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Review Paper on Network Analysis and Synthesis of Deriving Point Functions

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Abstract: ***Network analysis and synthesis of deriving point functions. The elementary synthesis basic philosophy behind the synthesis of driving point functions is to break up a positive real function Z(S) into sum of simpler positive functions likeZ_1(S), Z_2(S). The main aim of the network synthesis is to design and monitor the effect of combining different network segments as per desired response. This paper discusses about the procedure for designing electrical network as per desired specifications.***
Keywords: Network analysis and synthesis, Elemential equations, L-C imittance functions, R-C Driving point of impedance / R-L admittance, R-L Driving point of impedance / R-C admittance.

I. INTRODUCTION

The two complementary functions of the engineer are analysis and synthesis. In network analysis the network elements are known and the excitation is also known. Obtaining response for such a known network and known excitation is called network analysis. In the network synthesis the procedure is exactly opposite to the network analysis. The excitation is known and the response requirements are known. Thus obtaining response for known network and known response requirements is called network synthesis. The synthesize individual function $Z_i(S)$ as elements of the overall network whose dp impedance is expressed as

$$Z(S) = Z_1(S) + Z_2(S) + \ldots\ldots. + Z_n(S)$$

After that the breaking up processes is done with one restriction is that all $Z_i(S)$ must be positive. Sometimes we arrange all the $Z_i(S)$, we could synthesize a net work those driving impendence is Z(S) by simply connecting the $Z_i(S)$ in series.
Moreover, if we were to start from Z(S) alone, at that time we decompose Z(S) into $Z_i(S)$ by expressing equation

$$Z(S) = \frac{a_n s^n + a_{n-1} s^{n-1} + \cdots + a_1 s + a_0}{b_m s^m + b_{m-1} s^{m-1} + \cdots + b_1 s + b_0} = \frac{P(S)}{Q(S)}$$

1) *Case 1:* At that time removing a pole at S=0, if there is a pole at S=0, we can write Q(S) as

$$Q(S) = SG(S)$$

Hence, the Z(S) becomes

$$Z(S) = \frac{D}{S} + R(S)$$
$$= Z_1(S) + Z_2(S)$$

$Z_1(S)$ is a capacitor. We know that $Z_1(S)$ is positive real, and then we prove that $Z_2(S)$ also positive real by some real functions. Hear, the poles of $Z_2(S)$ are also poles of $Z_1(S)$, hence $Z_2(S)$ doesn't have poles on the right hand of the S plane and no multiple poles on the J_W axis the satisfies the first 2 properties of positive real functions.

Hear, $ReZ_2(J_W) = Re(Z_1(J_W) + Z_2(J_W)) = Re(Z_1(J_W) + Re(Z_2(J_W) = Re(Z_2(J_W)$

Since Z(S) is positive real $Re(Z_2(J_W) = Re(Z(J_W) > 0$

Then $Z_2(S)$ is also positive real.

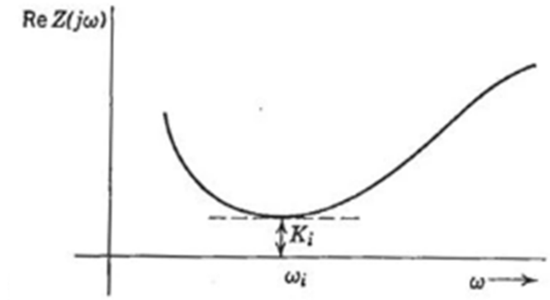
2) *Case 2:* removing a pole at S = ∞, Then Z(S) can be written as

$$Z(S) = LS + RS = Z_1(S) = Z_2(S)$$

Using a similar argument as mention previously, then we can express that $Z_2(S)$ is positive real.
$Z_1(S)$ is an inductor.
If suppose the removing complex conjugate poles on the JW axis ,then Z(S) has complex conjugate poles on the JW axis , Z(S) can be expanded into

$$Z(S) = \frac{2KJW}{S^2 + w1^2} + Z^2(S)$$

Note that Re$(\frac{2KJW}{S^2+w1^2})$ = 0
Hence, Re Z_2(S) = Re Z(S) >0, Then Z_2S is positive real.
If removing constant K, then Re Z (J_W) is minimum at some points $W_{1.}$ then Re Z (J_W) =K_i as show in graph



Graph: which illustrate analysis part of K

At that time we can remove that K_i as Z(S) = K_t Z_2(S) , then Z_2(S) is positive real
Note: This is essential for removing a resistor.
At construction period we can consider some assumessions thoes are , using one of the removal processes discussed we expanded Z(S) into Z_1(S) and Z_2(S).and connect Z_1(S) and Z_2(S) in series as show in circuit diagram.

