} - \frac{8}{3(s+4)}$$

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

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

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

$$\frac{R \times LS}{R+LS} = \frac{RLS}{LS+R} = \frac{RLS}{L\left(S+\frac{R}{L}\right)} = \frac{RS}{S+\frac{R}{L}}$$



31/10/17

$$Z(s) = \frac{(s+1)(s+4)}{s(s+2)(s+5)}$$

Poles = 0, −2, −5

Zeroes = −1, −4

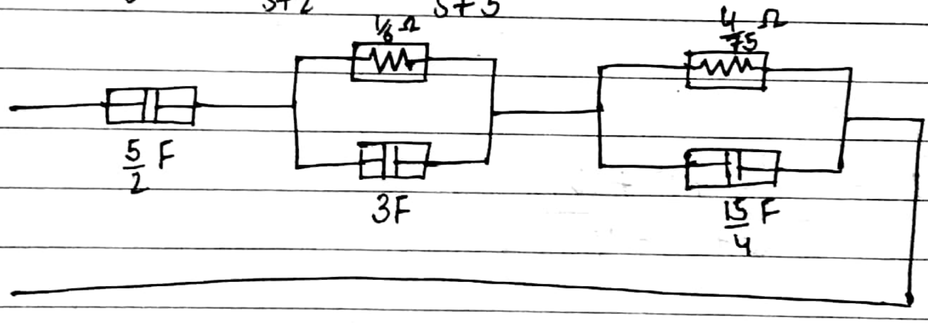
Z_{RC}

Y_{RL}

Foster 1

$$Z(s) = \frac{2/5}{s} + \frac{1/3}{s+2} + \frac{4/15}{s+5}$$

$$\frac{\frac{1}{CS} \times R}{\frac{1}{CS} + R} = \frac{\frac{1}{C}}{s+\frac{1}{RC}}$$



Foster 2

$$Y(s) = \frac{1}{Z(s)} = \frac{s(s+2)(s+5)}{(s+4)(s+1)}$$

Poles = −4, −1

Zeroes = 0, −2, −5

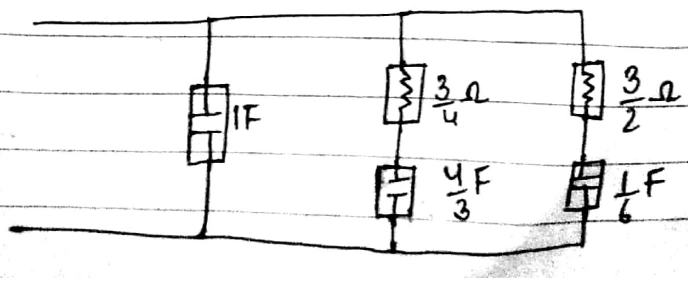
$$= \frac{s(s+2)(s+5)}{(s+1)(s+4)}$$

Z_{RL}

Y_{RC}

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

$$\cancel{\frac{RS}{S+\frac{R}{L}}} \quad \frac{\frac{1}{R}s}{s+\frac{1}{RC}}$$



$$\frac{Cs}{RCs+1} \qquad \frac{\cancel{C}s}{R\cancel{C}(s+\frac{1}{RC})} \qquad \frac{\frac{1}{R}s}{s+\frac{1}{RC}}$$

