**Circuit Theory**
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**Lecture - 42**
**LC Driving Point Synthesis (Contd.)**

The light has come. Forty-second lecture, we are going to talk about LC driving point synthesis, a continuation of the discussion that we held earlier.

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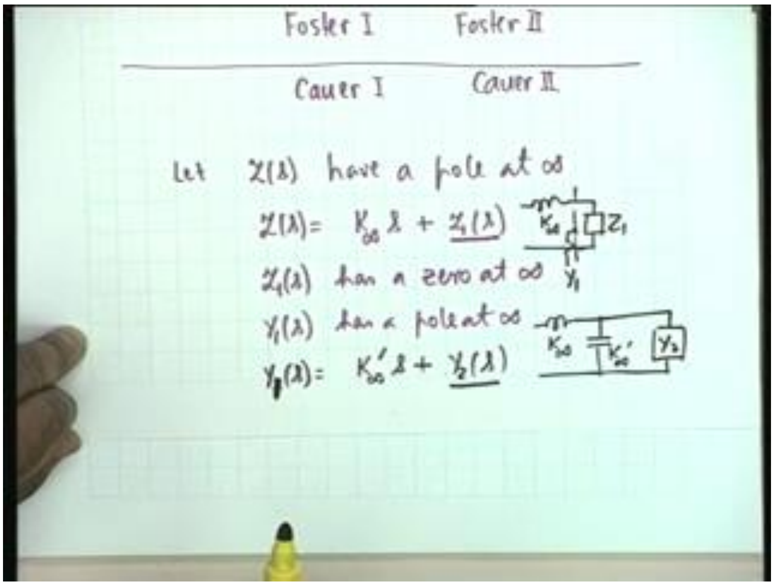


You remember, last time we talked about foster 1 and foster 2. The 2 forms, foster 1 was a series connection whereas, foster 2 as a parallel connection of impedance. And, then we said we will; there are 2 other canonic forms: 1 is cover 1 and the other is cover 2. And as you said cover 1 and cover 2, are quite different from foster 1 and foster 2. Cover 1 and cover 2 are neither series nor parallel connection; they are in the form of ladder networks. And 1 arrives at these ladder forms by the following logic.

You see, if Z of s is LC, if it consists of LC, then you know that, it must have a pole or 0 at infinity. Let us say that Z of s let Z of s have a pole at infinity. If, it has a pole at infinity then obviously, I can write Z of s as equal to K infinity s, where K infinity is the residue of Z of s at this pole plus another function Z 1 of s, which as we had showed earlier is also PR and also LC because, real part of this on the Z omega axis is equal to the real part of Z of Z omega which is equal to 0. And therefore, Z 1 of s at s equal to infinity, some since this is LC and it does not have a pole at infinity, the pole at infinity has been removed, it must be a 0 at infinity.

Therefore, Z 1 of s has a 0 at infinity. All LC functions must have either a pole or a 0 at infinity. If that is, so then its reciprocal Y 1 of s has a pole at infinity. Now, up to this, there was a partial realization like this; we had K infinity and the rest of the impedance was Z 1 partial realization. Now, Y 1 of s has a pole at infinity, Y 1 is this admittance. And therefore, I can remove this pole and write Y 2 of s as equal to know, let me write Y 1 of s as equal to K infinity prime let say s plus Y 2 of s; that is, K infinity prime is the residue of Y 1 at s equal to infinity. Then by the same token Y 2 must also be LC. And the partial realization that I have got now is an inductance K infinity. Then, from Y 1 you have taken an admittance of K infinity prime s, which corresponds to a capacitor. And the value of a capacitor is K infinity prime. The rest of the admittance is Y 2.

Now, what does Y 2 have at infinity?

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0.

The pole has been removed, therefore Y 2 must have a 0.