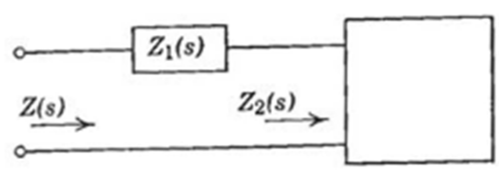


Figure 1 : The circuit which illustrate analysis part

II. STEP BY STEP ANALYSIS FOR DESIGNING THE NETWORK

The synthesis of one port networks with two kind of elements , in the first section we will focus on the synthesis of networks with only L-C, R-C or R-L elements. The deriving poins impedance of these kinds of networks have special properties that makes them to easy to synthesize.

A. L-C Immittance Functions

This networks have only inductors and capacitors, hence theaverage power consumed in these kind of network is Zero. Because inductors and the capacitor don't disspate energy. T Then L-C deriving point impedance Z(S) then Z(S) can be expressed as

$$Z(S) = \frac{M_1 \ (S)+N_1(S)}{M_2(S)+N_2(S)}$$

Where, $M_1$and M_2 are even parts
$N_1$and N_2 are odd parts
The average power dissipated by the network is

$$\text{Average Power} = \frac{1}{2} \text{Re } Z(J_W)|I(JW)|^2 = 0$$
$$\Longrightarrow \text{Re } Z(J_W) = 0$$
$$= \frac{M_1 \ (S)M_2\ (S)-N_1(S)N_2}{M_2^2 \ (S)-N_2^2(S)}$$
$$= M_1(S)\ M_2\ (S) - N_1\ (S)\ N_2\ (S) = 0$$
$$= M1(S) = 0 = N_1(S) \ \text{ or } \ M_2(S) = 0 = N_2(S)$$
$$= Z\ (S) \frac{N_1\ (S)}{M_2\ (S)} \quad \text{or} \quad Z\ (S) \frac{M_1\ (S)}{N_2\ (S)}$$
$$Z\ (S) = \frac{even}{odd} \quad \text{or} \quad Z\ (S) = \frac{odd}{even}$$

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B. Properties of L-C Functions

1) The driving point impedance of an L-C network is even/odd or odd/even
2) Both are Hurwitz, hence only simple imaginary zeros and poles on the JW axis.
3) Poles and zeros interlace on the JW axis
4) Highest power of the numerator and denominator may only differ by 1.
5) Either a zero or pole at origin or infinity.

Four simple canonical forms for the realization of one-port reactance functions are the first and second Foster forms and the first and the second Cauer forms. These four topologies are canonical in that they can always be realized, and they are also minimal in that they realize the driving point admittance with the least number of elements. The four canonical forms are described in this paper. The following are the steps to follow the mathematical analisation in each form.

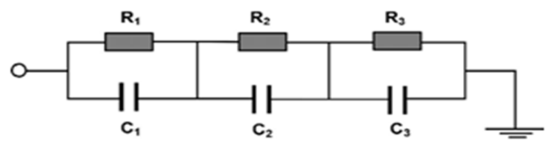

Figure 2: This shows the step by step by process Foster Network synthesis

a) Case1.Foster Canonoical Form-I

i) *Step1:* The first Foster form realization of a one port immittance function is obtained by expanding the given system equation (Z(s)) by partial fractions and identifying terms in the summation with impedances of simple network.

$$Z(S) = Z_1(S) + Z_2(S) + \ldots\ldots \qquad \text{–(1)}$$

ii) *Step2:* The general form for the above equation is given by

$$Z(S) = \frac{K_0}{s} + \sum (i = 1)^{\wedge n} \left(\frac{2K_i s}{s^2} + w_i^2\right) + K_\infty s + \ldots.. \quad \text{–(2)}$$

iii) *Step3:* Calculate the residues by applying partial fractions for the Eq (2),then we get the following residues

$$C_o = \frac{1}{K_0}$$

$$C_i = \frac{1}{2_{Ki}}$$

$$L_i = \frac{2K_i}{W_i^2}$$

$$L_\infty = K_\infty$$

Keywords: system equation

C_o- The first term after applying partial fractions is expressed in the form of series capacitance $C_{o.}$

C_i - The second term after applying partial fractions is expressed in the form of parallel capacitance C_i.