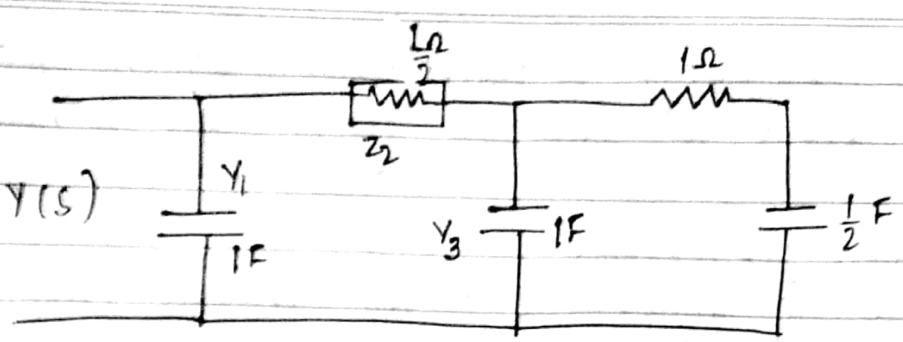
Cauer 1

$$Z(s) = \frac{s^2+5s+4}{s^3+7s^2+10s}$$

$$
\begin{array}{l}
s^3+7s^2+10s\,)\,s^2+5s+4\,(\frac{1}{s} \leftarrow Z_1 \\
\qquad\qquad s^2+7s+10 \\
\qquad\qquad \overline{-2s-6\,)\,s^3+7s^2+10s\,(-\frac{s^2}{2} \leftarrow Y_2} \\
\qquad\qquad\qquad s^3+3s^2 \\
\qquad\qquad\qquad \overline{4s^2+10s\,)\,-2s-6\,(\frac{-1}{2s} \leftarrow Z_3} \\
\qquad\qquad\qquad\qquad -2s-5 \\
\qquad\qquad\qquad\qquad \overline{-1\,)\,4s^2+10s\,(-4s^2 \leftarrow Y_4} \\
\qquad\qquad\qquad\qquad\qquad 4s^2 \\
\qquad\qquad\qquad\qquad\qquad \overline{10s\,)\,-1\,(\frac{-1}{10s} \leftarrow Z_5} \\
\qquad\qquad\qquad\qquad\qquad\qquad -1 \\
\qquad\qquad\qquad\qquad\qquad\qquad \overline{\times}
\end{array}
$$

$$Y(s) = \frac{s^3+7s^2+10s}{s^2+5s+4}$$

$$
\begin{array}{l}
s^2+5s+4\,)\,s^3+7s^2+10s\,(s \leftarrow Y_1 \\
\qquad\qquad s^3+5s^2+4s \\
\qquad\qquad \overline{2s^2+6s\,)\,s^2+5s+4\,(\frac{1}{2} \leftarrow Z_2} \\
\qquad\qquad\qquad s^2+3s \\
\qquad\qquad\qquad \overline{2s+4\,)\,2s^2+6s\,(s \leftarrow Y_3} \\
\qquad\qquad\qquad\qquad 2s^2+4s \\
\qquad\qquad\qquad\qquad \overline{2s\,)\,2s+4\,(1 \leftarrow Z_4} \\
\qquad\qquad\qquad\qquad\qquad 2s \\
\qquad\qquad\qquad\qquad\qquad \overline{4\,)\,2s\,(\frac{1s}{2} \leftarrow Y_5} \\
\qquad\qquad\qquad\qquad\qquad\qquad 2s \\
\qquad\qquad\qquad\qquad\qquad\qquad \overline{\times}
\end{array}
$$



Cauer 2

$\cancel{Z(s)} = Y(s) = \cancel{\frac{10s + 7s^2 + s^3}{4 + 5s + s^2}}$ $\qquad Z(s) = \frac{4+5s+s^2}{10s+7s^2+s^3}$

$\cancel{4+5s+s^2 \,\big)\, 10s + 7s^2 + s^3 \,\big(\, \frac{5}{2}s}$
$10s$

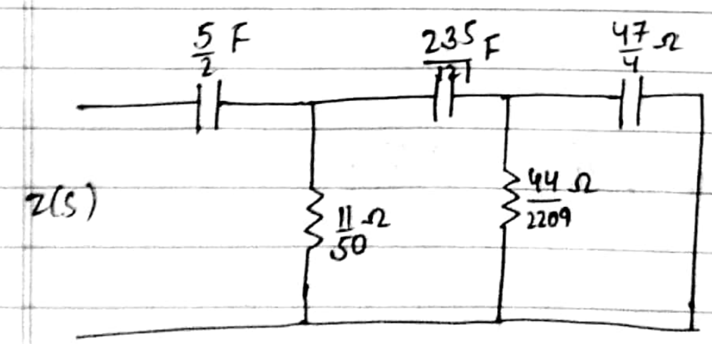
$10s + 7s^2 + s^3 \,\big)\, 4 + 5s + s^2 \,\big(\, \frac{4}{10s} \leftarrow Z_1$
$4 + \frac{14}{5}s + \frac{2}{5}s^2$

$\frac{11}{5}s + \frac{3}{5}s^2 \,\big)\, 10s + 7s^2 + s^3 \,\big(\, \frac{50}{11} \leftarrow Y_2$
$10s + \frac{30}{11}s^2$