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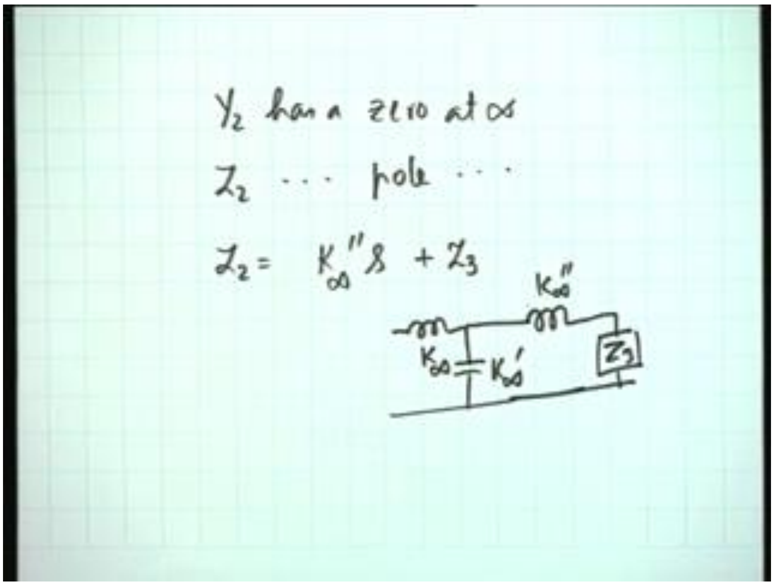

In other words; If Y 2 has a 0 at infinity then its reciprocal Z 2 has a pole at infinity. And therefore, Z 2 can be written as K infinity double prime s, where K infinity double prime is the residue of Z 2 at s equal to infinity plus some impedance Z 3. And the realization that I have obtain so far is K infinity, then K infinity prime, then K infinity double prime and inductance and the rest of the impedance is Z 3.

Now, we understand the mechanization the algorithm, that is, what you do is; you look at the function, if the function is a pole at infinity, remove it, then take the reciprocal of the remainder function, remove the pole at infinity, once again take the reciprocal of the remainder function, remove the pole at infinity and go on doing this.

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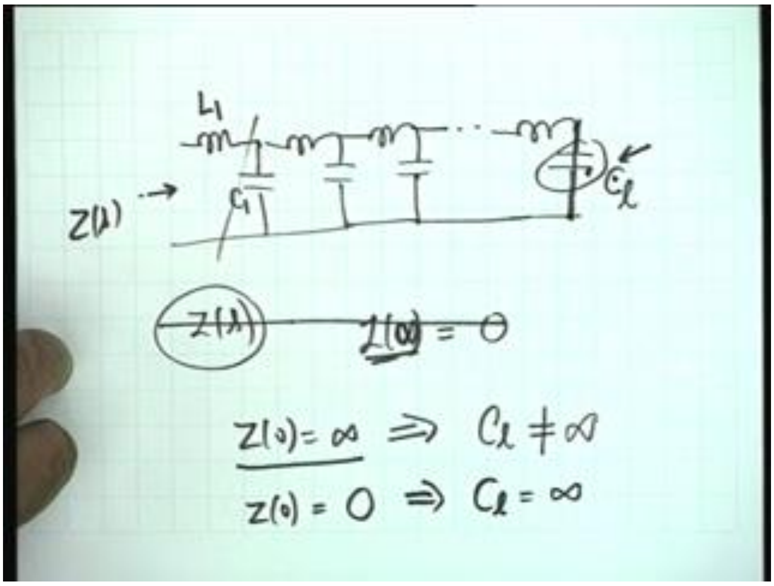


So, the ultimate form that we shall get is like this. We shall have an inductance, a capacitance and inductance, a capacitance and so on. Now, 1 can argue this is the most be general form. One can argue suppose, the original function Z of s. Suppose, the original function Z of s did not have a pole at infinity.

Student: (Refer Time: 05:46)

Then we start with the admittance. If, impedance did not have a pole at infinity, then it must be 0 at infinity. So, you take the reciprocal and start with the admittance and this capacitance this will be the first capacitance. The first element would be a capacitance. So, this inductance, the first inductance L 1 may or may not be present. It shall be present if the impedance function has a pole at infinity. It shall not be present if the impedance function has a 0 at infinity. In a similar manner the last capacitance, when will this be present?

Student: (Refer Time: 06:26)

Has a pole at 0. No, we are talking of infinity.

Student: (Refer Time: 06:37)

The behavior at infinity, can we, you see at infinity this is short. Therefore, this itself this inductance itself takes care of the pole at infinity. Now, when will this be absent; that is the question I am asking.

