UNIT - I

Network:- A N/w is interconnection of diff electrical components in any manner.

Classification of Networks:-

1. Active & passive N/ws
2. Linear & Non-linear N/ws
3. Unilateral & Bi-lateral N/ws
4. Symmetrical & Asymmetrical N/ws.
5. Lumped & Distributed N/ws
6. Recurrent & Non-recurrent N/ws
7. Balanced & Unbalanced N/ws.

1) **Active N/w:-** A N/w which consists sources of energy (or) A N/w which consists active elements like diodes & transistors etc.-

passive N/w:- A N/w which consists only passive elements like R, L, C is called a passive N/w.

2) **Linear & Non-linear Nws:-**

- A N/w which consists only linear elements is called a linear N/w

ex:- pure RLC N/w's

["Elements which obeys Ohm's law are called "Linear" elements] (ex: RLC)

- A N/W which consists non-linear elements like diodes, transistors etc is called non-linear N/w.

3) <u>Unilateral</u> & <u>Bi-lateral</u> <u>N/W</u> :-

- If the magnitude of the current is same after changing the polarity of the battery then such elements are called "Bilateral elements". (ex: RLC)

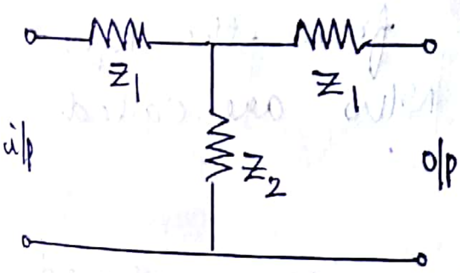
- otherwise the elements are called Unilateral elements. (ex: diodes, transistors etc)

- The N/W which consists only bilateral elements is called "Bilateral N/W" & otherwise Unilateral N/w.

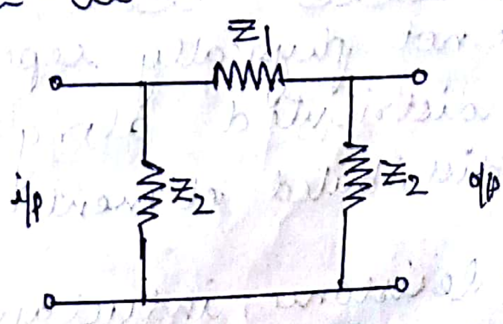
*4) <u>Symmetrical</u> & <u>Asymmetrical</u> <u>N/W's</u> :-

- A symmetrical N/W is a N/W in which the electrical properties doesn't change after interchanging its i/p & o/p terminals, is "Symmetrical N/w" otherwise the N/W is "Asymmetrical N/W".

<u>Examples of Symmetrical N/w's</u> :-

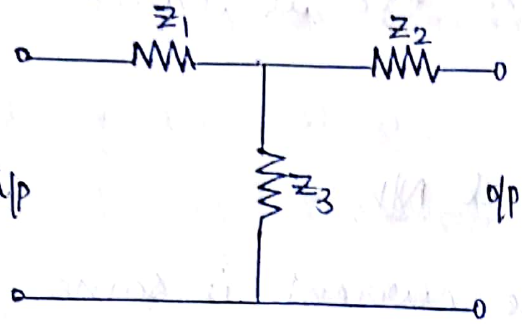


Symmetrical T-type

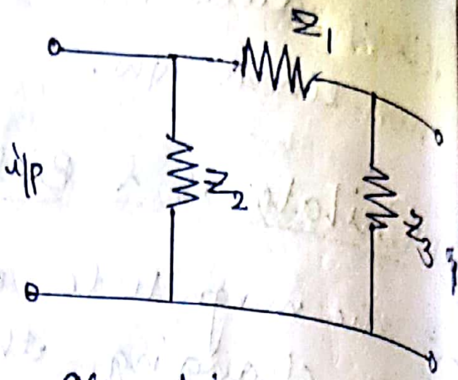


Symmetrical π-type

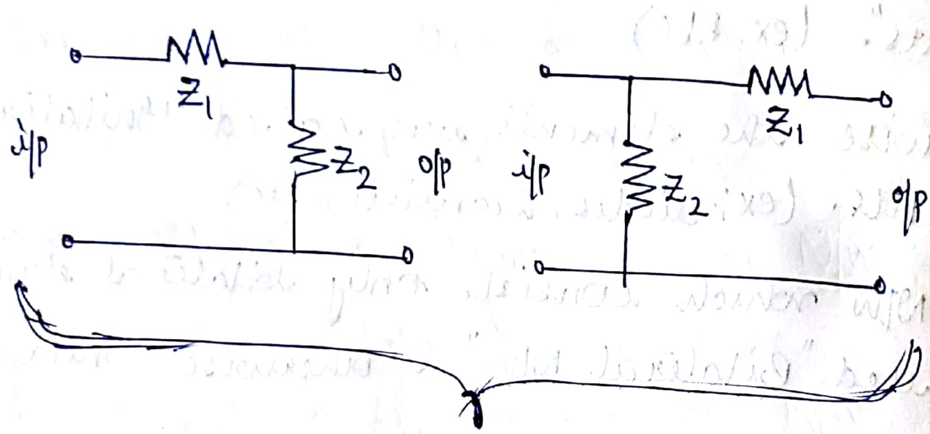
Examples of asymmetrical N/w's :-



asymmetrical T-type



asymetrical π-type



asymetrical L-type.

5.) Lumped & Distributed N/w's :-

- **Lumped Elements** :- An element which is physically seperable from the N/W is called lumped element.

ex:- discrete R, L, C components, diodes, transistors

- **Distributed Elements** :- The elements which are not physically seperable from the N/W & distributed along the N/W are called distributed elements.

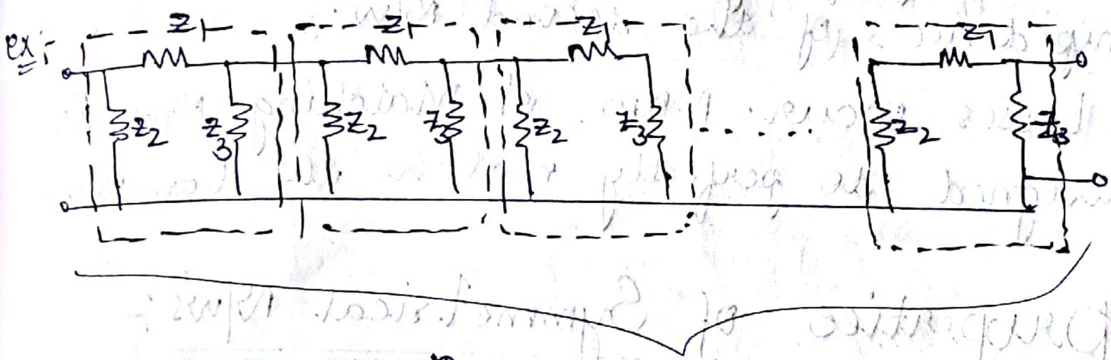
ex:- Resistance, inductance & capacitance offered by a transmission line.

6) Recurrent & Non-Recurrent N/w's:-

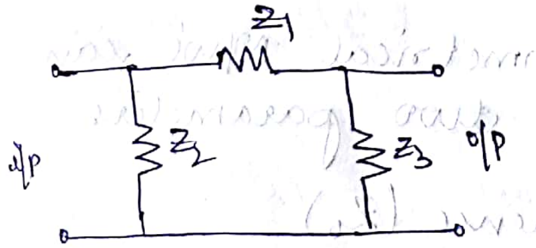
(cascaded) (or) (ladder)

- When a large ckt consists similar N/w's connected in series one after the other, then the N/w is called recurrent N/w otherwise it is non-recurrent N/w.

ex:-



Recurrent N/w.



Non-recurrent N/w [only single N/w]

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Functional classification of N/w:-

Depending on the purpose for which a N/w is designed, N/w's are classified into 4 types:-

1. Filters:- (unit-2): It is a N/w which allows a req'd (desired) frequencies & blocks the other frequencies.

2. Attenuators:- It is a N/w designed to reduce the i/p voltage by req'd amount (whatever may be the i/p frequency).

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3) Equalizer :- It is a N/w designed to counteract the (to regain the losses) attenuation & phase distortion occured.

4) Matching N/w :- At high frequencies reflection takes place if o/p impedence of the first N/w is not perfectly matched with the i/p impedence of the second N/w.

∴ Losses occur. Now, A Matching N/w is designed to perfectly match the two N/w's.

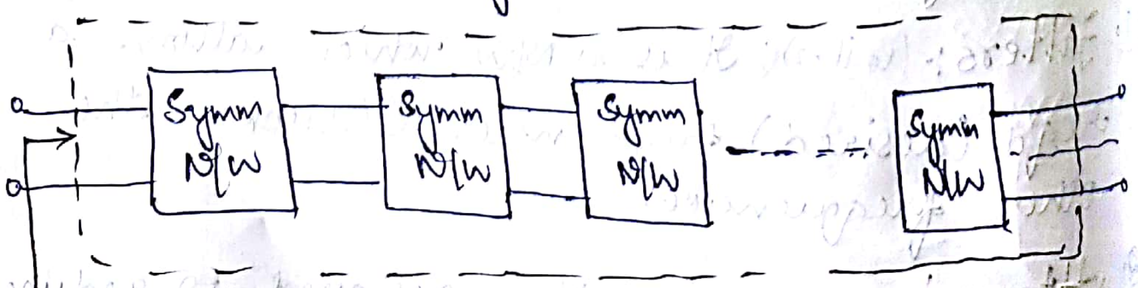
Properties of Symmetrical N/w's :-

The properties of Symmetrical N/w's can be described using two parameters

(i) Characteristic Impedence (Z_0)

(ii) Propagation Constant. (P or γ)

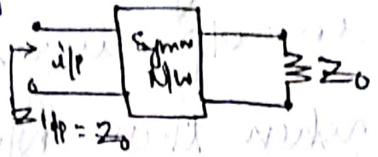
① Characteristic Impedence :- If ~~infinite~~ infinite no. of symmetrical N/w's cascaded, then the i/p impedence of first symmetrical N/w is "characteristic Impedence".



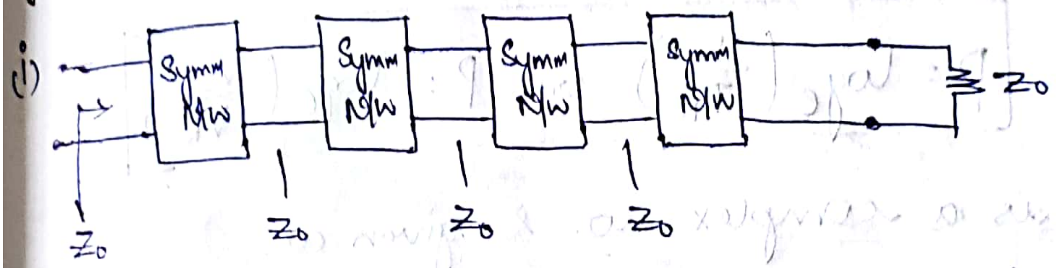
$Z_{i/p} = Z_0$ Infinite Symm. Cascade N/w

(Or)

→ The unique impedence of the Symm. N/w for which i/p impedence of the N/w becomes the load impedence is called "characteristic impedence Z_0".



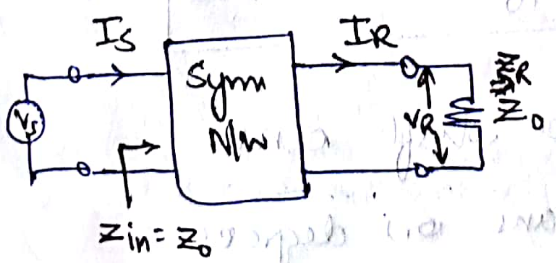
properties of Z_0:



i) If finite no. of similar symmetrical N/w's are cascaded & if last N/w terminated by Z_0 (characteristic impedence) then the impedence looking into any N/w is 'Z_0'.

units:- ohms

② propagation constant (P or γ):-



$V_S = I_S Z_{in} \Rightarrow V_S = I_S Z_0$

$V_R = I_R Z_R \Rightarrow V_R = I_R Z_0$

$$\boxed{\frac{V_S}{V_R} = \frac{I_S}{I_R}}$$

propagation constant of a symm. N/w is defined as the natural logarithm of ratio of input current to o/p current or i/p voltage to o/p voltage when the N/w is terminated by 'Z_0'

$$\boxed{P = \log_e\left(\frac{I_S}{I_R}\right) \text{ or } P = \log_e\left(\frac{V_S}{V_R}\right)}$$

'P' is a complex no. & given as:

$$\boxed{P = \alpha + j\beta}$$

$$\boxed{e^{P} = \frac{I_S}{I_R}}$$

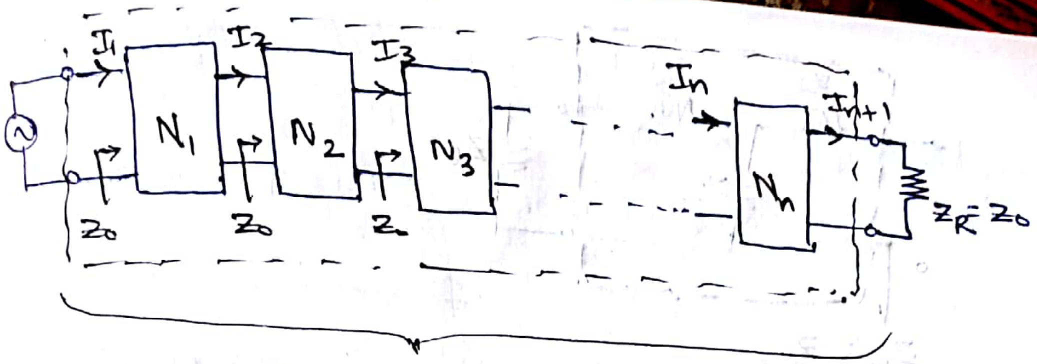
where (α) - attenuation const
units - Nepers or decibles

$$\boxed{1NP = 20\log_{10} e = 8.686dB}$$

& (β) - phase shift const
units - radians or degrees

$$\boxed{1 \text{ degree} = \frac{\pi}{180^\circ} \text{ rad}}$$

→ If 'n' identical symm. N/w's are cascaded & last N/w is terminated by Z_0 as shown in fig then



n-identical symm n/w's

1^{st} N/w $e^P = \frac{I_1}{I_2}$

2^{nd} N/w $e^P = \frac{I_2}{I_3}$

⋮

n^{th} N/w $e^P = \frac{I_n}{I_{n+1}}$

then $\frac{I_1}{I_{n+1}} = \frac{I_1}{I_2} \times \frac{I_2}{I_3} \times \frac{I_3}{I_4} \cdots \times \frac{I_n}{I_{n+1}}$