$\frac{47}{11}s^2 + s^3 \,\big)\, \frac{11}{5}s + \frac{3}{5}s^2 \,\big(\, \frac{121}{235s} \leftarrow Z_3$
$\frac{11}{5}s + \frac{121}{235}s^2$

$\frac{4}{47}s^2 \,\big)\, \frac{47}{11}s^2 + s^3 \,\big(\, \frac{2209}{44} \leftarrow Y_4$
$\frac{47}{11}s^2$

$s^3 \,\big)\, \frac{4}{47}s^2 \,\big(\, \frac{4}{47s} \leftarrow Z_5$
$\frac{4}{47}s^2$
$\times$



Filter is frequency selective ckt which passes desired band of freq. & reject the others.

Parameters of filter:

1.) Characteristic impedance - The charac. impedance Z_c or Z_0 ~~must~~ of a filter must be chosen such that the filter may fit into a given line or ~~with~~ ~~w~~ between two type of equipments.

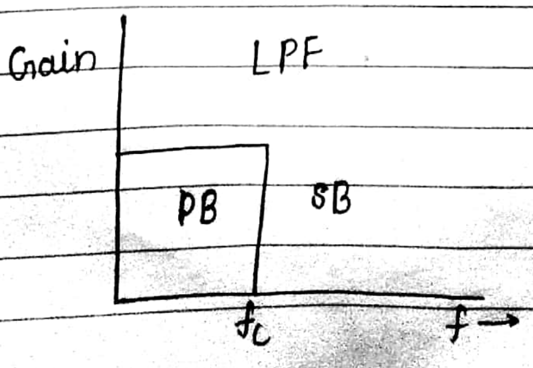
2.) Pass band: Band in which ideal filter have to pass all frequencies w/o reduction in magnitude are k/a pass band.

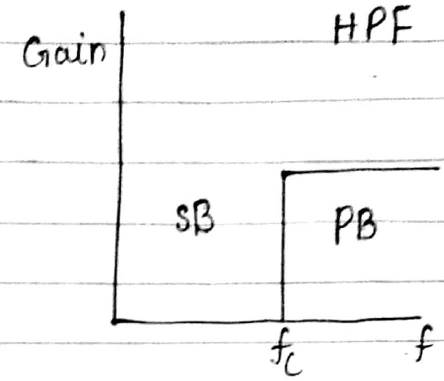
3.) Stop band: Band in which ideal filter have to attenuate all frequencies are k/a Stop band.

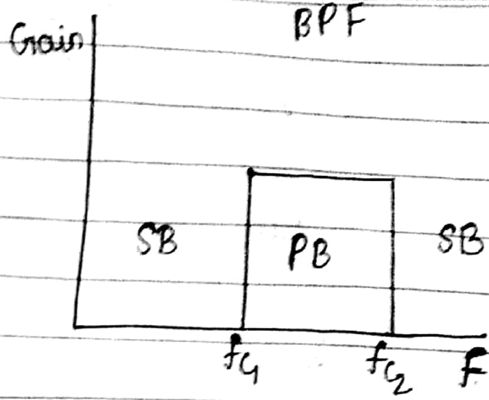
4.) ~~Cutt~~ Cut off frequency f_c : The freq. which separates pass band & stop band is defined as cut off freq. of the filter.

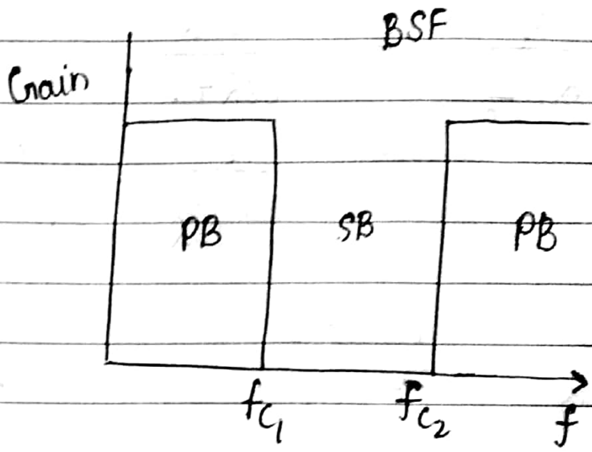
Classification of filter

- Low pass filter
- High pass filter
- Band pass filter
- Band stop or band reject filter