Student: (Refer Time: 06:58)

The function Z … you mean the Z of s?

Student: (Refer Time: 07:05)

No

He is quite right. You see this can be described… the presence or absence of this can be described only in terms of s equal to 0. You see if this is present, then impedance function, what happens at s equal to 0? This axis is short, this is short, this is short and all of them are short. This is open, this is open, this is open, the last capacitor if it is there, that mean: this is also open. In other words these inductances do not have a path to ground, which means that, Z of s original Z of s must have had a pole at the origin.

On the other hand, if this capacitor is absent that if, there is a short here. Then; obviously, at s equal to 0 Z of s has a 0. So, this is the most general form; the last capacitance may or may not be present, the first inductor may or may not be present. Otherwise it is completely general. And this is cover 1. Now, if you notice carefully, what we have really done is, we have a made a continued, yes

Student: (Refer Time: 08:21)

If the original Z of s does not have a pole at infinity, that is, Z of 0 is not infinity, Z of infinity is not infinity. If it is infinity, if Z of infinity is infinity then; obviously, L 1 shall be there and L 1 will be the residue of Z of s at s equal to infinity. On the other hand, if Z of infinity equal to 0, then; obviously, L 1 shall not be there because, the impedance function does not have a pole at infinity. It is the admittance which has a pole at infinity and therefore, we started C 1 instead of L 1.

On the other hand, the last capacitor, take the situation at s equal to 0. At s equal to 0 all these capacitors are open and all these inductors are short. So, what is the input impedance? Infinity. Now, therefore, Z 0 equal to infinity implies; that the last capacitor let’s say C l is not equal to

Student: (Refer Time: 09:44)

If there is C l, what does it mean? C l is not equal to infinity. If, C l is not there which means there will be a short that is; C l would be equal to infinity. So, if Z of 0 is a if the the original impedance had a pole at the origin, at s equal to 0 if the value was infinity, then; obviously, C l shall be there. On the other hand, if Z of 0 is equal to 0, this means: that C l is equal to infinity. In other words it is a short.

So, this is a general ladder; series L shunt C, it is the cover 1 ladder

Student: (Refer Time: 10:34)

Suppose, there was a driving point admittance

Student: (Refer Time: 10:41)

If this is an Y of s, then we look at Y of s, does it have a pole at infinity? If it has a pole at infinity, then we start with a capacitor. If it is a 0’th infinity, then we take the reciprocal, that is we go back to the impedance. So, whether it is impedance or admittance the same process repeats. You notice that, we have focused our attention on a single point in the s plane and what is this point? The point at infinity and the synthesis is complete, you go on doing this. You go on insisting that, we shall remove pole at infinity from either the impedance or the admittance. We are guaranteed that the point at infinity shall be either a pole or a 0.

So, if it is a pole we will remove it. If it is a 0 then we shall take the reciprocal of the function and then removal. Now, if you see this process of pole removal at infinity, it just amounts to expanding the function in continue fraction in a particular manner, we start with highest powers. This continued fraction expansion starts with, highest powers in the numerator as well as denominator. Why highest powers? Because, we are concerned with the behavior at infinity, it is the highest powers; we determine the behavior at infinity.

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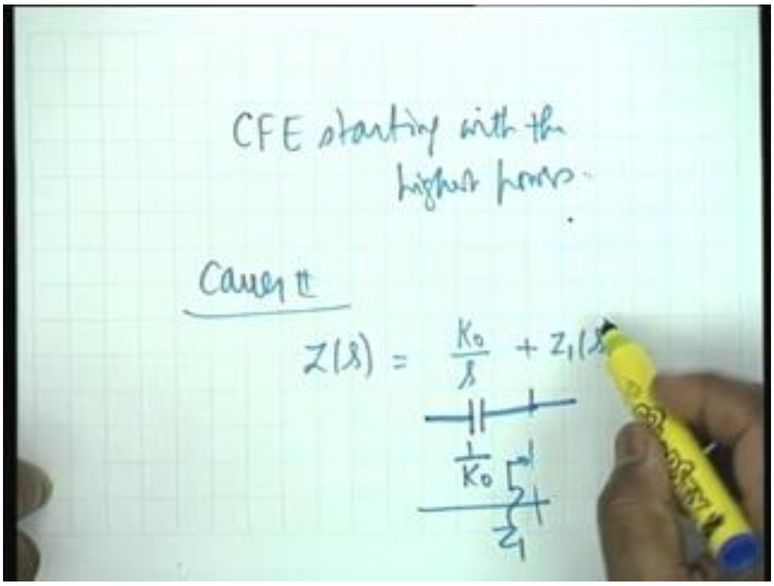