$= \underbrace{e^P \cdot e^P \cdot e^P \cdot \cdots \cdot e^P}_{n\text{-times}}$

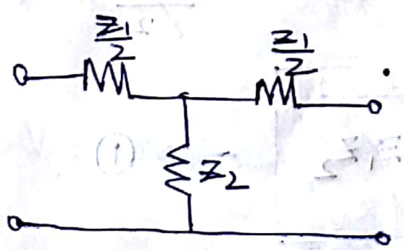
$\frac{I_1}{I_{n+1}} = e^{np}$

$\log_e e^x$

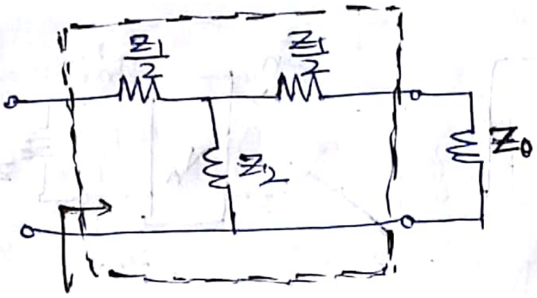
$$\boxed{\ln_e\left(\frac{I_1}{I_{n+1}}\right) = np \Rightarrow P = \frac{1}{n}\log_e\left(\frac{I_1}{I_{n+1}}\right)}$$

Analysis of Symmetrical T-N/w :-

Standard Symmetrical T-N/W :



(i) Characteristic Impedence : (Z_0) :-



$Z_{in} = Z_0$

$$Z_{in} = \frac{Z_1}{2} + \left(\frac{Z_1}{2} + Z_0\right) \parallel Z_2$$

if $Z_R = Z_0 \Rightarrow Z_{in} = Z_0$

$$Z_0 = \frac{Z_1}{2} + \frac{\left(\frac{Z_1}{2} + Z_0\right) Z_2}{\frac{Z_1}{2} + Z_2 + Z_0}$$

$$Z_0 = \frac{\frac{Z_1}{2}\left(\frac{Z_1}{2} + Z_2 + Z_0\right) + \left(\frac{Z_1}{2} + Z_0\right) Z_2}{\left(\frac{Z_1}{2} + Z_2 + Z_0\right)}$$

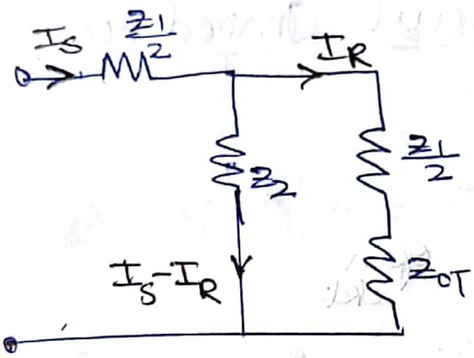
$$Z_0\left(\frac{Z_1}{2} + Z_2 + Z_0\right) = \frac{Z_1^2}{4} + \frac{Z_1 Z_2}{2} + \frac{Z_1 Z_0}{2} + \frac{Z_1 Z_2}{2} + Z_0 Z_2$$

$$\Rightarrow \cancel{\frac{Z_0 Z_1}{2}} + \cancel{Z_0 Z_2} + Z_0^2 = \frac{Z_1^2}{4} + Z_1 Z_2 + \cancel{\frac{Z_1 Z_0}{2}} + \cancel{Z_0 Z_2}$$

$$\boxed{Z_{0T} = \sqrt{\frac{Z_1^2}{4} + Z_1 Z_2}} \longrightarrow (1)$$

i) propagation Constant (P):-

W.K.T $\boxed{e^P = \frac{I_S}{I_R}}$



from the above fig

$$(I_S - I_R) Z_2 = \left(\frac{Z_1}{2} + Z_{OT}\right) I_R$$

$$I_S Z_2 = \left(\frac{Z_1}{2} + Z_{OT} + Z_2\right) I_R$$

$$\frac{I_S}{I_R} = e^P = \frac{\frac{Z_1}{2} + Z_{OT} + Z_2}{Z_2}$$

$$\frac{I_S}{I_R} = e^P = \frac{Z_1}{2Z_2} + \frac{Z_{OT}}{Z_2} + 1$$

$$\boxed{e^P = 1 + \frac{Z_1}{2Z_2} + \frac{Z_{OT}}{Z_2}} \longrightarrow 2a$$

sub eq 1 in 2a

$$e^P = 1 + \frac{Z_1}{2Z_2} + \frac{\sqrt{\frac{Z_1^2}{4} + Z_1 Z_2}}{Z_2}$$

$$e^P = 1 + \frac{Z_1}{2Z_2} + \sqrt{\frac{Z_1^2}{4Z_2^2} + \frac{Z_1 Z_2}{Z_2^2}}$$

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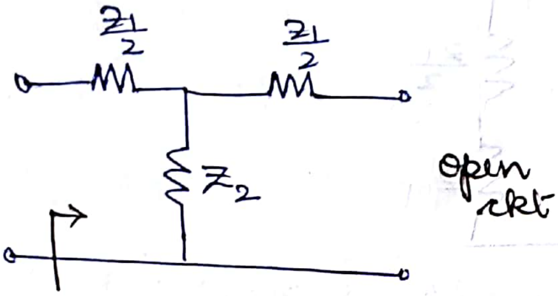
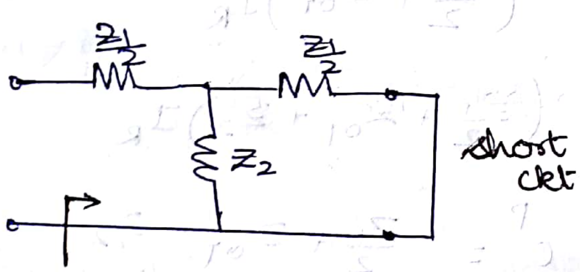
$$\boxed{e^{P} = 1 + \frac{Z_1}{2Z_2} + \sqrt{\frac{Z_1}{Z_2}\left[1 + \frac{Z_1}{4Z_2}\right]}} \rightarrow (26)$$

(iii) Open & Short Circuit Impedences :-



$Z_{in} = Z_{oc}$

fig. (a)



$Z_{in} = Z_{sc}$

fig. (b)

from fig (a) :

$$Z_{in} = Z_{oc} = \frac{Z_1}{2} + Z_2$$

from fig (b) :

$$Z_{in} = Z_{sc} = \frac{Z_1}{2} + \left(\frac{Z_1}{2} \| Z_2\right)$$

$$Z_{sc} = \frac{Z_1}{2} + \frac{\left(\frac{Z_1 Z_2}{2}\right)}{\frac{Z_1}{2} + Z_2}$$

$$Z_{sc} = \frac{\frac{Z_1}{2}\left(\frac{Z_1}{2} + Z_2\right) + \frac{Z_1 Z_2}{2}}{\left(\frac{Z_1}{2} + Z_2\right)}$$

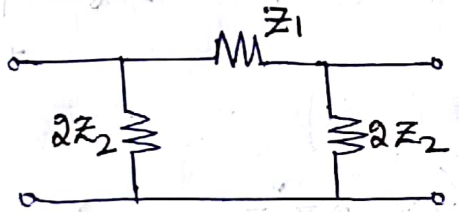
$$Z_{SC} \cdot \left(\frac{Z_1}{2} + Z_2\right) = \frac{Z_1^2}{4} + Z_1 Z_2$$

$$Z_{SC} \cdot Z_{OC} = Z_{OT}^2$$

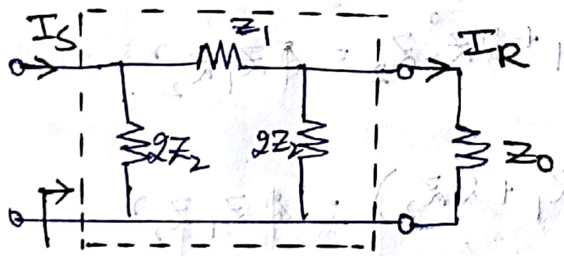
$$\boxed{Z_{OT} = \sqrt{Z_{OC} \cdot Z_{SC}}} \longrightarrow (3)$$

Analysis of Symmetrical π - N/w :-

standard Symm. π - N/w :



(i) Characteristic Impedence :- ($Z_{0\pi}$)



$$Z_{in} = \left[(2Z_2 \| Z_0) + Z_1\right] \| (2Z_2)$$

if $Z_R = Z_0$ then $Z_{in} = Z_0$

$$Z_0 = \frac{\left[\left(\frac{2Z_2 Z_0}{Z_0 + 2Z_2}\right) + Z_1\right](2Z_2)}{2Z_2 + Z_1 + \left(\frac{2Z_2 Z_0}{Z_0 + 2Z_2}\right)}$$

$$Z_0 = \frac{[(2Z_2Z_0 + Z_1Z_0 + 2Z_1Z_2)](2Z_2)}{[(2Z_2+Z_1)(Z_0+2Z_2) + 2Z_2Z_0]}$$

$$Z_0[(2Z_2+Z_1)(Z_0+2Z_2)+2Z_2Z_0] = [(2Z_2Z_0+Z_1Z_0+2Z_1Z_2)](2Z_2)$$

$$Z_0[(2Z_2+Z_1)(Z_0+2Z_2)+2Z_2Z_0] = 4Z_2^2Z_0 + 2Z_1Z_2Z_0 + 4Z_1Z_2^2$$

$$Z_0[2Z_0Z_2 + 4Z_2^2 + Z_0Z_1 + 2Z_1Z_2 + 2Z_2Z_0] = 4Z_2^2Z_0 + 2Z_1Z_2Z_0 + 4Z_1Z_2^2$$

$$\Rightarrow 2Z_0^2Z_2 + \cancel{4Z_0Z_2^2} + Z_0^2Z_1 + \cancel{2Z_0Z_1Z_2} + 2Z_0^2Z_2 = \cancel{4Z_2^2Z_0} + \cancel{2Z_1Z_2Z_0} + 4Z_1Z_2^2$$

$$2Z_2Z_0^2 + Z_0^2Z_1 + 2Z_0^2Z_2 = 4Z_1Z_2^2$$

$$Z_0^2(2Z_2 + Z_1 + 2Z_2) = 4Z_1Z_2^2$$

$$Z_0^2(4Z_2 + Z_1) = 4Z_1Z_2^2$$

$$4Z_0^2Z_2 + Z_1Z_0^2 = 4Z_1Z_2^2$$

$$Z_0^2 = \frac{4Z_1Z_2^2}{4Z_2 + Z_1}$$

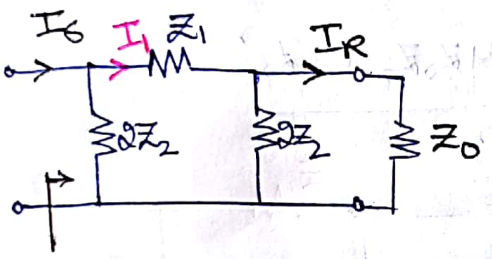
$$\cancel{Z_0^2 = Z_1Z_2 + 4Z_2^2}$$

$$Z_0 = \sqrt{\frac{4Z_1Z_2^2}{Z_1 + 4Z_2}}$$

$$Z_0 = \sqrt{\frac{\cancel{4} Z_1 Z_2}{\cancel{4} Z_2\left(1+\frac{Z_1}{4Z_2}\right)}}$$

$$\boxed{Z_{0\pi} = \sqrt{\frac{Z_1 Z_2}{\left(1+\frac{Z_1}{4Z_2}\right)}}} \rightarrow (4)$$

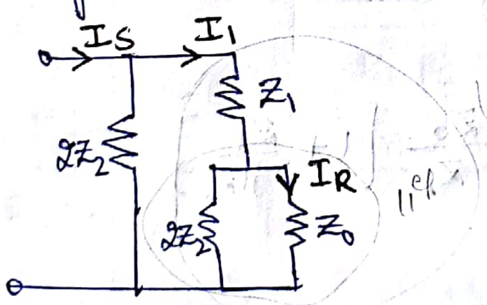
(ii) propagation constant :



$Z_{in} = Z_0$

W.K.T $\quad e^P = \frac{I_S}{I_R} \quad$ or $\quad P = \log_e\left(\frac{I_S}{I_R}\right)$

Redrawing the ckt



$$I_R = I_1\left(\frac{2Z_2}{Z_0+2Z_2}\right)$$

Finding I_1 in terms of I_S

$$I_1 = \frac{(2Z_2)}{2Z_2 + Z_1 + \left(\frac{2Z_2 Z_0}{Z_0+2Z_2}\right)} \cdot I_S$$

$$I_1 = \frac{(2Z_2)(Z_0+2Z_2)}{(Z_1+2Z_2)(Z_0+2Z_2)+2Z_0Z_2} \cdot I_S$$

sub I_1 in I_R. we get

$$I_R = \left[\frac{(2Z_2)\cancel{(Z_0+2Z_2)}}{(Z_1+2Z_2)(Z_0+2Z_2)+2Z_0Z_2}\right]\cdot\left[\frac{(2Z_2)}{\cancel{(Z_0+2Z_2)}}\right]I_s$$

$$I_R = \left[\frac{4Z_2^2}{Z_0Z_1+2Z_1Z_2+2Z_0Z_2+4Z_2^2+2Z_0Z_2}\right]\cdot I_s$$

$$\frac{I_s}{I_R} = \frac{Z_0Z_1+2Z_1Z_2+4Z_0Z_2+4Z_2^2}{4Z_2^2}$$

$$e^P = \frac{Z_0Z_1}{4Z_2^2}+\frac{2Z_1Z_2}{\underset{2}{4Z_2^2}}+\frac{4Z_0Z_2}{4Z_2^2}+1$$

$$e^P = 1+\frac{Z_1}{2Z_2}+\frac{Z_0}{Z_2}+\frac{Z_0Z_1}{4Z_2^2}$$

$$e^P = 1+\frac{Z_1}{2Z_2}+\frac{Z_0}{Z_2}\left[1+\frac{Z_1}{4Z_2}\right]$$

$$e^P = 1+\frac{Z_1}{2Z_2}+Z_0\left[\frac{1}{Z_2}+\frac{Z_1}{4Z_2^2}\right]$$

$$e^P = 1+\frac{Z_1}{2Z_2}+Z_0\left[\frac{4Z_2+Z_1}{4Z_2^2}\right]$$

$$e^P = 1+\frac{Z_1}{2Z_2}+\frac{Z_0}{4Z_2^2}(Z_1+4Z_2)$$

$$e^{P} = 1 + \frac{Z_1}{2Z_2} + \left(\sqrt{\frac{4Z_1Z_2^2}{Z_1+4Z_2}}\right)\left(\frac{Z_1+4Z_2}{4Z_2^2}\right) \quad \left[\because \text{From eqn } ②\right]$$

$$e^{P} = 1 + \frac{Z_1}{2Z_2} + \sqrt{\frac{\cancel{4}Z_1\cancel{Z_2^2}}{\cancel{(Z_1+4Z_2)}} \cdot \frac{(Z_1+4Z_2)^{\cancel{2}}}{(\cancel{4}Z_2^{\cancel{2}})^2}}$$

$$e^{P} = 1 + \frac{Z_1}{2Z_2} + \sqrt{\frac{Z_1(Z_1+4Z_2)}{4Z_2^2}}$$

$$e^{P} = 1 + \frac{Z_1}{2Z_2} + \sqrt{\frac{Z_1^2+4Z_1Z_2}{4Z_2^2}}$$

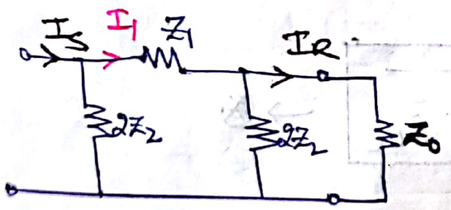
$$e^{P} = 1 + \frac{Z_1}{2Z_2} + \sqrt{\frac{Z_1^2}{4Z_2^2} + \frac{\cancel{4}Z_1\cancel{Z_2}}{\cancel{4}Z_2^{\cancel{2}}}}$$

$$\boxed{e^{P} = 1 + \frac{Z_1}{2Z_2} + \sqrt{\frac{Z_1}{Z_2}\left[1 + \frac{Z_1}{4Z_2}\right]}} \longrightarrow ⑤$$