L_∞ = The last term in the given system equation expressed in the form of inductance.

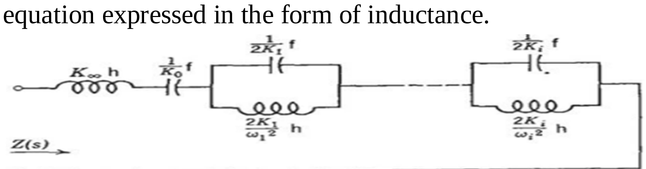

Figure 3: Which shows the driving point impedance

b) *Case2: Foster Canonical Form –II:* This form is similar to that of FOSTER FORM I but in the first foster form we consider the reactance Z(s) where as in this form we have to consider the admittance Y(s) .Then the equation becomes

$$Y(s)=Y_{1(s)} + Y_2(s) + Y_3(s)+\ldots.$$

The remaining steps are same as that of foster form I, but the values of capacitors and inductors are different. The following are the values corresponding to inductors and capacitors after applying partial fractions

$$L_o = \frac{1}{K_0}$$

$$C_i = \frac{2K_i}{W_i^2}$$

$$C_\infty = K_\infty$$

Keywords: system equation

L_o – The first term in general equation expressed in the form of shunt admittance.

C_i – The second term in general equation is expressed in the form of shunt capacitance.

C_∞ - The last term in the general equation is expressed in the form of shunt capacitance.

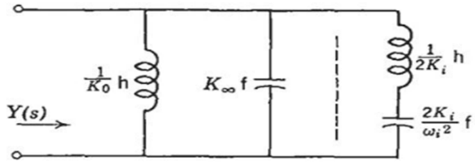

Figure 4: which shows the driving point admittance

c) *Case3: Cauer Form – I:* We had seen that by the use of foster forms, we removed the poles of immittance function by converting into the form of partial fractions, but that partial fractions may consists of poles at origin or infinity. In such cases we have to use Cauer forms to remove the poles. This can be elpains in two modes they expressed below cases.

In this form we remove the poles at infinity.

$$Z(S) = \frac{P(S)}{Q(S)}$$

Since the degree of the numerator and denominator differ by only 1, there is either a pole at S = ∞ or zero at S = ∞

If a pole at S = ∞ , then we remove it.

If a zero at S = ∞ , first we inverse it and remove the pole at S = ∞

1. *Case 1:* pole at S = ∞

In this case , Z(S) can be written as

$Z(S) = K\infty + \frac{P(S)}{Q(S)}$

Order of Q(S) = ordewr of P(S) +1

Hence ,

$$Z(S) = K\infty\ S\ + \frac{1}{\frac{P(S)}{Q(S)}}$$

$$= K\infty\ S\ + \frac{1}{K1S+\frac{1}{K2}+\cdots}$$

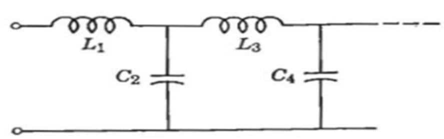

Figure 5: which shows the expansion of the equation.

2. *Case 2 :* zero at S = ∞

In this case G(S) $=\frac{1}{F(S)}$ will have a pole at S = ∞

We synthesize G(S) using the procedure previous step.

Removing the if F(S) is an impendance function, G(S) will be an admittance function and vioce viersa.

The step by step procedure is shown below

Step1: First verify whether the numerator degree [P(s)] is greater than the denominator [Q(s)]. If so , then the given system of equation[Z(s)]has a pole at infinity

$Z(s) = \frac{P(S)}{Q(S)}$

Step2: Then divide P(s) by Q(s) until the degree of the given system equation reduces to zero.

Step3: The quotients obtained are arranged to form a network of desired specifications.

Step4: If the given equation is in the impedance form the first quotient is series impedance followed by shunt admittance again the series impedance .Likewise it follows till the lat quotient

Step5: If the system equation is in the form of admittance form, then the quotients are expressed exactly opposite to that of impedance quotients

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d) Case 4: Cauer Form – II: This form is used to remove the poles at the origin .The step by step by procedure is same to that of Cauer form I but before going to divide the numerator with denominator make sure that they are arranged in ascending order.