Therefore, all that 1 is doing instead of this step by step removal; we can mechanize this by continued fraction expansion CFE starting with the highest powers. Now, we will come to an illustration of this a little later, but in the same breath, let’s discuss cover 2. While cover 1 focuses attention on the point at infinity, cover 2 focuses attention on the point at the origin, that is, s equal to 0 because, for an LC driving point immittance s equal to 0 is also a critical point, it is either a pole or a 0. It cannot be anything else. And therefore, what we do is; if we start with a Z of s, if it has a pole at the origin, then we remove it. That is we write this as K 0 by s plus some impedance Z 1 of s, if it has a pole at the origin. You may say if plane, if it does not have a pole at the origin it has a 0 at the origin, so we take the reciprocal.

Student: (Refer Time: 13:37)

Admittance. So, if it is impedance then all we are removing is a series capacitor, of value 1 by K 0 and the rest of the function is Z 1. Now, what can you say about Z 1? Z 1 cannot have a pole at the origin because, this pole has been removed. So, Z 1 must have a

Student: (Refer Time: 14:00)

0, no infinity, 0 at the origin which means; that the admittance has a pole at the origin.

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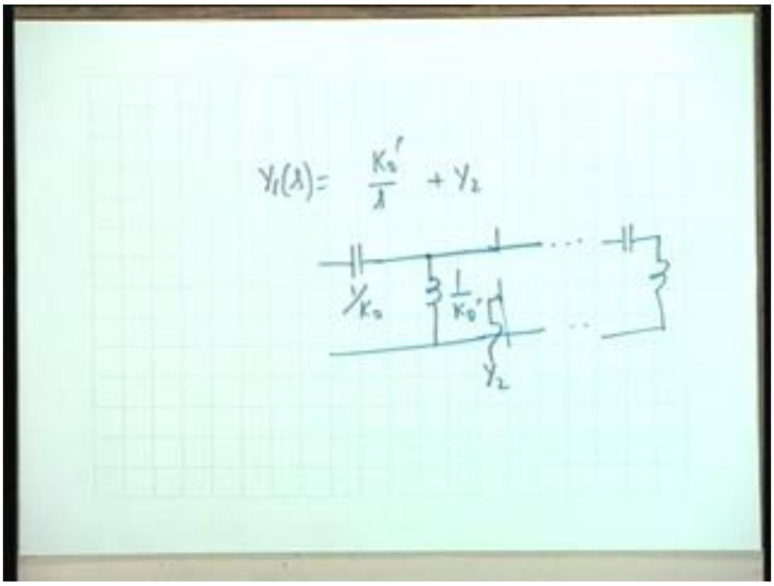


That means; Y 1 can be written as K 0 prime by s plus Y 2 which means that, what we are doing is, we are removing a 1 by K 0, then from admittance we are removing K 0 prime by s which means: an inductor in shunt

Student: (Refer Time: 14:31)

1 by K 0 prime and the rest of the admittance is Y 2 and this process is repeated till, we can proceed no further. In other words, we shall end of in an inductor. Once again, this will be the general form. Once again, you see it is a ladder, but of a different kind, that is; series capacitance and shunt inductors. The first capacitor may or may not be present, under which condition will the first capacitor be not present?

Student: (Refer Time: 15:20)

If the impedance has a 0 at

Student: (Refer Time: 15:24)

At 0

We do not say 0, we say origin because, 0 at 0 it is confusing. Poles and 0s are reserved for the behavior of the total function, where at S equal to 0 is called the origin. Similarly, the last inductor who will determine whether the last inductor is present or absent? The behavior at

Student: (Refer Time: 15:50)

At infinity because, in infinity all the series I am say short. So, if the original impedance has a pole at infinity, then this inductor shall be there. If it a 0 at infinity

Student: (Refer Time: 16:02)

The inductor shall not be there. Now, it is enough of theory, let us look at examples.