*$\boxed{\text{NOTE}}$:-

The above eqn ⑤ is similar to eqn ②b i.e propagation constant of symm. T & π N/w are 'same' but characteristic may change

iii) Open & Short circuit Impedence :-



open ckt   short ckt

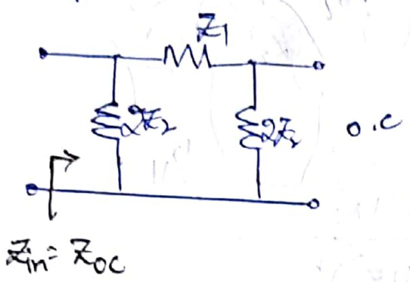


fig (a)

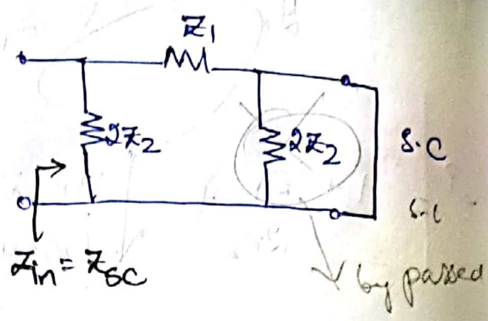


fig (b)

From fig (a):-

$$Z_{in} = Z_{oc} = \frac{(2Z_2)(Z_1 + 2Z_2)}{Z_1 + 4Z_2}$$

From fig (b):-

$$Z_{in} : Z_{sc} = \frac{(Z_1)(2Z_2)}{(Z_1 + 2Z_2)}$$

Now,

$$Z_{oc} \cdot Z_{sc} = \left[\frac{(2Z_2)\cancel{(Z_1 + 2Z_2)}}{(Z_1 + 4Z_2)}\right] \cdot \left[\frac{(Z_1)(2Z_2)}{\cancel{(Z_1 + 2Z_2)}}\right]$$

$$Z_{sc} \cdot Z_{oc} = \frac{4Z_1 Z_2^2}{(Z_1 + 4Z_2)}$$

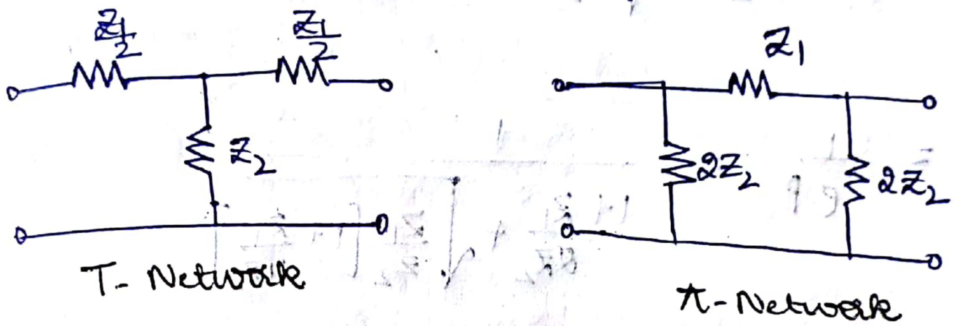
$$Z_{sc} \cdot Z_{oc} = Z_{o\pi}^2$$

$$\boxed{\therefore Z_{o\pi} = \sqrt{Z_{sc} \cdot Z_{oc}}} \rightarrow \otimes$$

*NOTE :-

→ For any Symm. N/w characteristic Impedance 'Z_0' is geometric mean of O.C & S.C impedances (i.e Z_{oc} & Z_{sc})

Relation between Z_{0T} & $Z_{0\pi}$:-



$$Z_{0T} = \sqrt{\frac{Z_1^2}{4} + Z_1 Z_2} \qquad Z_{0\pi} = \sqrt{\frac{4Z_1 Z_2^2}{Z_1 + 4Z_2}}$$

Now, consider;

$$Z_{0\pi} = \sqrt{\frac{4Z_1 Z_2^2}{(Z_1+4Z_2)} \times \frac{Z_1}{Z_1}}$$

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

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

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

$$\boxed{Z_{0\pi} \cdot Z_{0T} = Z_1 Z_2} \rightarrow (6)$$

***

Design of Symmetrical T-N/W when Z_{OT} & P are given :-

W.K.T

$$e^{P} = 1 + \frac{Z_1}{2Z_2} + \sqrt{\frac{Z_1}{Z_2}\left[1 + \frac{Z_1}{4Z_2}\right]}$$

$$e^{-P} = \frac{1}{e^{P}} \Rightarrow \frac{1}{1 + \frac{Z_1}{2Z_2} + \sqrt{\frac{Z_1}{Z_2}\left[1 + \frac{Z_1}{4Z_2}\right]}}$$

Rationalising

$$e^{-P} = \frac{1}{1 + \frac{Z_1}{2Z_2} + \sqrt{\frac{Z_1}{Z_2}\left[1 + \frac{Z_1}{4Z_2}\right]}} \times \frac{\left(1 + \frac{Z_1}{2Z_2}\right) - \sqrt{\frac{Z_1}{Z_2}\left[1 + \frac{Z_1}{4Z_2}\right]}}{\left(1 + \frac{Z_1}{2Z_2}\right) - \sqrt{\frac{Z_1}{Z_2}\left[1 + \frac{Z_1}{4Z_2}\right]}}$$

$$= \frac{\left(1 + \frac{Z_1}{2Z_2}\right) - \sqrt{\frac{Z_1}{Z_2}\left[1 + \frac{Z_1}{4Z_2}\right]}}{\left(1 + \frac{Z_1}{2Z_2}\right)^2 - \left(\sqrt{\frac{Z_1}{Z_2}\left[1 + \frac{Z_1}{4Z_2}\right]}\right)^2}$$

$$= \frac{\left(1 + \frac{Z_1}{2Z_2}\right) - \sqrt{\frac{Z_1}{Z_2}\left(1 + \frac{Z_1}{4Z_2}\right)}}{1 + \cancel{\frac{Z_1^2}{4Z_2^2}} + \cancel{2}(1)\left[\cancel{\frac{Z_1}{2Z_2}}\right] - \cancel{\frac{Z_1}{Z_2}} - \cancel{\frac{Z_1^2}{4Z_2^2}}}$$

$$\boxed{e^{-P} = \left(1 + \frac{Z_1}{2Z_2}\right) - \sqrt{\frac{Z_1}{Z_2}\left[1 + \frac{Z_1}{4Z_2}\right]}}$$

W.K.T

$$\cosh(p) = \frac{e^{p}+e^{-p}}{2} \quad \& \quad \sinh(p) = \frac{e^{p}-e^{-p}}{2}$$

$$\Rightarrow \cosh(p) = \frac{\cancel{2}\left(1+\frac{Z_1}{2Z_2}\right)}{\cancel{2}}$$

$$\boxed{\cosh(p) = 1+\frac{Z_1}{2Z_2}} \rightarrow (7)$$

$$\Rightarrow \sinh(p) = \frac{\cancel{2}\sqrt{\frac{Z_1}{Z_2}\left[1+\frac{Z_1}{4Z_2}\right]}}{\cancel{2}}$$

$$\sinh(p) = \sqrt{\frac{Z_1}{Z_2}+\frac{Z_1^2}{4Z_2^2}}$$

$$\sinh(p) = \frac{\sqrt{Z_1Z_2+\frac{Z_1^2}{4}}}{Z_2}$$

$$\boxed{\sinh(p) = \frac{Z_{OT}}{Z_2}} \rightarrow (8)$$

Also W.K.T

$$\cosh(p) = \cosh^2(p/2)+\sinh^2(p/2)$$

$$\cosh(p) = 1+2\sinh^2(p/2)$$

Now, from eqn (7)

$$\cancel{1}+\frac{Z_1}{2Z_2} = \cancel{1}+2\sinh^2(p/2)$$

$$\boxed{\sinh(p/2) = \sqrt{\frac{Z_1}{4Z_2}}} \rightarrow (9a)$$

Now, consider

$$\sinh(P) = 2\sinh(P/2)\cdot\cosh(P/2)$$

From eqn 8 & 9a

$$\frac{Z_{OT}}{Z_2} = \cancel{2}\sqrt{\frac{Z_1}{\cancel{4}Z_2}}\cdot\cosh(P/2)$$

$$\cosh(P/2) = \frac{Z_{OT}}{Z_2}\cdot\sqrt{\frac{Z_2}{Z_1}}$$

$$\cosh(P/2) = Z_{OT}\cdot\sqrt{\frac{\cancel{Z_2}}{Z_1 Z_2^{\cancel{2}}}}$$

$$\boxed{\cosh(P/2) = \frac{Z_{OT}}{\sqrt{Z_1 Z_2}}} \longrightarrow 9b$$

$$\tanh(P/2) = \frac{\sinh(P/2)}{\cosh(P/2)}$$

$$= \sqrt{\frac{Z_1}{4Z_2}}\cdot\frac{\sqrt{Z_1 Z_2}}{Z_{OT}}$$

$$= \frac{1}{Z_{OT}}\cdot\sqrt{\frac{Z_1^2\cancel{Z_2}}{4\cancel{Z_2}}}$$

$$= \frac{1}{2Z_{OT}}\cdot Z_1$$

$$\boxed{\tanh(P/2) = \frac{Z_1}{2Z_{OT}}} \longrightarrow 9c$$

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∴ From eq'n 8 & 9c

$$\boxed{Z_1 = 2Z_{OT} \cdot \tanh(P/2)}$$

$$\boxed{Z_2 = \frac{Z_{OT}}{\sinh(P)}} \longrightarrow 10$$

Design of Symmetrical π-N/W when $Z_{O\pi}$ & P are given:-

W.K.T from eq'n 6 & 10

$$Z_{O\pi} \cdot Z_{OT} = Z_1 Z_2 \quad - 6$$

$$Z_{OT} = \frac{Z_1 Z_2}{Z_{O\pi}}$$

From 10 → $Z_1 = 2Z_{OT} \cdot \tanh(P/2)$

sub Z_{OT}

$$\cancel{Z_1} = 2\left[\frac{\cancel{Z_1}Z_2}{Z_{O\pi}}\right] \cdot \tanh(P/2)$$

$$\boxed{Z_2 = \frac{Z_{O\pi}}{2\tanh(P/2)}}$$

$\Rightarrow Z_2 = \frac{Z_{OT}}{\sinh(P)}$

$$\text{ly} \quad \cancel{Z_2} = \frac{Z_1 \cancel{Z_2}}{(Z_{O\pi})\sinh(P)}$$

$$\boxed{Z_1 = Z_{O\pi} \sinh P}$$

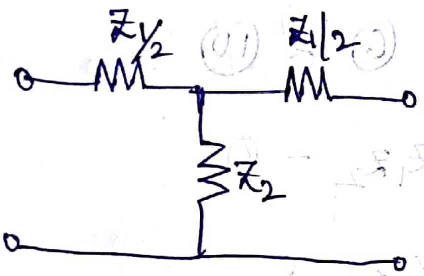
∴ For Symm. π - N/W

$$\boxed{Z_1 = Z_{o\pi} \sinh(P)}$$

$$\boxed{Z_2 = \frac{Z_{o\pi}}{2\tanh(P/2)}} \longrightarrow (11)$$

Relation between P, Z_{SC} & Z_{oc} :-

consider T-N/W



$$Z_{oc} = \frac{Z_1}{2} + Z_2 \Rightarrow Z_{oc} = \frac{Z_1 + 2Z_2}{2}$$

From eqn (7) & (8) we have

$$\cosh(P) = 1 + \frac{Z_1}{2Z_2}, \quad \sinh(P) = \frac{Z_{oT}}{Z_2}$$

$$\tanh(P) = \frac{\sinh(P)}{\cosh(P)} = \frac{Z_{oT}}{Z_2} \cdot \left[\frac{2Z_2}{Z_1 + 2Z_2}\right]$$

$$= Z_{oT}\left[\frac{1}{Z_{oc}}\right]$$

W.K.T

$$Z_{oT} = \sqrt{Z_{oc} \cdot Z_{sc}}$$

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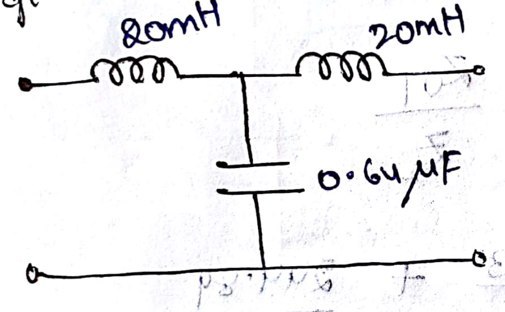
$$\tanh(p) = \sqrt{Z_{oc} \cdot Z_{sc}} \left[\frac{1}{Z_{oc}}\right]$$

$$= \sqrt{\frac{Z_{oc} \cdot Z_{sc}}{Z_{oc}^2}}$$

$$\boxed{\tanh(p) = \sqrt{\frac{Z_{sc}}{Z_{oc}}}} \rightarrow (12)$$

problems:-

Ex-1:- Find the propagation const & characteristic impedence of symm. T- N/W given at 400Hz given below:



sol:- $\frac{Z_1}{2} = \cancel{80mH}\ j\omega L$

$Z_1 = 2j \times 2\pi \times 400 \times 20 \times 10^{-3}$

$\boxed{Z_1 = j\,100.53\,\Omega}$

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

$Z_2 = \frac{1}{j \times 2\pi \times 400 \times 0.64 \times 10^{-6}}$

$\boxed{Z_2 = -j621.699\,\Omega}$

Characteristic Impedence is

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

$$= \sqrt{\frac{(j100.53)^2}{4} + (j100.53)(-j621.6991)}$$

$$\boxed{Z_{OT} = 244.89\ \Omega}$$

propagation const is

$$e^P = 1 + \frac{Z_1}{2Z_2} + \frac{Z_{OT}}{Z_2}$$

$$= 1 + \frac{j100.53}{2(-j621.69)} + \frac{244.89}{(-j621.69)}$$

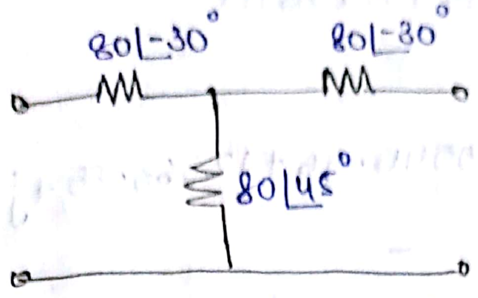
$$e^P = 0.9192 + j0.3939$$

$$\boxed{\ln[r\angle\theta^\circ] = \ln r + \left[\theta \times \frac{\pi}{180^\circ} + 2n\pi\right]}$$

$$= \ln(1) + \left[(23.19) \times \frac{\pi}{180^\circ} + 2n\pi\right]$$

$$P = 0 + [0.404 + 2n\pi]$$

Ex-2:- Calculate the characteristic impedance & propagation constant of the symm T-n/w given below.