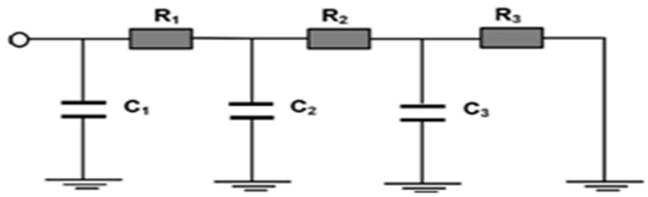

Figure 6: This shows the step by step by process Cauer Network synthesis

R-C Driving point of impedance / R-L admittance

In R-C impedance and R-L admittance driving point functions have the same properties.in this case we are replacing the inductor in LC by a resistor an R-C driving point impedance or R-L driving point admittanc, it can be expressed as

$$F(S) = \frac{K_0}{S} + K\infty + \frac{K}{S+\alpha} + ...$$

Where

$\frac{1}{K_0}, \frac{1}{K_i}$ Capaictors for R-C impedance and inductor for R-L admittance

$K\infty, \frac{K_i}{\alpha_i}$ ..... Represent resistors

C. Properties of R-C Driving point of impedance / R-L admittance

1) Poles and zeros lies on the negative real axis.
2) The singularity nearest origin must be pole and zero near infity.
3) The residues of the poles must be positive and real.
4) Poles and zeros must alternate on thenegative real axis.

D. Synthesis of R-C Driving point of Impedance / R-L Admittance

Foster

In foster realization we decompose the function into simple imittances according to thr poles. That can be expressed as

$$F(S) = \frac{K_0}{S} + K\infty + \frac{K}{S+\alpha} + ...$$

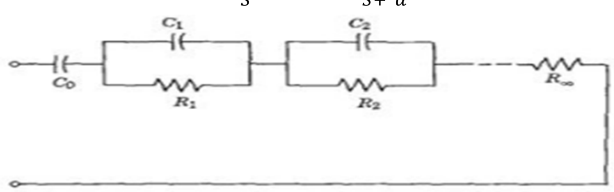

Figure 7: This shows For R-C impedance

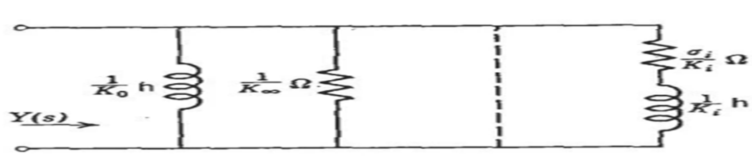

Figure 8: This shows For R-L admittance

E. Cauer Realization

1) Cauer realization uses continued fraction expansion
2) For R-c impedance and R-L admittance we remove a resistor first
3) Then invert and remove a capacitor
4) Then invert and remove a resistor

F. R-L Driving Point of Impedance / R-C Admittance

The R-L impendance driving point function and R-C admittance driving point function have same property.

If F(S) is R-L impedance or R-C admittance , it can be expressed as

$$F(S) = K_0 + K\infty S + \frac{K}{S+\alpha} + \ldots$$

$\frac{1}{K_0}, \frac{1}{K_i}$ Inductor for R- L impedance and Capacitors for R-C admittance

$K_0, \frac{K_i}{\alpha_i}$ ..... Represent resistors

G. Properties of R-L Driving point of Impedance / R-C Admittance

1) Poles and zeros are located on the negative real axis and they alternate.
2) The nearest singularity near origin is zero.The singularity near infinity is pole.
3) The residues of the poles must be real and negative

Because the residues are negative , we can't use standard decomposition methode to synthesize.

H. Synthesis of R-L Driving point of Impedance and R-C Admittance

Foster

The F(S) is R-L impedance d.p opr R- C admittance d.p function can be expressed as

$$F(S) = K_0 + K\infty S + \frac{Ki}{S+\alpha i} + \ldots$$

The third property of R-L impedance/ R-C admittance d.p function, can decompose F(S) into synthesizeable component with the way we were using till now. To find a new way where the residues wont be negative. In this case supose we divide F(S) by S , We get

$$\frac{F(S)}{S} = \frac{K_0}{S} + K\infty + \frac{Ki}{S+\alpha i} + \ldots$$

Note that this is a standard R-C impedance d.p function,

Hence, The residues of the poles of $\frac{F(S)}{S}$ will be positive.

Once we find ki and αi we multiply by S and draw the foster realization.