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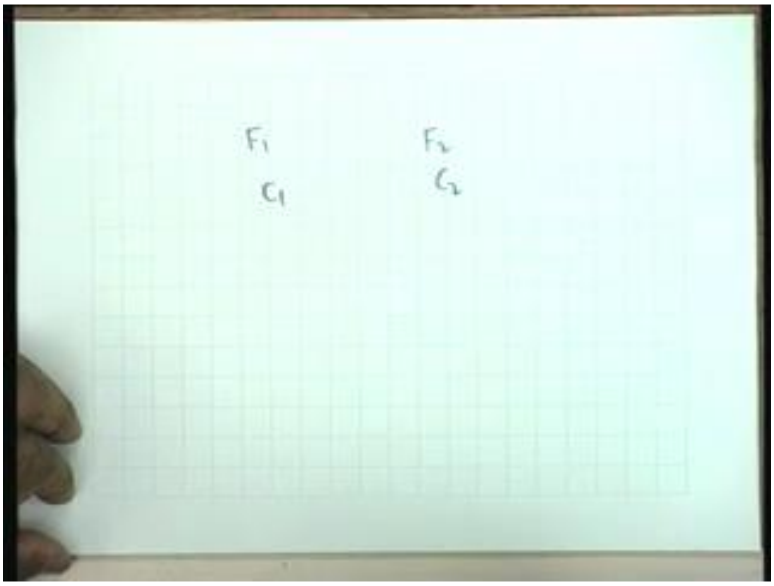


Summarizing: we have discussed 4 canonic forms of our synthesis of LC driving point functions: foster 1 foster two, cover 1 and cover 2. How do we claim that cover is also canonic?

How do you claim, yes you had a question?

Student: (Refer Time: 16:42)

The question is how do I claim?

I said F 1 F 2 C 1 C 2 all the 4 are canonic. Canonic means: the number of elements is exactly equal to the number of specifications. How do we claim that is; we we have already shown why F 1 and F 2 are canonic because, number of elements is equal to the total number of specs that is, omega 1 omega 2 etcetera and the residues. How do we claim that C 1 and C 2 are also canonic?

The reason is that, every time we are removing a pole, we are reducing the degree of the numerator or denominator by 1. And finally, we will be left with a single degree, either in the numerator or in the denominator which means: an inductor or a capacitor, as you saw in both cover 1 and cover 2. So, as simple as that, the logic is as simple as that every time we remove a pole at infinity or at the origin, we are reducing the degree of 1 of the polynomials prime 1. And therefore, we are making progress and the number of elements shall be exactly equal to the degree of the numerator or the denominator, whichever is higher.

Now, let us take some example. Now, 1 more point before we take example. These are 4 realizations of the same function same, LC function 4 realization. Now, how do you prove? At least verify that, if there is 1 solution to a synthesis problem, there are indefinite numbers of solutions. You see given an impedance function, there is nothing sacred about going foster 1 all the going. You can go foster 1 for a few steps and then switch over to foster 2. Remove some of the poles in series, rest of the function you develop in first 2.

So, you get a variation and this where you break the step is you choice. So, you can make a combination of foster 1 and foster 2. You can make a combination of foster 2 and foster 1 that is, start with foster 2, end of in foster 1 or you can go, you can oscillate. Start with foster 1, do foster 2 for a well then go to foster 2 1 again. And therefore, there is infinite variety of networks that you can generate. In a similar manner, you can start with foster 1 and after a few steps you switch to cover 1. And all of these shall be canonic. Foster 1 foster 2 cover 1 and cover 2 are called basic canonic forms. And if, you make a mixture of them for example, F 1 and C 2 it is called a mixed canonic form. Basic canonic form and mixed form.

Student: (Refer Time: 20:00)

Any 2 and therefore, virtually the possibilities are indefinite infinite number of possible. Now, let us take some examples.