Sol:- $\frac{Z_1}{2} = 80\angle{-30^\circ}$

$Z_1 = (2\angle 0^\circ)(80\angle{-30^\circ})$

$Z_1 = 160\angle{-30^\circ}$

$\boxed{Z_1 = 138.56 - j80}$

$Z_2 = 80\angle 45^\circ$

$\boxed{Z_2 = 56.56 + j56.56}$

Characteristic Imp:

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

$Z_{OT} = \sqrt{\frac{(160\angle{-30^\circ})^2}{4\angle 0^\circ} + (160\angle{-30^\circ})(80\angle 45^\circ)}$

$Z_{OT} = \sqrt{\frac{160 \times \cancel{160}^{\,40}\angle{-60^\circ}}{\cancel{4}} + 12800\angle 15^\circ}$

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$$= \sqrt{160 \times 40 \angle -60^\circ + 12800 \angle 15^\circ}$$

$$= \sqrt{6400 \angle -60^\circ + 12800 \angle 15^\circ}$$

$$= \sqrt{3200 - j5540.56 + 12363.85 + j3312.88}$$

$$= \sqrt{15722.06 \angle -8.152^\circ}$$

$$\boxed{\sqrt{r \angle \theta} = \sqrt{r} \cdot \angle \theta/2}$$

$$\boxed{Z_{OT} = 125.39 \angle -4.076^\circ}$$

prop. const is

$$e^P = 1 + \frac{Z_1}{2Z_2} + \frac{Z_{OT}}{Z_2}$$

$$= 1 + \frac{\cancel{160} \angle -30^\circ}{\cancel{160} \angle 45^\circ} + \frac{125.39 \angle -4.076}{80 \angle 45^\circ}$$

$$= 1 + 1 \angle -75^\circ + 1.56 \angle -49.076$$

$$= 1 + 0.258 - j0.965 + 1.026 - j1.184$$

$$e^P = 2.284 - j2.15$$

$$e^P = 3.138 \angle -43.25^\circ$$

$$p = \ln\left[3.138 \angle -43.25^\circ\right]$$

$$p = \ln(3.138) + j\left[-43.25 \times \frac{\pi}{180^\circ} + 2n\pi\right]$$

$$p = 1.14 + j\left[-0.7548 + 2n\pi\right]$$

$$p = \alpha + j\beta$$

$$\therefore p = 1.14 + j\left[-0.7548 + 2n\pi\right]$$

for $n = 0$; $\beta = -0.7548$ Invalid

$n = 1$; $\beta = -0.7548 + 2\pi = 5.528$

$$\therefore \boxed{\alpha = 1.14\,Np} \;\&\; \boxed{\beta = 5.528\,rad}$$

Ex-3:- A symm. T-N/w with unknown elements yields the following measurements

$Z_{OC} = (750 + j0)\Omega$; $Z_{SC} = (270 + j0)\Omega$

Determine the characteristic imp. (Z_{0T}), prop. const (p) & also series & shunt arm impedences.

Sol: $Z_{0T} = \sqrt{Z_{SC} \cdot Z_{OC}}$

$$= \sqrt{750 \cdot 270}$$

$$\boxed{Z_{0T} = 450\,\Omega}$$

(ii) $\tanh(p) = \sqrt{\frac{Z_{sc}}{Z_{oc}}}$

$p = \tanh^{-1}\sqrt{\frac{750}{250}}$

$\boxed{p = 0.693}$

$\frac{e^{p} - e^{-p}}{e^{p} + e^{-p}} = \frac{0.6}{1}$

componendo & dividendo

$\frac{e^{p} - \cancel{e^{-p}} + e^{p} + \cancel{e^{-p}}}{\cancel{e^{p}} - e^{-p} - \cancel{e^{p}} - e^{-p}} = \frac{0.6+1}{0.6-1}$

$\frac{\cancel{2}e^{p}}{\cancel{-2}e^{-p}} = \frac{1.6}{\cancel{-}0.4}$

$e^{2p} = 4$

$2p = \ln 4$

$p = \frac{\ln 4}{2}$

$\boxed{p = 0.693}$

(iii) $Z_1 = 2 Z_{OT} \times \tanh(p/2)$

$Z_2 = \frac{Z_{OT}}{\sinh(p)}$

$Z_1 = 2 \times 450 \times \tanh\left(\frac{0.693}{2}\right)$

$\boxed{Z_1 = 300\,\Omega}$

$Z_2 = \frac{Z_{OT}}{\sinh(p)} = \frac{450}{\sinh(0.693)}$

$\boxed{Z_2 = 600.14\,\Omega}$

$\frac{Z_1}{2} = \frac{300}{2}$

Ex-4:- Design a symm. π-n/w having o.c & s.c impedences as $375\,\Omega$, $240\,\Omega$ respectively. Also find char. Imp & P.

sol:- $Z_{OC} = 375\,\Omega$, $Z_{SC} = 240$

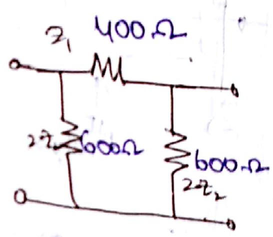
$$Z_{0\pi} = \sqrt{Z_{SC} \cdot Z_{OC}}$$

$$\boxed{Z_{0\pi} = 300\,\Omega}$$

ii) $$\tanh(p) = \sqrt{\frac{Z_{SC}}{Z_{OC}}}$$

$$p = \tanh^{-1}\sqrt{\frac{240}{375}}$$

$$\boxed{P = 1.098}$$



iii) $\cancel{Z_1 = 2Z_{0T} \times \tanh(p/2)}$

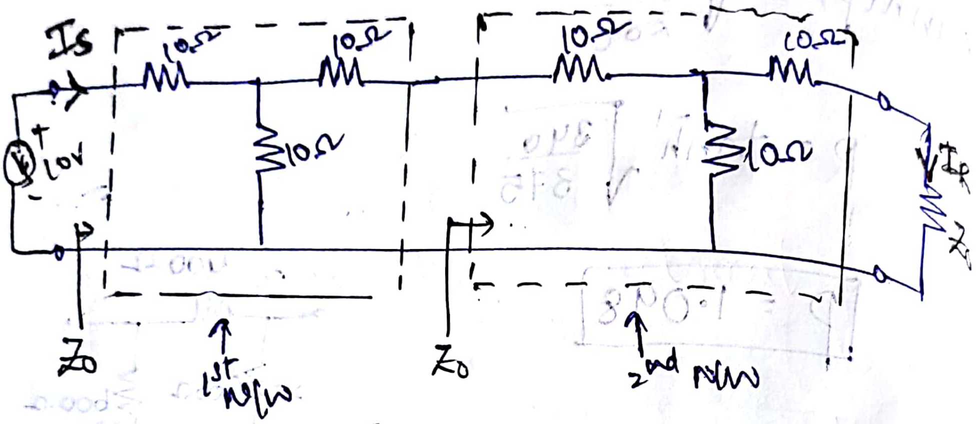
$\cancel{= 2 \times 300 \times \tanh\left(\frac{1.098}{2}\right)}$

iii) $Z_1 = Z_{0\pi} \sinh(p)$ & $Z_2 = \dfrac{Z_{0\pi}}{2\tanh(p/2)}$

$Z_1 = 300 \times \sinh(1.098)$; $Z_2 = \dfrac{300}{2\tanh\left(\frac{1.098}{2}\right)}$

$\boxed{Z_1 = 400\,\Omega}$ $\boxed{Z_2 = 300\,\Omega}$

Ex-5:- 2 similar T-N/W's each consisting of a series arm impedence 20 Ω (Z_1) & shunt arm impedence 10 Ω (Z_2) respectively connected in series. The output of the series N/W is terminated by char. imp. Z_0 & the input N/W is fed by 10 V. compute the current flowing through the terminating impedence Z_0.



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

$$= \sqrt{\frac{20^2}{4} + (20)(10)}$$

$$\boxed{Z_0 = 17.32\,\Omega}$$

$$e^{\gamma} = 1 + \frac{Z_1}{2Z_2} + \frac{Z_0}{Z_2}$$

$$= 1 + \frac{\cancel{20}}{\cancel{20}} + \frac{17.321}{10}$$

$e^{P} = 3.7321$

$P = \ln(3.7321)$

$\boxed{P = 1.316}$

W.k.T

$\frac{I_S}{I_R} = \frac{I_S}{I_1} \times \frac{I_1}{I_R}$

$\frac{I_S}{I_R} = e^{P} \cdot e^{P}$

$\frac{I_S}{I_R} = (3.7321)^2$

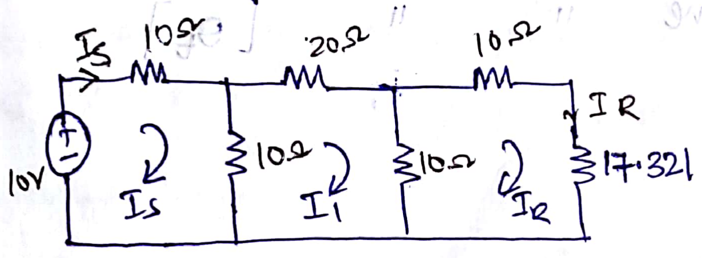
$\frac{I_S}{I_R} = 13.928$

$I_S = \frac{V_S}{Z_0} = \frac{10}{17.321} = 0.577$

$I_R = \frac{I_S}{13.928} = \frac{0.577}{13.928} = 0.0414$

$\simeq 41.4 mA$

<u>using</u> <u>mesh Analysis</u> :-



①:- $-10 + 10I_S + 10(I_S - I_1) = 0$

$20I_S - 10I_1 + 0.I_R = 10$ — ①

②:- $10(I_1 - I_s) + 20I_1 + 10(I_1 - I_R) = 0$

$40I_1 - 10I_s - 10I_R = 0$ — ⓑ

③:- $10(I_R - I_1) + 10I_R + 17.321I_R = 0$

$0I_s + 37.321I_R - 10I_1 = 0$ — ⓒ

$I_s = 0.57A$

$I_1 = 0.154A$

$I_R = 0.0414A$

$\boxed{I_R \simeq 41.4mA}$

Asymmetrical N/w & electrical properties:

Asymmetrical N/w's can be described by four parameters

1) Image Impedences $[Z_{i1}$ & $Z_{i2}]$
2) Iterative " $[Z_{t1}$ & $Z_{t2}]$
3) Image Transfer Constant $[\theta_i]$
4) Iterative " " $[\theta_t]$

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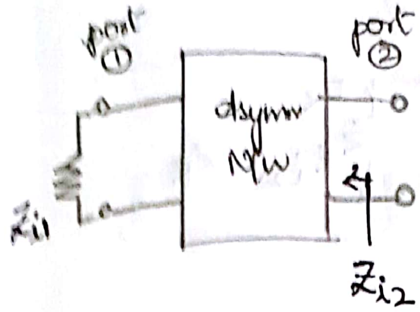
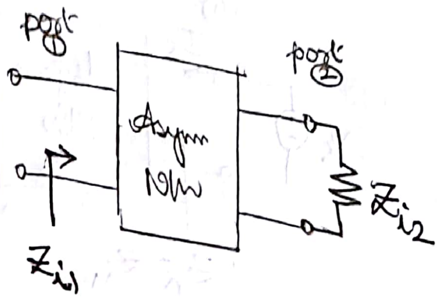
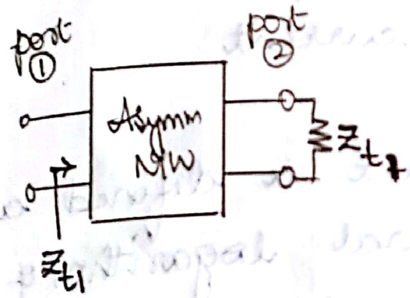
1) Image Impedences:- [Z_{i1} & Z_{i2}]

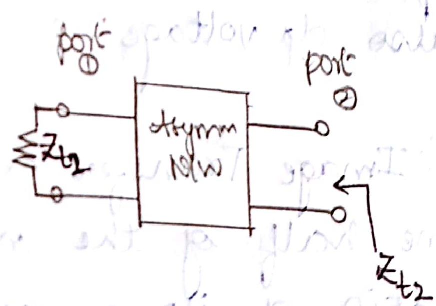




→ Two impendences Z_{i1} & Z_{i2} of an asymmetrical N/W are such that if port ② is terminated by Z_{i2} then impedence looking into port ① is Z_{i1} & if port ① is terminated by Z_{i1} then impedence looking into port ② is Z_{i2} then Z_{i1} & Z_{i2} are called "Image impedences".

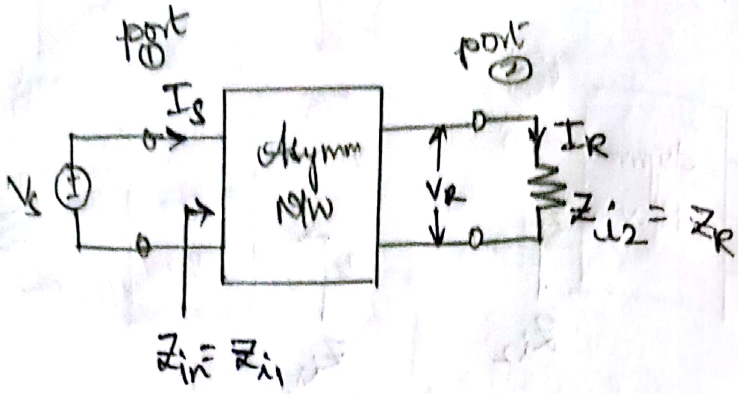
2) Iterative Impedences:- [Z_{t1} & Z_{t2}]





→ Two impedences Z_{t1} & Z_{t2} of an asymmetrical N/W are such that if port ② is terminated by Z_{t1} then impedence looking into port ① is Z_{t1} & if port ① is terminated by Z_{t2} then impedence looking into port ② is Z_{t2} then Z_{t1} & Z_{t2} are called "Iterative impedences".

3) Image Transfer Constant $[\theta_i]$:-



$$V_s = Z_{in} I_s \Rightarrow V_s = Z_{i_1} I_s$$

$$V_R = I_R Z_R \Rightarrow V_R = I_R Z_{i_2}$$

i.e $\frac{V_s}{V_R} \neq \frac{I_s}{I_R}$

$$\boxed{\theta_i = \frac{1}{2} \ln \left[\frac{V_s I_s}{V_R I_R} \right]}$$

∴ Image Transfer constant is defined in terms of both i/p voltage & i/p current & also o/p voltage & o/p current.