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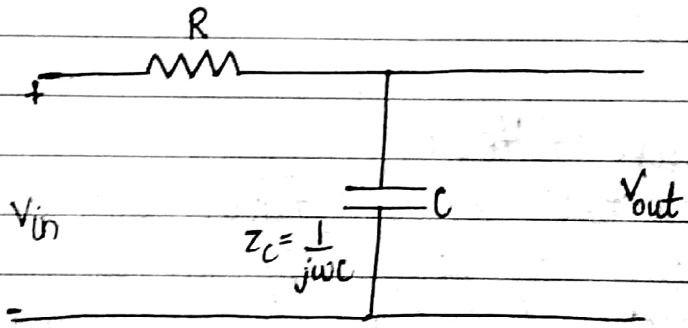
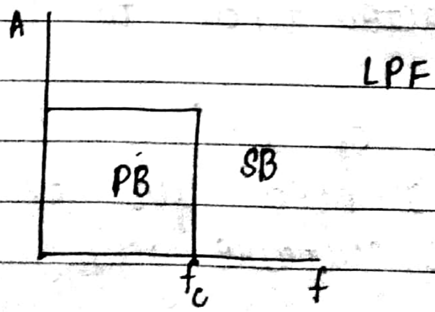


$f = 0$ $\quad V_{in} \simeq V_{out}$ $\quad Z_c = \infty$

$f = \infty$ $\quad V_{out} = 0$ $\quad Z_c = 0$



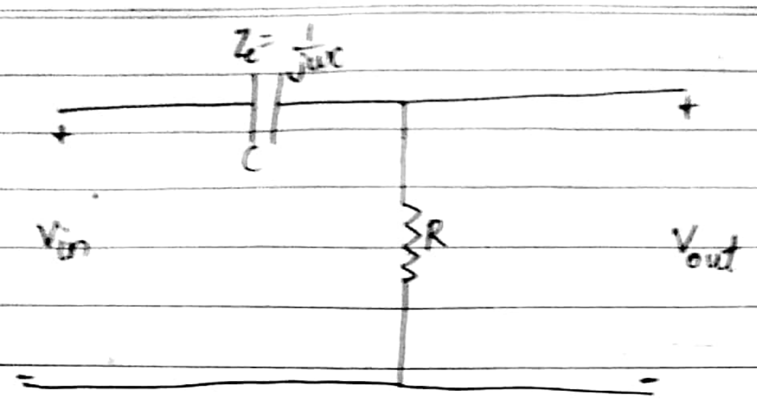
$f = 0$

$A = \dfrac{V_{out}}{V_{in}} = 1$

$$\text{Transfer function} = \frac{\frac{1}{CS}}{R + \frac{1}{CS}} = \frac{1}{RCS + 1}$$

$S = 0$ $\qquad\qquad S = \infty$

$TF = 1$ $\qquad\qquad TF = 0$

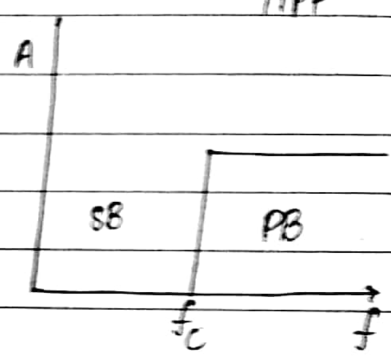


$f = 0 \quad Z_c = \infty \quad V_{out} = 0$
$f = \infty \quad Z_c = 0 \quad V_{out} = V_{in}$