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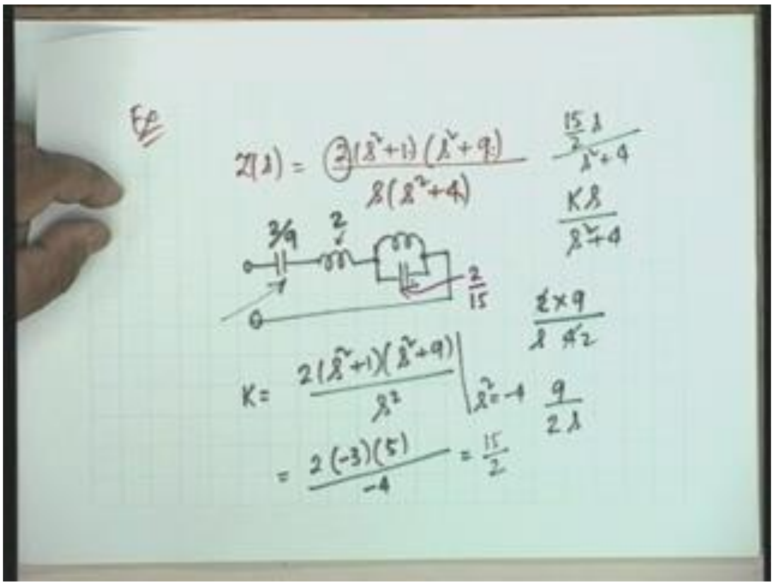

Suppose, Z of s is 2 s square plus 1 s square plus 9 divided by s times s square plus 4. This is the function that is given. The first thing to to check is whether it is LC or not. Does it qualify to be an LC? Actually first critical frequency is a pole at the origin, then at root 1, then at root 4 which is 2, then at root 9. So, the poles at 0s alternate. It is a purely odd rational function. There is nothing in this function, which can disqualify it for LC. Therefore, it is an LC function, without finding be element values. We will find the element values later, but can we by looking at the function, determine the 4 basic canonic forms.

So, for example if, I want foster 1, I argue does it have a pole at the origin? Yes it does. The occurrence of s in the denominator shows that it is a pole at the origin. Therefore, we must have a capacitor in series. Does it have a pole at infinity? Yes it has s to the fourth highest power and s cubed. So, I must have this 1 also, the inductance. What else shall I have? In the partial fraction expansion, I shall have term of the form K s by s square plus 4, which corresponds to a parallel combination of an inductance and the capacitance. So, this must be my foster 1, just by looking at the function

Student: (Refer Time: 22:00)

Can I explain it again? I have a pole at the origin, so there shall be a capacitor. I have a pole at infinity because, the numerator degree is 4, the denominator degree is 3 and it is already the highest power which counts at infinity. Therefore, there is a pole at infinity, in other words, I shall have this inductor also. Then, what do I have? I have a term of the form K s by s square plus 4 corresponding to this pair of poles. And this corresponds to 2 elements in parallel. This is foster 1; 1 inductor and the capacitor. The total number of elements is 1 2 3 4. How many specs are there? 1 2 3 now, this is also a spec; the multiplying constant. And therefore, there are 4. You see if this multiplying constant was not there, element values would have been different. Inductors would have been halved and capacitors would have been doubled. So, this is my foster 1 form.

Student: (Refer Time: 23:09)

Isn't origin? No, the origin is see origin is not a spec; infinity is not a spec why not? Why not because, origin I know it must be a 0 or a pole, there is no other way. So, origin is not a spec. Similarly, the point at infinity is not a spec. All I am given is, what I need is these 2 these 4 numbers 2 1 9 and 4 this type. And if the numerator is of degree 4 and the denominator has only a pair of 0s on the Z omega axis, s must belong to the denominator, there is no other way. You cannot bring s here then the function will not be p r because, the degree difference would be more.

Now, to find the element values, can you also do that by inspection? This 1 for example, would be, the capacitor would be, the trick is

Student: (Refer Time: 24:08)

That is correct

The trick is if, you put s equal to 0, then you get 2 into 1 into 9. So, 2 into 9 divided by this s keep this s because, this accounts for the pole at the origin 4. So, it is 9 by 2s 1 by s c. So, this 2 by 9 agreed. Similarly, the inductance, this inductance you look at the infinity point; that means: highest powers. Highest powers in the numerator be 2 times s to the 4 and the denominator in s cubed,, so it simply 2.