Def: Image Transfer constant is defined as "one half of the natural logarithm of ratio of i/p power $(V_s I_s)$ to the o/p power $(V_R I_R)$ of an assymmetrical N/W".

$$\Rightarrow \theta_i = \frac{1}{2} \ln \left[\frac{I_s^2 Z_{i_1}}{I_R^2 Z_{i_2}} \right]$$

$$\theta_i = \ln \sqrt{\frac{I_s^2 Z_{i_1}}{I_R^2 Z_{i_2}}}$$

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$$\boxed{\theta_i = \ln\left[\frac{I_s}{I_R}\sqrt{\frac{Z_{i1}}{Z_{i2}}}\right]}$$

$$\boxed{\theta_i = A_i + jB_i}$$

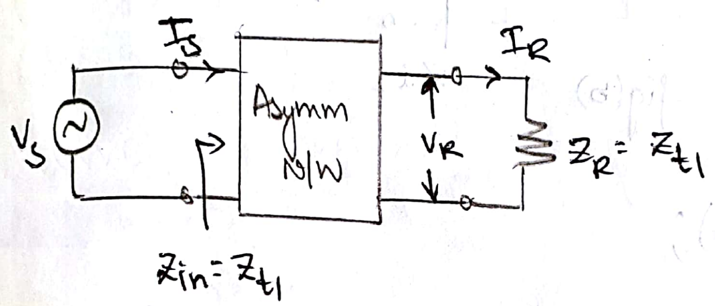
A_i - Image Attenuation constant

jB_i - Image phase shift const

units :- Np or dB

units : degree (°), radians

4.) Iterative Transfer constant [θ_t] :-



$$V_S = Z_{in} I_S = Z_{t1} I_S$$

$$V_R = Z_R I_R = Z_{t1} I_R$$

$$\frac{V_S}{V_R} = \frac{I_S}{I_R}$$

$$\boxed{\theta_t = \ln\left[\frac{V_S}{V_R}\right] \text{ (or) } \ln\left[\frac{I_S}{I_R}\right]}$$

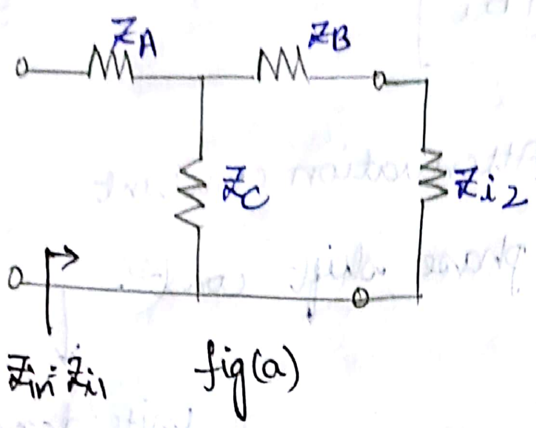
$$\theta_t = A_t + jB_t$$

A_t - Iterative attenuation const

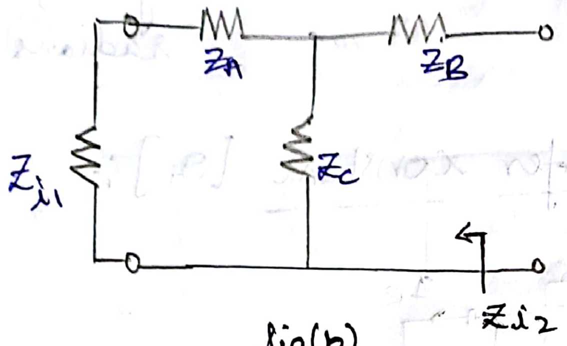
jB_t - Iterative phase-shift const.

Analysis of Asymmetrical T- N/W:-

Image Impedences:-



fig(a)



fig(b)

From fig(a);

$$Z_{in} = Z_{i1} = Z_A + Z_C \parallel (Z_B + Z_{i2})$$

$$Z_{i1} = Z_A + \frac{Z_C(Z_B + Z_{i2})}{Z_C + Z_B + Z_{i2}}$$

$$Z_{i1}(Z_C + Z_B + Z_{i2}) = Z_A(Z_C + Z_B + Z_{i2}) + Z_C(Z_B + Z_{i2})$$

$$Z_{i1}Z_{i2} + Z_{i1}(Z_C + Z_B) = Z_A Z_C + Z_A Z_B + Z_A Z_{i2}$$
$$+ Z_B Z_C + Z_C Z_{i2}$$

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$$Z_{i1} Z_{i2} + Z_{i1}(Z_C + Z_B) = (Z_A Z_B + Z_B Z_C + Z_C Z_A) + Z_{i2}(Z_A + Z_C)$$

$$\boxed{Z_{i1} Z_{i2} + Z_{i1}(Z_C + Z_B) = \sum Z_A Z_B + Z_{i2}(Z_A + Z_C)} \rightarrow (13a)$$

From fig (b);

$$Z_{in} = Z_{i2} = Z_B + Z_C \parallel (Z_A + Z_{i1})$$

$$Z_{i2} = Z_B + \frac{Z_C(Z_A + Z_{i1})}{Z_C + Z_A + Z_{i1}}$$

$$Z_{i2}(Z_C + Z_A + Z_{i1}) = Z_B(Z_C + Z_A + Z_{i1}) + Z_C(Z_A + Z_{i1})$$

$$Z_{i1} Z_{i2} + Z_{i2}(Z_A + Z_C) = Z_B Z_C + Z_A Z_B + Z_B Z_{i1} + Z_A Z_C + Z_C Z_{i1}$$

$$\boxed{Z_{i1} Z_{i2} + Z_{i2}(Z_A + Z_C) = \sum Z_A Z_B + Z_{i1}(Z_B + Z_C)} \rightarrow (13b)$$

(13a) − (13b)

$$2 Z_{i1}(Z_B + Z_C) = 2 Z_{i2}(Z_A + Z_C)$$

$$\boxed{\frac{Z_{i1}}{Z_{i2}} = \frac{(Z_A + Z_C)}{(Z_B + Z_C)}} \rightarrow (13c)$$

13a + 13b

$$\cancel{2} Z_{i_1} Z_{i_2} = \cancel{2} \sum Z_A Z_B$$

$$\boxed{Z_{i_1} Z_{i_2} = \sum Z_A Z_B} \rightarrow \text{13d}$$

13c × 13d

$$\frac{Z_{i_1}}{\cancel{Z_{i_2}}} \times (Z_{i_1} \cancel{Z_{i_2}}) = \frac{Z_A + Z_C}{Z_B + Z_C} \times \sum Z_A Z_B$$

$$\boxed{Z_{i_1} = \sqrt{\left(\frac{Z_A + Z_C}{Z_B + Z_C}\right) \times \left(\sum Z_A Z_B\right)}}$$

13d ÷ 13c

$$\frac{\cancel{Z_{i_1}} Z_{i_2}}{\frac{\cancel{Z_{i_1}}}{Z_{i_2}}} = \frac{\sum Z_A Z_B}{\frac{Z_A + Z_C}{Z_B + Z_C}}$$

$$Z_{i_2}^2 = \frac{\sum Z_A Z_B \times (Z_B + Z_C)}{Z_A + Z_C}$$

$$\boxed{Z_{i_2} = \sqrt{\left(\sum Z_A Z_B\right) \times \left(\frac{Z_B + Z_C}{Z_A + Z_C}\right)}}$$

$$Z_{i1} = \sqrt{(\Sigma Z_A Z_B)\left[\frac{Z_A + Z_A}{Z_B + Z_C}\right]}$$

$$Z_{i2} = \sqrt{(\Sigma Z_A Z_B)\left[\frac{Z_B + Z_C}{Z_A + Z_C}\right]} \quad \rightarrow (14)$$

Iterative Impedences:-

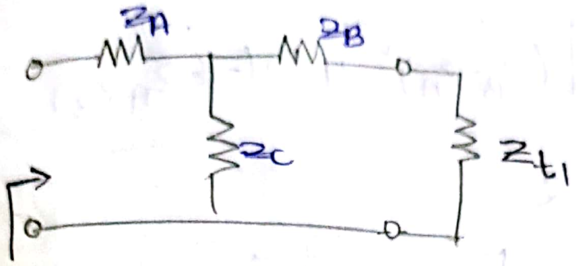


fig (a)

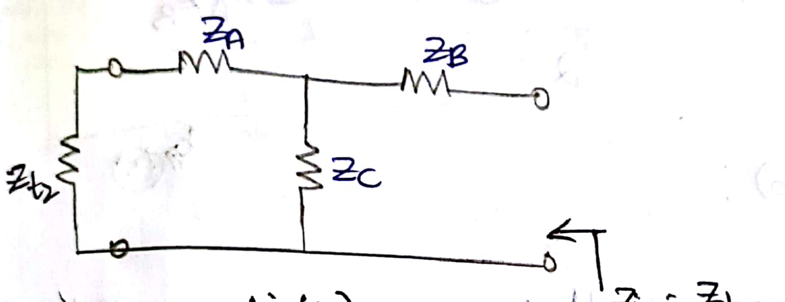


fig (b)

From fig (a);

$$Z_{t1} = Z_A + Z_C \,||\, (Z_B + Z_{t1})$$

$$Z_{t1} = Z_A + \frac{Z_C(Z_B + Z_{t1})}{Z_C + Z_B + Z_{t1}}$$

$$Z_{t1}(Z_C + Z_B + Z_{t1}) = Z_A(Z_C + Z_B + Z_{t1}) + Z_C(Z_B + Z_{t1})$$

$$Z_{t1}^2 + Z_{t1}(Z_C + Z_B) = \Sigma Z_A Z_B + Z_{t1}(Z_A + Z_C)$$

$$Z_{t_1}^2 + Z_{t_1}(\cancel{Z_C} + Z_B - Z_A - \cancel{Z_C}) - \Sigma Z_A Z_B = 0$$

$$Z_{t_1}^2 + Z_{t_1}(Z_B - Z_A) - \Sigma Z_A Z_B = 0$$

$$ax^2 + bx + c = 0$$

$$\frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$Z_{t_1} \Rightarrow \frac{-(Z_B - Z_A) \pm \sqrt{(Z_B - Z_A)^2 - 4(1)(-\Sigma Z_A Z_B)}}{2}$$

$$\boxed{Z_{t_1} \Rightarrow \frac{+(Z_A - Z_B) \pm \sqrt{(Z_B - Z_A)^2 + 4\Sigma Z_A Z_B}}{2}}$$

Eq (15)

From fig (b);

$$Z_{t_2} = (Z_B + Z_C) \parallel (Z_A + Z_{t_2})$$

$$Z_{t_2} = Z_B + \frac{Z_C(Z_A + Z_{t_2})}{Z_C + Z_A + Z_{t_2}}$$

$$Z_{t_2}(Z_C + Z_A + Z_{t_2}) = Z_B(Z_C + Z_A + Z_{t_2}) + Z_C(Z_A + Z_{t_2})$$

$$Z_{t_2}^2 + Z_{t_2}(Z_A + Z_C) = \Sigma Z_A Z_B + Z_{t_2}(Z_B + Z_C)$$

$$Z_{t_2}^2 + Z_{t_2}(Z_A + \cancel{Z_C} - Z_B - \cancel{Z_C}) - \Sigma Z_A Z_B = 0$$

$$Zt_2^2 + Zt_2(Z_A - Z_B) - \Sigma Z_A Z_B = 0$$

$$Z_{t_2} = \frac{-(Z_A - Z_B) + \sqrt{(Z_A - Z_B)^2 + 4\Sigma Z_A Z_B}}{2}$$

$$\boxed{Z_{t_2} = \frac{(Z_B - Z_A) + \sqrt{(Z_A - Z_B)^2 + 4\Sigma Z_A Z_B}}{2}} \rightarrow (15)$$

Analysis of Asymmetrical L-N/W :-

Image Impedences :-

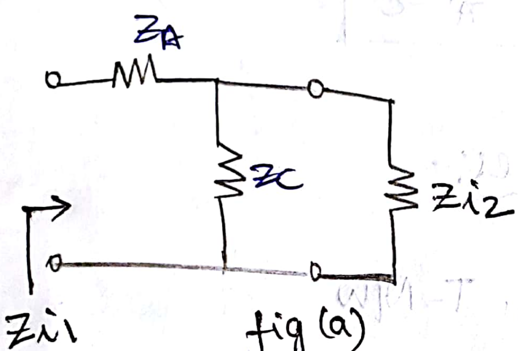


fig (a)

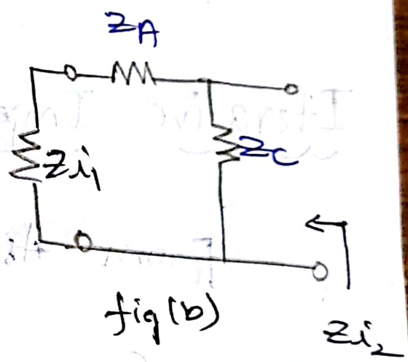


fig (b)