$$TF = \frac{R}{R + \frac{1}{CS}} = \frac{CSR}{CSR + 1}$$

$$= \frac{1}{1 + \frac{1}{CSR}}$$

HPF



$S = 0 \quad TF = 0$
$S = \infty \quad TF = 1$

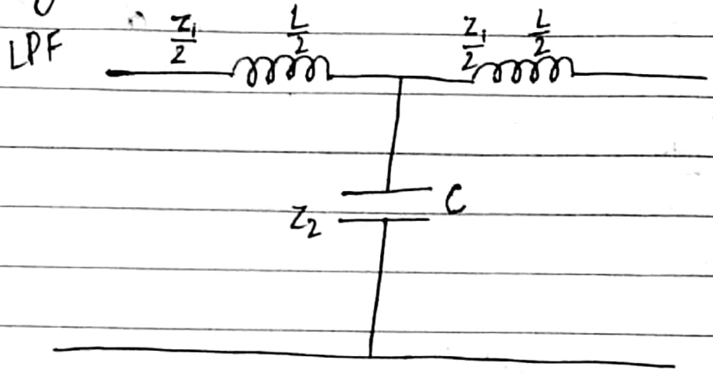
* Designing of filters
i) Passive filter
Limitation of passive filter:
a) The use of inductor as a filter element is not desirable especially at low freq. as at these frequencies practical inductors of reasonable Q (Quality) factor tends to become large, bulky and costly.
b) High range of Q-factor is not possible.
c) There is a need for an external ~~ampli~~ amplifier to provide suitable gain.

ii) Active filter
Active filter are being widely used in place of passive filters. Inductors cannot be fabricated with high quality of IC technology. So the RC ckt with active device replace the conventional LC filter &

provide the sharp cutoff in attenuation band.

Constant ~~Gain~~ K Low Pass filter

A n/w either T or π is said to be constant K type of Z_1 & Z_2 of a n/w if Z_1 & Z_2 satisfy the relation $Z_1 Z_2 = K^2 = R_0^2$

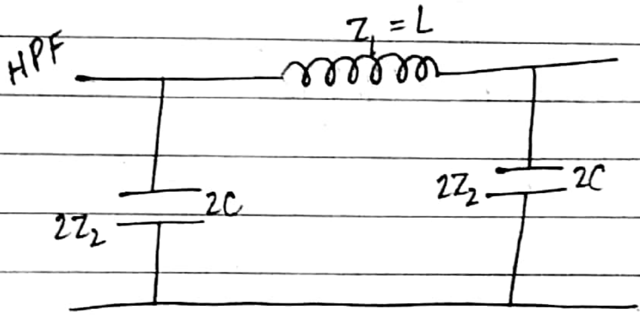


$Z_1 = j\omega L$

$Z_2 = \frac{1}{j\omega C}$

$Z_1 Z_2 = j\omega L \times \frac{1}{j\omega C} = \frac{L}{C} = K^2$

$R_0 = \sqrt{\frac{L}{C}}$



$\boxed{R_0 = \sqrt{\frac{L}{C}}}$ $\quad f_c = \frac{1}{\pi\sqrt{LC}}$

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

attenuation factor (in nepers)

Q. Design a LPF having cut off freq. of 1KHz to operate with terminate load Resistance of 200Ω. Find the freq. at which the filter offers the attenuation of 19.1 dB.

Solⁿ- $f_c = 1KHz$ $\quad R = 200\Omega$

$R = \sqrt{\frac{L}{C}} \Rightarrow 200 = \sqrt{\frac{L}{C}}$

$\sqrt{LC} = \frac{1}{\pi \times 1000} \Rightarrow C = \frac{1}{200 \times 1000 \times \pi} = 1.6 \times 10^{-6} F$

$= 1.6\ \mu F$

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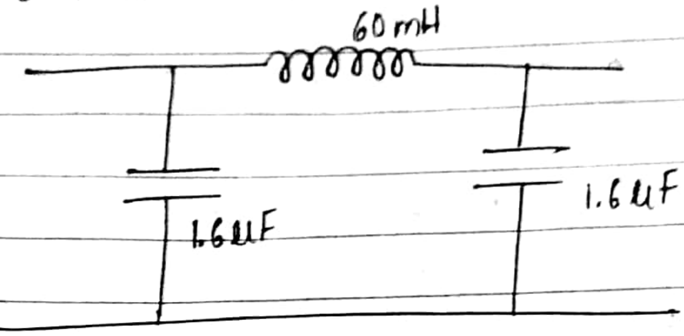
Date:

$L = 0.06H = 60mH$



$\frac{19.1}{2} = \cos^{-1}\left(\frac{f}{f_c}\right)$

α in $dB = 8.686 \times \alpha$ in nepers

$f = f_c \cos\left(\frac{19.1}{2}\right)$

$= 986.14\ Hz$

$\frac{19.1 \times 8.686}{2} = \cos^{-1}\left(\frac{f}{f_c}\right)$

$f = f_c \cos\left(19.1 \times 4.343\right)$

$= 122.71\ Hz$