I. Cauer Realization

1) Using continued fractional expansion .
2) The first remove R_o To do this we use fractional expansion methode by focusing on removing lowest S term first.
3) Write N(S) and M(S) starting with the lowestterm first.

III. LIMITATIONS

A. These network topologies do not give the accurate result.
B. The time complexity is large.
C. It is difficult to analyse and design the network in the case of complex equations.

IV. RESULTS AND DISCUSSIONS

By following the step by step procedure in each form the desired networks are synthesised. The following are the circuit diagrams obtained as a result of the analysis.

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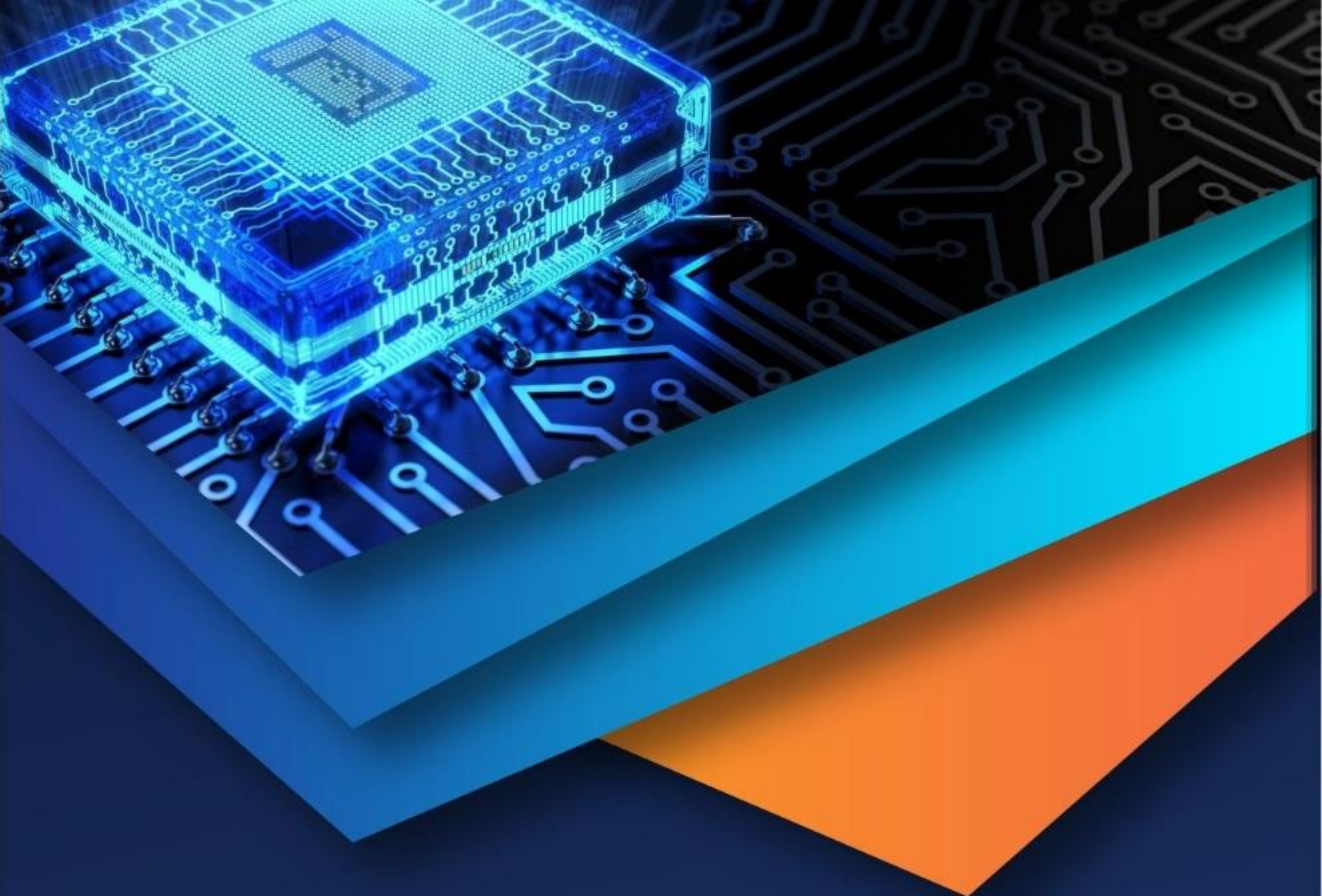

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