W.K.T for Asymm. T-N/W:

$$\Sigma Z_A Z_B = Z_A Z_B + Z_B Z_C + Z_C Z_A$$

in L-N/W $\boxed{Z_B = 0}$

$$\boxed{\Sigma Z_A Z_B = Z_A Z_C}$$

$$\therefore Z_{i_1} = \sqrt{(\Sigma Z_A Z_B)\left[\frac{Z_A + Z_C}{Z_B + Z_C}\right]}$$

$$Z_{i_1} = \sqrt{(Z_A \cancel{Z_C})\left[\frac{Z_A+Z_C}{\cancel{Z_C}}\right]}$$

$$\boxed{Z_{i_1} = \sqrt{Z_A^2 + Z_A Z_C}} \rightarrow (16)$$

||ly

$$Z_{i_2} = \sqrt{(\Sigma Z_A Z_B)\left[\frac{Z_B+Z_C}{Z_A+Z_C}\right]}$$

$$Z_{i_2} = \sqrt{(Z_A Z_C)\left[\frac{Z_C}{Z_A+Z_C}\right]}$$

$$\boxed{Z_{i_2} = Z_C\sqrt{\frac{Z_A}{Z_A+Z_C}}} \rightarrow (16)$$

Iterative Impedances:-

From Asymm. T-N/W

$$Z_{t_1} = \frac{(Z_A - Z_B) + \sqrt{(Z_B - Z_A)^2 + 4\Sigma Z_A Z_B}}{2}$$

$$\boxed{Z_B = 0}$$

$$\boxed{Z_{t_1} = \frac{Z_A + \sqrt{Z_A^2 + 4\Sigma Z_A Z_C}}{2}}$$

$$\cancel{Z_{t_1} = \frac{Z_A\left(1+\sqrt{1+4\Sigma Z_A Z_C}\right)}{2}}$$

&

$$Z_{t2} = \frac{(Z_B - Z_A) + \sqrt{(Z_A - Z_B)^2 + 4\Sigma Z_A Z_B}}{2}$$

$\boxed{Z_B = 0}$

$$Z_{t2} = \frac{-Z_A + \cancel{Z_A}\sqrt{Z_A^2 + 4 Z_A Z_C}}{2}$$

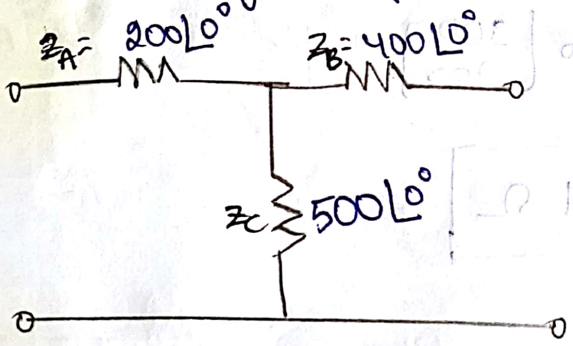
$$\boxed{Z_{t2} = \frac{-Z_A + \sqrt{Z_A^2 + 4 Z_A Z_C}}{2}}$$

$$\boxed{Z_{t1} = \frac{Z_A + \sqrt{Z_A^2 + 4 Z_A Z_C}}{2}} \rightarrow (17)$$

---

problems:-

Q1:) calculate the image & Iterative Impedences of Asymm. T-N/W



Sol: For Asymm. T-N/W,

$$Z_{i1} = \sqrt{(\Sigma Z_A Z_B)\left[\frac{Z_A + Z_C}{Z_B + Z_C}\right]}$$

$$Z_{i2} = \sqrt{(\Sigma Z_A Z_B)\left[\frac{Z_B + Z_C}{Z_A + Z_C}\right]}$$

$$Z_{t_1} = \frac{(Z_A - Z_B) + \sqrt{(Z_A - Z_B)^2 + 4\Sigma Z_A Z_B}}{2}$$

$$Z_{t_2} = \frac{(Z_B - Z_A) + \sqrt{(Z_A - Z_B)^2 + 4\Sigma Z_A Z_B}}{2}$$

$$Z_A = 200\angle 0^\circ = 200\,\Omega$$
$$Z_B = 400\angle 0^\circ = 400\,\Omega$$
$$Z_C = 500\angle 0^\circ = 500\,\Omega$$

$$\Sigma Z_A Z_B = (200)(400) + (400)(500) + (500)(200)$$

$$\Sigma Z_A Z_B = 3,80,000$$

$$Z_{i_1} = \sqrt{3,80,000\left[\frac{700}{900}\right]}$$

$$\boxed{Z_{i_1} = 543.65\,\Omega}$$

$$Z_{i_2} = \sqrt{3,80,000\left[\frac{900}{700}\right]}$$

$$\boxed{Z_{i_2} = 698.97\,\Omega}$$

$$Z_{t_1} = \frac{(200-400) + \sqrt{(200-400)^2 + 4(3,80,000}}{2}$$

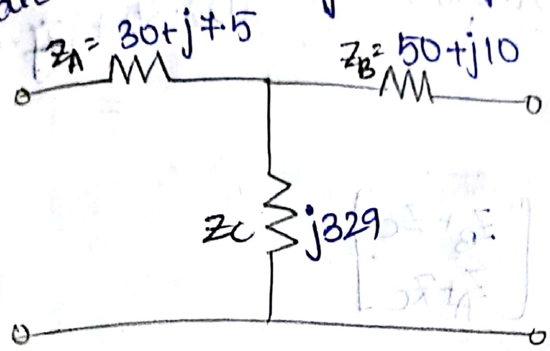
$$\boxed{Z_{t_1} = 524.49\,\Omega}$$

$$Z_{t_2} = \frac{(400-200) + \sqrt{(200)^2 + 4(3,80,000)}}{2}$$

$$\boxed{Z_{t_2} = 724.49\,\Omega}$$

Calculate Image Impedences

Q2)



$$Z_{i1} = \sqrt{\Sigma Z_A Z_B \left[\frac{Z_A + Z_C}{Z_B + Z_C}\right]}$$

$Z_A = 30+j7.5$

$Z_B = 50+j10$

$Z_C = j329$

$$\Sigma Z_A Z_B = Z_A Z_B + Z_B Z_C + Z_C Z_A$$

$$= (30+j7.5)(50+j10) + (50+j10)(j329) + (j329)(30+j7.5)$$

$$\Sigma Z_A Z_B = -4332.5 + j26995$$

$$Z_{i1} = \sqrt{(-4332.5+j26995)\left[\frac{30+j7.5+j329}{50+j10+j329}\right]}$$

$$Z_{i_1} = \sqrt{-5794.31 + 26324.7j}$$

$$Z_{i_1} = 26954.8 \angle 102.41$$

$$Z_{i_1} = 164.1 \angle 51.205 \Rightarrow 102.85 + 127.9j$$

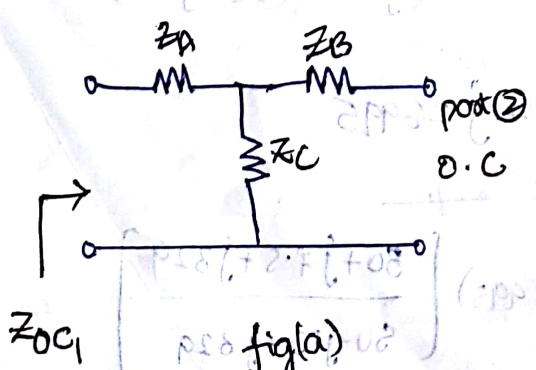
$$Z_{i_2} = \sqrt{(\Sigma Z_A Z_B)\left[\frac{Z_B + Z_C}{Z_A + Z_C}\right]}$$

$$= \sqrt{(-4332.5 + 26995j)[1.01 - 0.58j]}$$

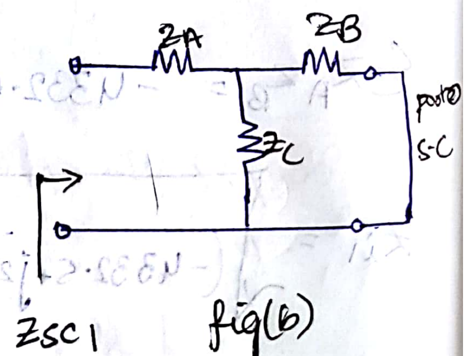
$$= 166.853 \angle 48.123$$

$$Z_{i_2} = 111.3 + 124.23j$$

Short circuit & open circuit Impedances of Asymm. T-N/w :-



fig(a)



fig(b)

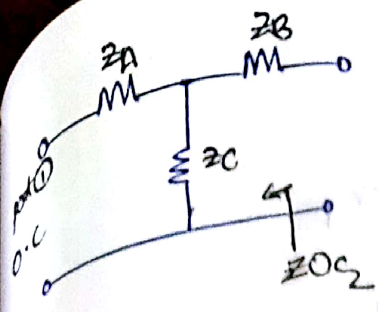


fig (c).

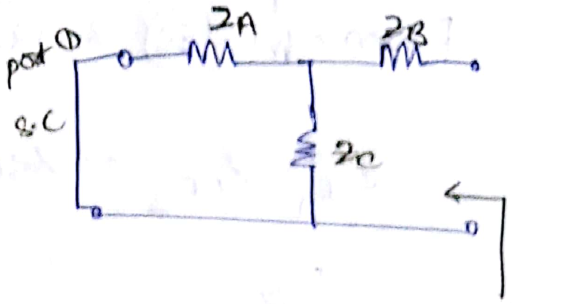


fig (d)

From fig (a); $Z_{OC_1} = Z_A + Z_C \rightarrow$ (18a)

" fig (c); $Z_{OC_2} = Z_B + Z_C \rightarrow$ (18b)

" fig (b); $Z_{SC_1} = Z_A + \dfrac{Z_B Z_C}{Z_B + Z_C}$

$$Z_{SC_1} = \frac{Z_A Z_B + Z_A Z_C + Z_B Z_C}{Z_B + Z_C}$$ From (18b)

$$Z_{SC_1} = \frac{\Sigma Z_A B}{Z_{OC_2}}$$

$$Z_{SC_1} \cdot Z_{OC_2} = \Sigma Z_A Z_B \rightarrow \text{(18c)}$$

From fig (d);

$$Z_{SC_2} = Z_B + \frac{Z_A Z_C}{Z_A + Z_C}$$

$$Z_{SC_2} = \frac{Z_A Z_B + Z_B Z_C + Z_A Z_C}{Z_A + Z_C}$$

$$Z_{SC_2} \cdot Z_{OC_1} = \Sigma Z_A Z_B \rightarrow \text{(18d)}$$

From eqn (18c) & (18d)

$$Z_{sc_1} \cdot Z_{oc_2} = Z_{sc_2} Z_{oc_1}$$

$$\boxed{\frac{Z_{sc_1}}{Z_{sc_2}} = \frac{Z_{oc_1}}{Z_{oc_2}}} \rightarrow (18e)$$

From (13d)

$$\frac{Z_{i_1}}{Z_{i_2}} = \frac{Z_A + Z_C}{Z_B + Z_C} = \frac{Z_{oc_1}}{Z_{oc_2}} \rightarrow (18f)$$

From (18e) & (18f)

$$\therefore \boxed{\frac{Z_{sc_1}}{Z_{sc_2}} = \frac{Z_{oc_1}}{Z_{oc_2}} = \frac{Z_{i_1}}{Z_{i_2}}} \rightarrow (19)$$

Now $Z_{oc_1} \cdot Z_{sc_1} = (Z_A + Z_C)\left[\frac{\Sigma Z_A Z_B}{Z_B + Z_C}\right]$

$$Z_{i_1}^2 = Z_{oc_1} \cdot Z_{sc_1}$$

$$\boxed{Z_{i_1} = \sqrt{Z_{oc_1} \cdot Z_{sc_1}}} \rightarrow (20)$$

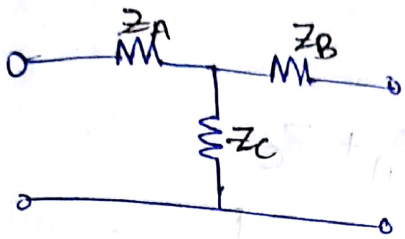
||^{ly}

$$Z_{oc_2} \cdot Z_{sc_2} = (Z_B + Z_C)\left[\frac{\Sigma Z_A Z_B}{Z_A + Z_C}\right]$$

$$Z_{i_2}^2 = Z_{oc_2} Z_{sc_2}$$

$$\boxed{Z_{i_2} = \sqrt{Z_{oc_2} Z_{sc_2}}} \longrightarrow (20)$$

Asymmetrical T-N/W Design in terms of Z_{sc_1}, Z_{oc_1}, Z_{oc_2} & Z_{sc_2} :-



$$Z_{oc_1} = Z_A + Z_C$$

$$Z_{oc_2} = Z_B + Z_C$$

$$Z_{oc_1} \cdot Z_{oc_2} = (Z_A + Z_C)(Z_B + Z_C)$$

$$= Z_A Z_B + Z_A Z_C + Z_B Z_C + Z_C^2$$

$$Z_{oc_1} \cdot Z_{oc_2} = \Sigma Z_A Z_B + Z_C^2 \longrightarrow (21a)$$

W.K.T from eqn (18d)

$$Z_{i_1} \cdot Z_{i_2} = \Sigma Z_A Z_B$$

$$Z_{oc_1} Z_{oc_2} = Z_{i_1} Z_{i_2} + Z_C^2 \longrightarrow (21b)$$

From eqn (18d)

$$Z_{sc_2} \cdot Z_{oc_1} = \Sigma Z_A Z_B + Z_C^2 - Z_C^2$$

From (21a)

$$Z_{SC_2} \cdot Z_{OC_1} = Z_{OC_1} Z_{OC_2} - Z_C^2$$

$$Z_C^2 = Z_{OC_1} Z_{OC_2} - Z_{OC_1} Z_{SC_2}$$

$$Z_C = \sqrt{Z_{OC_1} [Z_{OC_2} - Z_{SC_2}]}$$

from

$$Z_{OC_1} = Z_A + Z_C$$

$$Z_A = Z_{OC_1} - \sqrt{Z_{OC_1} [Z_{OC_2} - Z_{SC_2}]}$$

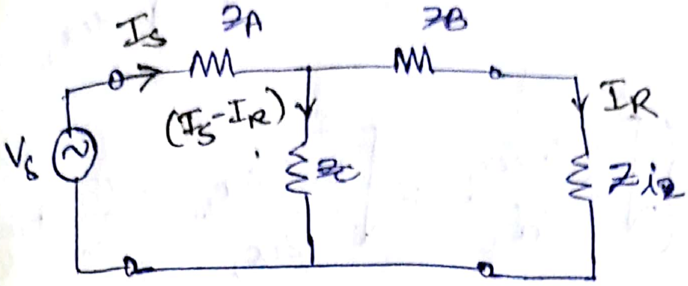
From $\rightarrow$ $Z_{OC_2} = Z_B + Z_C$

$$Z_B = Z_{OC_2} - \sqrt{Z_{OC_1} [Z_{OC_2} - Z_{SC_2}]}$$

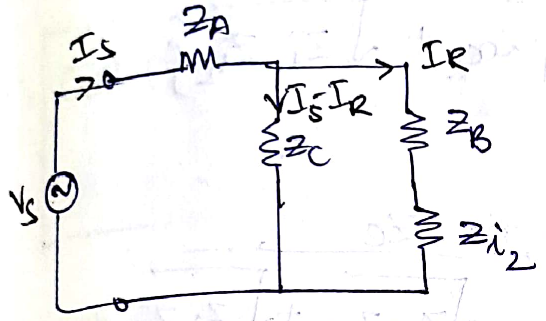
$$\boxed{\begin{aligned} \therefore\ Z_C &= \sqrt{Z_{OC_1} [Z_{OC_2} - Z_{SC_2}]} \\ Z_B &= Z_{OC_2} - \sqrt{Z_{OC_1} [Z_{OC_2} - Z_{SC_2}]} \\ Z_A &= Z_{OC_1} - \sqrt{Z_{OC_1} [Z_{OC_2} - Z_{SC_2}]} \end{aligned}}$$

$\rightarrow$ (22)

Image Transfer Constant Interms of Z_{SC_1}, Z_{OC_1}, Z_{SC_2} & Z_{OC_2} :-



W.K.T $e^{\theta i} = \frac{I_S}{I_R}\sqrt{\frac{Z_{i_1}}{Z_{i_2}}}$



$$Z_C(I_S - I_R) = (Z_B + Z_{i_2})I_R$$

$$Z_C I_S = (Z_B + Z_{i_2} + Z_C)I_R$$

$$\frac{I_S}{I_R} = \frac{(\overbrace{Z_B + Z_C}^{Z_{OC_2}} + Z_{i_2})}{Z_C}$$

$$\boxed{\frac{I_S}{I_R} = \frac{Z_{OC_2} + Z_{i_2}}{Z_C}}$$

$$e^{\theta i} = \left[\frac{Z_{OC_2} + Z_{i_2}}{Z_C}\right]\sqrt{\frac{Z_{OC_1}}{Z_{OC_2}}} \quad \therefore \text{from eqn } (19)$$

$$e^{\theta i} = \frac{Z_{oc_2}}{Z_c}\sqrt{\frac{Z_{oc_1}}{Z_{oc_2}}} + \frac{Z_{i_2}}{Z_c}\sqrt{\frac{Z_{oc_1}}{Z_{oc_2}}}$$

$$e^{\theta i} = \frac{1}{Z_c}\left\{\sqrt{\frac{Z_{oc}^2 Z_{oc_1}}{\cancel{Z_{oc_2}}}} + \sqrt{\frac{Z_{i_2}^2 \cdot Z_{oc_1}}{Z_{oc_2}}}\right\} \rightarrow \frac{Z_{i_1}}{Z_{i_2}} \text{ from } (19)$$

$$e^{\theta i} = \frac{1}{Z_c}\left\{\sqrt{Z_{oc_1} \cdot Z_{oc_2}} + \sqrt{\frac{Z_{i_2}^2 \cdot Z_{i_1}}{\cancel{Z_{i_2}}}}\right\}$$

$$e^{\theta i} = \frac{1}{Z_C}\left\{\sqrt{Z_{oc_1} \cdot Z_{oc_2}} + \sqrt{Z_{i_1} \cdot Z_{i_2}}\right\}$$

$$e^{-\theta i} = \frac{1}{e^{\theta i}} = \frac{Z_c}{\sqrt{Z_{oc_1} Z_{oc_2}} + \sqrt{Z_{i_1} Z_{i_2}}}$$

$$\cosh(\theta i) = \frac{e^{\theta i} + e^{-\theta i}}{2}$$

$$\cosh \theta i = \frac{1}{2}\left[\frac{\sqrt{Z_{oc_1} Z_{oc_2}} + \sqrt{Z_{i_1} Z_{i_2}}}{Z_c} + \frac{Z_c}{\sqrt{Z_{oc_1} Z_{oc_2}} + \sqrt{Z_{i_1} Z_{i_2}}}\right]$$

$$= \frac{1}{2}\left[\frac{Z_{oc_1} Z_{oc_2} + Z_{i_1} Z_{i_2} + 2\sqrt{Z_{oc_1} Z_{oc_2} Z_{i_1} Z_{i_2}} + Z_c^2}{Z_c\left[\sqrt{Z_{oc_1} Z_{oc_2}} + \sqrt{Z_{i_1} Z_{i_2}}\right]}\right]$$

from eqn (21b). $Z_{oc_1} Z_{oc_2} = Z_{i_1} Z_{i_2} + Z_c^2$

$$\cosh\theta_i = \frac{1}{2}\left[\frac{Z_{oc_1}Z_{oc_2} + Z_{oc_1}Z_{oc_2} + 2\sqrt{Z_{oc_1}Z_{oc_2}Z_{i_1}Z_{i_2}}}{Z_c\left(\sqrt{Z_{oc_1}Z_{oc_2}} + \sqrt{Z_{i_1}Z_{i_2}}\right)}\right]$$

$$= \left[\frac{Z_{oc_1}Z_{oc_2} + \sqrt{Z_{oc_1}Z_{oc_2}Z_{i_1}Z_{i_2}}}{Z_c\left(\sqrt{Z_{oc_1}Z_{oc_2}} + \sqrt{Z_{i_1}Z_{i_2}}\right)}\right]$$

$$= \frac{\sqrt{Z_{oc_1}Z_{oc_2}}}{Z_c}\left[\frac{\sqrt{Z_{oc_1}Z_{oc_2}} + \cancel{\sqrt{Z_{i_1}Z_{i_2}}}}{\sqrt{Z_{oc_1}Z_{oc_2}} + \cancel{\sqrt{Z_{i_1}Z_{i_2}}}}\right]$$

$$\boxed{\cosh\theta_i = \frac{\sqrt{Z_{oc_1}Z_{oc_2}}}{Z_c}}$$

W.K.T $\cosh^2\theta_i - \sinh^2\theta_i = 1$

$$\sinh^2\theta_i = \cosh^2\theta_i - 1$$

$$= \frac{Z_{oc_1}Z_{oc_2}}{Z_c^2} - 1$$

$$\boxed{\sinh^2\theta_i = \frac{Z_{oc_1}Z_{oc_2} - Z_c^2}{Z_c^2}}$$

from eqn (21b), $\sinh^2\theta_i = \frac{Z_{i_1}Z_{i_2}}{Z_c^2}$

$$\boxed{\sinh\theta_i = \frac{\sqrt{Z_{i_1}Z_{i_2}}}{Z_c}} \rightarrow (23a)$$

$$\tanh\theta_i = \frac{\sinh\theta_i}{\cosh\theta_i} = \sqrt{\frac{Z_{i_1} Z_{i_2}}{Z_{oc_1} Z_{oc_2}}}$$

$$\tanh\theta_i = \sqrt{\frac{\sqrt{Z_{oc_1} Z_{sc_1} Z_{oc_2} Z_{sc_2}}}{Z_{oc_1} Z_{oc_2}}}$$

$$= \sqrt{\sqrt{\frac{\cancel{Z_{oc_1}} Z_{sc_1} \cancel{Z_{oc_2}} Z_{sc_2}}{Z_{oc_1}^2 Z_{oc_2}^2}}}$$

$$= \sqrt{\sqrt{\frac{Z_{sc_1}}{Z_{oc_1}} \cdot \frac{Z_{sc_2}}{Z_{oc_2}}}}$$

from eqn (19)

$$\frac{Z_{sc_1}}{Z_{sc_2}} = \frac{Z_{oc_1}}{Z_{oc_2}}$$

$$\frac{Z_{sc_1}}{Z_{oc_1}} = \frac{Z_{sc_2}}{Z_{oc_2}}$$

$$\boxed{\tanh\theta_i = \sqrt{\frac{Z_{sc_1}}{Z_{oc_1}}} \text{ (or) } \sqrt{\frac{Z_{sc_2}}{Z_{oc_2}}}}$$

Design of Asymmetrical T-N/W when Z_{i_1}, Z_{i_2} & θ_i are given:-

W.K.T $\sinh\theta_i = \frac{\sqrt{Z_{i_1} Z_{i_2}}}{Z_C}$

$$\Rightarrow Z_C = \frac{\sqrt{Z_{i_1} Z_{i_2}}}{\sinh\theta_i}$$

consider;

$$\tanh\theta_i = \sqrt{\frac{Z_{i_1} Z_{i_2}}{Z_{OC_1} Z_{OC_2}}}$$

M & D by Z_{OC_1}

$$\tanh\theta_i = \sqrt{\frac{Z_{i_1} \cdot Z_{i_2}}{Z_{OC_1} \boxed{Z_{OC_2}}} \times \boxed{\frac{Z_{OC_1}}{Z_{OC_1}}}}$$

$$\frac{Z_{OC_1}}{Z_{OC_2}} = \frac{Z_{i_1}}{Z_{i_2}}$$

$$= \sqrt{\frac{Z_{i_1} \cdot \cancel{Z_{i_2}}}{Z_{OC_1}^2} \cdot \frac{Z_{i_1}}{\cancel{Z_{i_2}}}}$$

$$\tanh\theta_i = \frac{Z_{i_1}}{Z_{OC_1}}$$

$$\Rightarrow Z_{OC_1} = \frac{Z_{i_1}}{\tanh\theta_i}$$

$$Z_A = \frac{Z_i}{\tanh\theta_i} - Z_C$$

$$Z_A = \frac{Z_i}{\tanh\theta_i} - \frac{\sqrt{Z_{i_1} Z_{i_2}}}{\sinh\theta_i}$$

Now again;

$$\tanh\theta_i = \sqrt{\frac{Z_{i_1} Z_{i_2}}{Z_{oc_1} Z_{oc_2}} \times \frac{Z_{oc_2}}{Z_{oc_2}}}$$

$$\tanh\theta_i = \sqrt{\frac{\cancel{Z_{i_1}} Z_{i_2}}{\cancel{Z_{i_1}}} \times \frac{Z_{i_2}}{Z_{oc_2}^2}}$$

$$\tanh\theta_i = \frac{Z_{i_2}}{Z_{oc_2}}$$

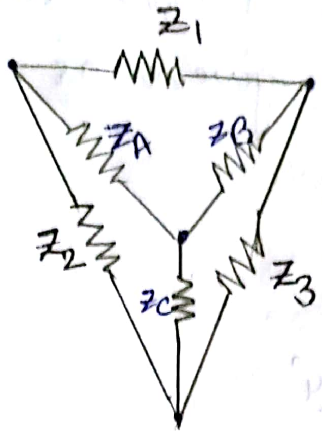
$$Z_{oc_2} = \frac{Z_{i_2}}{\tanh\theta_i}$$

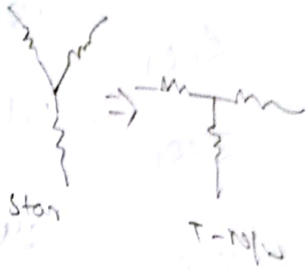
$$Z_B \cancel{+ Z_C} = \frac{Z_{i_2}}{\tanh\theta_i} - Z_C$$

$$Z_B = \frac{Z_{i_2}}{\tanh\theta_i} - \frac{\sqrt{Z_{i_1} Z_{i_2}}}{\sinh(\theta_i)}$$

$$\boxed{\begin{aligned} Z_A &= \frac{Z_{i_1}}{\tanh\theta_i} - \frac{\sqrt{Z_{i_1} Z_{i_2}}}{\sinh(\theta_i)} \\ Z_B &= \frac{Z_{i_2}}{\tanh\theta_i} - \frac{\sqrt{Z_{i_1} Z_{i_2}}}{\sinh(\theta_i)} \\ Z_C &= \frac{\sqrt{Z_{i_1} Z_{i_2}}}{\sinh\theta_i} \end{aligned}} \longrightarrow (24)$$

Star- Delta Conversions:-





Star to Delta:-

$$Z_1 = \frac{Z_A Z_B + Z_B Z_C + Z_C Z_A}{Z_C} = \frac{\Sigma Z_A Z_B}{Z_C}$$

$$Z_2 = \frac{\Sigma Z_A Z_B}{Z_B}$$

$$Z_3 = \frac{\Sigma Z_A Z_B}{Z_A}$$

Delta to Star:-

$$Z_A = \frac{Z_1 Z_2}{Z_1 + Z_2 + Z_3} = \frac{Z_1 Z_2}{\Sigma Z_1}$$

$$Z_B = \frac{Z_1 Z_3}{\Sigma Z_1}$$

$$Z_C = \frac{Z_2 Z_3}{\Sigma Z_1}$$

problems:-

Q.) For an Asymm. T-N/W O.C & S.C impedences are given as.

$Z_{OC_1} = 1260\angle 30^\circ$

$Z_{SC_1} = 318\angle 72^\circ$

$Z_{OC_2} = 2430\angle -34^\circ$

$Z_{SC_2} = 613\angle 8^\circ$

Then find;

i, Image Impedences (Z_{i_1}, Z_{i_2})

ii, Image Transfer Constant

iii, Circuit elements (Z_A, Z_B, Z_C)

Sol:- $Z_{i_1} = \sqrt{Z_{OC_1} \cdot Z_{SC_1}}$; $Z_{i_2} = \sqrt{Z_{OC_2} \cdot Z_{SC_2}}$

$Z_{i_1} = \sqrt{1260\angle 30^\circ \cdot 318\angle 72^\circ}$; $Z_{i_2} = \sqrt{2430\angle -34^\circ \cdot 613\angle 8^\circ}$

$Z_{i_1} = 632.99\angle 51^\circ$

$= 1220.48\angle -13^\circ$

$Z_{i_2} = 1220.48\angle -13^\circ$

$\tanh\theta_1 = \sqrt{\dfrac{Z_{SC_1}}{Z_{OC_1}}}$

$= \sqrt{\dfrac{318\angle 72^\circ}{1260\angle 30^\circ}} = 0.5\angle 21^\circ$

$$Z_A = Z_{OC_1} - Z_C \Rightarrow -487.94 + 848j$$

$$Z_B = Z_{OC_2} - Z_C \Rightarrow 435.62 - 1140.55j$$

$$Z_C = \sqrt{Z_{OC_1}\left[Z_{OC_2} - Z_{SC_2}\right]}$$

$$\rightarrow \frac{e^{\theta i} - e^{-\theta i}}{e^{\theta i} + e^{-\theta i}} = \frac{0.46 + j0.17}{1}$$

Componendo & Dividendo

$$\frac{e^{\theta i} - \cancel{e^{-\theta i}} + e^{\theta i} + \cancel{e^{-\theta i}}}{\cancel{e^{\theta i}} - e^{-\theta i} \cancel{+ e^{\theta i}} - e^{-\theta i}} = \frac{1.46 + j0.17}{-0.54 + j0.17}$$

$$\frac{\cancel{2}e^{\theta i}}{-\cancel{2}e^{-\theta i}} = \frac{1.46 \angle 6.64^\circ}{0.566 \angle 162.52^\circ}$$

2) For a Asymmetrical T-N/W O.C & S.C impedences are given as

$Z_{OC_1} = 200\angle 0^\circ \, \Omega$

$Z_{OC_2} = 40\angle 0^\circ \, \Omega$

$Z_{SC_1} = 219\angle 0^\circ \, \Omega$

$Z_{SC_2} = 68\angle 0^\circ \, \Omega$

Calculate the image & Iterative impedance & image & iterative transfer constant.

Sol. Given;

$Z_{OC_1} = 200\Omega$

$Z_{OC_2} = 40\Omega$

$Z_{SC_1} = 219\Omega$

$Z_{SC_2} = 68\Omega$

$Z_{i_1} = \sqrt{Z_{OC_1} \cdot Z_{SC_1}}$

$Z_{i_2} = \sqrt{Z_{OC_2} \cdot Z_{SC_2}}$

$Z_{i_1} = \sqrt{200 \times 219} = 209.284\Omega$

$Z_{i_2} = \sqrt{40 \times 68} = \cancel{5}52.153$

Iterative Impedences

$$Z_{t_1} = (Z_A - Z_B) + \frac{\sqrt{(Z_B - Z_A)^2 + 4 \leq Z_A Z_B}}{}$$

&

$$Z_A = Z_{OC_1} - \sqrt{Z_{OC_1}(Z_{OC_2} - Z_{SC_2})}$$

$$= 200 - \sqrt{200(40-60)}$$

$$Z_A = 200 - j74.83$$

$$Z_B = Z_{OC_2} - \sqrt{Z_{OC_1}(Z_{OC_2} - Z_{SC_2})}$$

$$= 40 - \sqrt{200(40-68)}$$

$$Z_B = 40 - j74.83$$

$$Z_C = \sqrt{Z_{OC_1}(Z_{OC_2} - Z_{SC_2})}$$

$$= \sqrt{200(40-68)}$$

$$Z_C = j74.83$$

$$Z_{t_1} = \frac{(200-j74.83) - (40-j74.83) + \sqrt{(40-j74.8) - (200-j74.83)\,4\,(13599.52)}}{2}$$

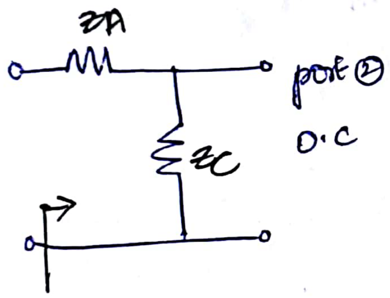
$Z_{t_1} = 168.088\,\Omega$

$Z_{t_2} = -(Z_A - Z_B) + \sqrt{(Z_B - Z_A) + 4\Sigma Z_A Z_B}$

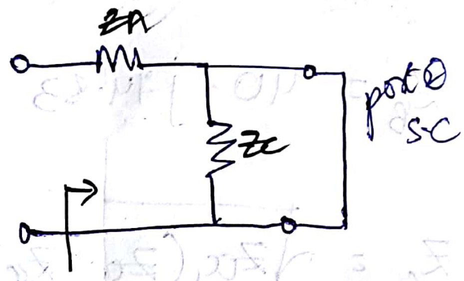
$Z_{t_2} = -168.688\,\Omega$

$\therefore Z_{t_1} = -Z_{t_2}.$

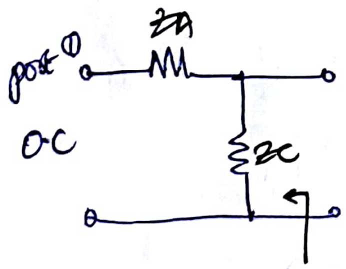
Z_{i_1} & Z_{i_2} of L-N/w Interms of Short & open circuit Impedences:-



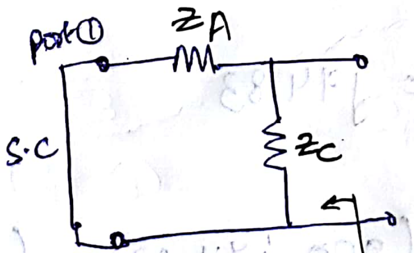
$Z_{oc_1} = Z_A + Z_C$



$Z_{sc_1} = Z_A$



$Z_{oc_2} = Z_C$



$Z_{sc_2} = \frac{Z_A Z_C}{Z_A + Z_C}$

$Z_{sc_1} Z_{oc_1} = Z_A (Z_A + Z_C)$

$Z_{sc_1} \cdot Z_{oc_1} = Z_i^2$

$\therefore Z_{i_1} = \sqrt{Z_A^2 + Z_A Z_C}$

$$\boxed{Z_{i_1} = \sqrt{Z_{sc_1} \cdot Z_{oc_1}}}$$

consider

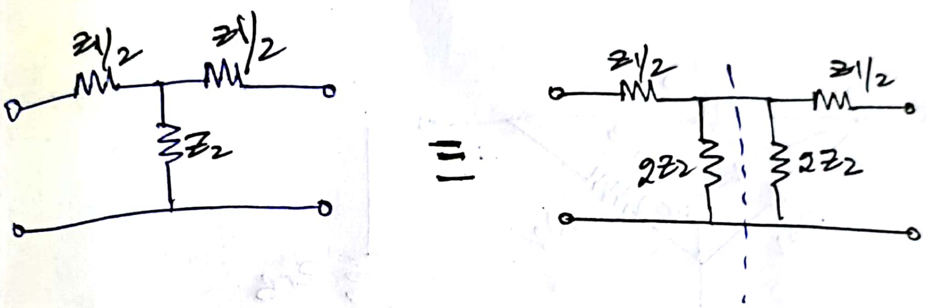
$$Z_{sc_2} \cdot Z_{oc_2} = \frac{Z_A \cdot Z_c^2}{(Z_A + Z_c)}$$

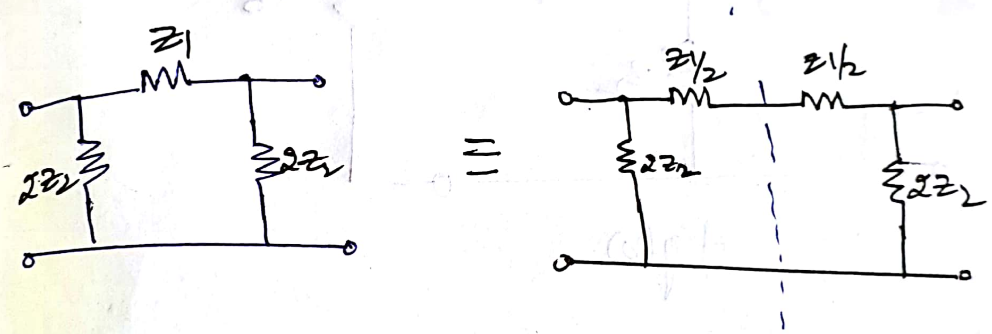
$$\therefore Z_{i_2} = Z_c\sqrt{\frac{Z_A}{Z_A+Z_c}}$$

$$= Z_{i_2}^2$$

$$\boxed{Z_{i_2} = \sqrt{Z_{sc_2} \cdot Z_{oc_2}}}$$

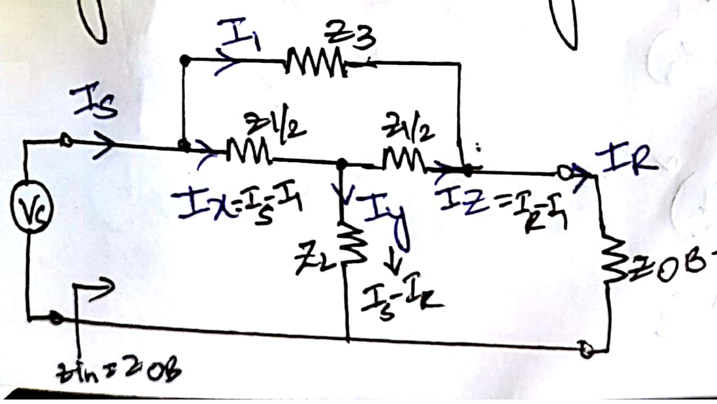
Half Sections:-





Half sections are the L-N/ws extracted from either symmetrical π or T-N/w when equally divided

Bridged-T N/w Analysis (symmetrical):-



$\rightarrow$ characteristic impedence of symmetric Bridge T-N/w

$I_S = I_1 + I_x \Rightarrow I_x = I_S - I_1$

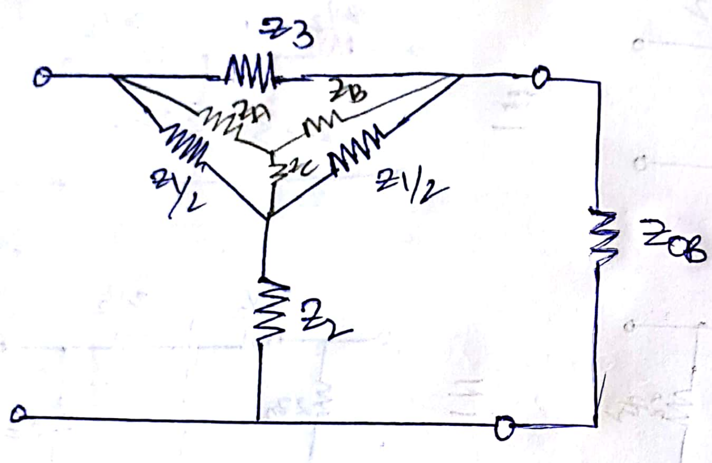
$I_R = I_1 + I_2 \Rightarrow I_2 = I_R - I_1$

$I_x = I_y + I_2$

$I_y = I_x - I_2$

$= I_S - \cancel{I_1} - I_R + \cancel{I_1}$

$I_y = I_S - I_R$



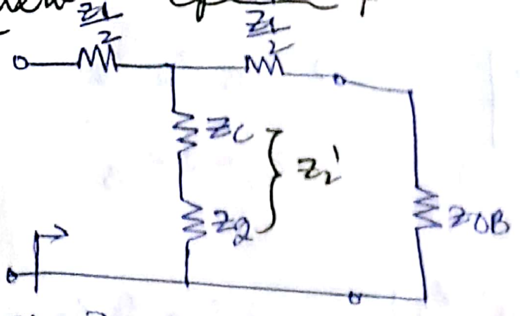
fig(b).

$$Z_A = \frac{\frac{Z_1}{2} \cdot Z_3}{Z_1 + Z_3} = \frac{Z_1 Z_3}{2(Z_1 + Z_3)}$$ i.e. $Z_A = Z_B$

$$Z_B = \frac{Z_1 Z_3}{2(Z_1 + Z_3)}$$

$$Z_C = \frac{\left(\frac{Z_1}{2}\right)^2}{Z_1 + Z_3}$$

characteristic Impedence :



$Z_{in} = Z_{OB}$

fig(c)

$$\frac{Z_1'}{2} = \frac{Z_1 Z_3}{2(Z_1+Z_3)} \quad ; \quad Z_2' = Z_2 + Z_C = Z_2 + \frac{Z_1^2}{4(Z_1+Z_3)}$$

$$Z_{OB} = \sqrt{\frac{Z_1'}{4} + Z_1' Z_2'}$$

$$= \sqrt{\frac{Z_1^2 Z_3^2}{4(Z_1+Z_3)^2} + \frac{Z_1 Z_2 Z_3}{(Z_1+Z_3)} + \frac{Z_1^3 Z_3}{4(Z_1+Z_3)^2}}$$

$$= \sqrt{\frac{Z_1^2 Z_3 \cancel{(Z_3+Z_1)}}{4(Z_1+Z_3)^{\cancel{2}}} + \frac{Z_1 Z_2 Z_3}{(Z_1+Z_3)}}$$

$$\boxed{Z_{OB} = \sqrt{\frac{Z_1^2 Z_3}{4(Z_1+Z_3)} + \frac{Z_1 Z_2 Z_3}{(Z_1+Z_3)}}}$$

But, in pratical cases $\frac{Z_1}{2}$ is replaced by Z_{OB}

$$\left[\frac{Z_1}{2} = Z_{OB}\right]$$

$$Z_{OB}^2 = \frac{Z_{OB}^2 Z_3}{2Z_{OB}+Z_3} + \frac{2Z_{OB} Z_2 Z_3}{2Z_{OB}+Z_3}$$

$$Z_{OB}^2\left[1-\frac{Z_3}{2Z_{OB}+Z_3}\right] = \frac{2Z_{OB}Z_2Z_3}{Z_3+2Z_{OB}}$$

$$Z_{OB}^2 = \left[\frac{\cancel{Z_3}+2Z_{OB}-\cancel{Z_3}}{Z_3+2\cancel{Z_{OB}}}\right] = \frac{2\cancel{Z_{OB}}Z_2Z_3}{(Z_3+2Z_{OB})}$$

$$Z_{OB}^2 = Z_2Z_3$$

$$\boxed{Z_{OB} = \sqrt{Z_2 * Z_3}} \quad \text{for } \frac{Z_1}{2} = Z_{OB}$$

ii) propagation constant (P):-

$V_S = Z_{in}I_S = Z_{OB}I_S$; $V_R = Z_RI_R = Z_{OB}I_R$

Apply KVL to outer loop:

$$\boxed{V_S = Z_3I_1 + V_R} \rightarrow 25a$$

$$\Rightarrow I_1 = \frac{V_S - V_R}{Z_3} = \frac{Z_{OB}}{Z_3}(I_S - I_R)$$

$$Z_3I_1 = \frac{Z_1}{2}(I_S - I_1) + \frac{Z_1}{2}(I_R - I_1)$$

$$Z_3I_1 = \frac{Z_1}{2}(I_S - 2I_1 + I_R) \rightarrow 25b$$

Sub eqn (21.b) in eqn (20)

$$Z_{OB} I_S = \frac{Z_1}{2}\left(I_S - 2I_1 + I_R\right) + Z_{OB} I_R$$

$$Z_{OB} I_S = \frac{Z_1}{2} I_S - Z_1 I_1 + \left(\frac{Z_1}{2} + Z_{OB}\right) I_R$$

$$Z_{OB} I_S = \frac{Z_1}{2} I_S - \frac{Z_1 Z_{OB}}{Z_3} I_S + \frac{Z_1 Z_{OB}}{Z_3} I_R + \left(\frac{Z_1}{2} + Z_{OB}\right) I_R$$

$$I_S\left[Z_{OB} - \frac{Z_1}{2} + \frac{Z_1 Z_{OB}}{Z_3}\right] = \left[Z_{OB} + \frac{Z_1}{2} + \frac{Z_1 Z_{OB}}{Z_3}\right] I_R$$

$$\boxed{\frac{I_S}{I_R} = e^P = \frac{\left[Z_{OB} + \frac{Z_1 Z_{OB}}{3} + \frac{Z_1}{2}\right]}{\left[Z_{OB} + \frac{Z_1 Z_{OB}}{3} - \frac{Z_1}{2}\right]}}$$

But practically, we consider $\frac{Z_1}{2} = Z_{OB}$

$$e^P = \frac{\left[2Z_{OB} + \frac{2Z_{OB}^2}{Z_3}\right]}{\frac{2Z_{OB}^2}{Z_3}}$$

$$e^P = \frac{\cancel{2} Z_{OB}}{\left(\frac{\cancel{2} Z_{OB}^{\cancel{2}}}{Z_3}\right)} + 1$$

$$\boxed{e^P = 1 + \frac{Z_3}{Z_{OB}}}$$

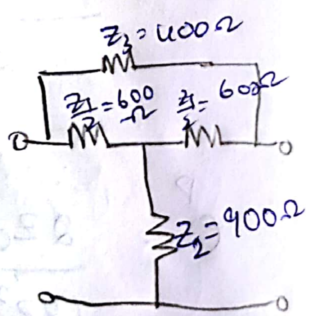
w.k.T $Z_{OB} = \sqrt{Z_2 Z_3} \Rightarrow \frac{Z_{OB}^2}{Z_2} = Z_3$

$$e^P = 1 + \frac{Z_{OB}^{\cancel{2}}}{Z_2 \cancel{Z_{OB}}}$$

$$\boxed{e^P = 1 + \frac{Z_{OB}}{Z_2}}$$

problems:-

Q1.> Evaluate characteristic Impedance & propagation constant of a bridged T-N/W which consists of series arm resistance 1200Ω & shunt arm resistance 900Ω & bridged arm resistance 400Ω



Sol:- $Z_{OB} = \sqrt{\frac{Z_1^2 Z_3}{4(Z_1+Z_3)} + \frac{Z_1 Z_2 Z_3}{(Z_1+Z_3)}}$

$$= \sqrt{\frac{Z_3}{(Z_1+Z_3)}\left[\frac{Z_1^2}{4} + Z_1 Z_2\right]}$$

$$\boxed{Z_{OB} = 600\,\Omega}$$

propagation const:

$$e^P = 1 + \frac{Z_{OB}}{Z_2}$$

$$= 1 + \frac{6\cancel{00}}{9\cancel{00}}$$

$$e^P = 1.66 \text{ Np}$$

$$P = \ln(1.66)$$

$$\boxed{P = 0.506 \text{ Np}}$$