Now, as far as these 2 elements are concerned, you shall have to find K. K is multiplied by s square plus 4 and divide by s. So, we get 2 s square plus 1 s square plus 9 divided by s square, under the condition s squared equal to minus 4. So, let us do that 2 minus 3 5 divided by minus 4 could this be negative? If you get this is negative, then you suspect that you have done some mischief somewhere.

So, this must this is equal to 15 by 2. In other words, what I get is 15 by 2 s divided by s square plus 4. And I can like down the element values now, this 1 for example, the capacitor.

Student: (Refer Time: 25:49)

What is residue?

Student: (Refer Time: 25:52)

No, K is not residue, K is twice the residue

Student: (Refer Time: 25:57)

Residue is half of K

Student: (Refer Time: 26:00)

Capacitance value is simply 1 by K, not K because, this is an impedance say would it be s by K. So, capacitor value would be how much?

Student: (Refer Time: 26:15)

2 by 15. And the inductor value?

Student: (Refer Time: 26:18)

15 by 8 I hope you are right

4 into 2 divided by 15 is

Student: (Refer Time: 26:29)

How we got the K?

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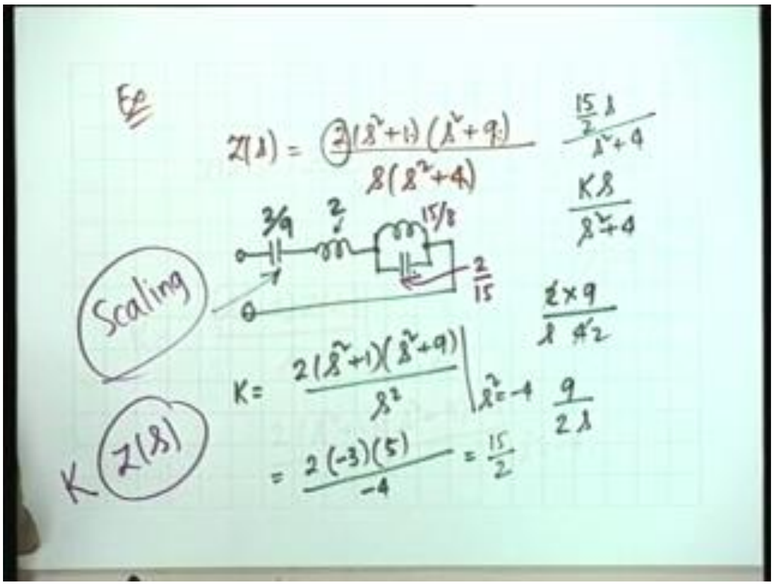

Let me do this. This is written as 2 s square plus 1 s square plus 9 divided by s into s square plus 4. We wrote this is K 0 by s plus K infinity s plus some K s divided by s square plus 4. So, how do I find K? I multiply both sides by s square plus 4. Then, on the right hand side I shall have K s. I want to find K, so I divided by s. Then, I put s square equal to minus 4. In the right hand side this term will be 0, this term will be 0 because, I am multiplied by s square plus 4. It is only this that shall remain. So, I multiply this by s square plus 4, s square plus 4 cancels and divided by s.

So, K is therefore, equal to 2 s square plus 1 s square plus 9 divided by s squared, under the condition s square equal to minus 4, this is what I did. Now, before I pass to foster 2, can I ask you this question again? I did ask you, but I want to being out a point. Suppose, we had here, a very large constant, let say 159.38. Then, instead of handling such large numbers with fractions and all that we could have simple ignored it and obtain a realization of this with nice numbers. Finally, after I get the network, I can change the element valves. How do I change the element valves?

Student: (Refer Time: 28:31)

That is right. So, the multiplying constant, we will the multiply the inductors and divide the capacitors. This is called scaling. That is the principle, a extremely simple principle, it is that if you know the syntheses of Z of s, then you also know the synthesis of K Z of s. All that you have to do is to change the inductors, multiply them by K and divide the capacitors by K. Now, instead of an LC network, if I had RNC network, then what would have happen to the resistors?

Student: (Refer Time: 29:18)

Multiply the resistors by K.

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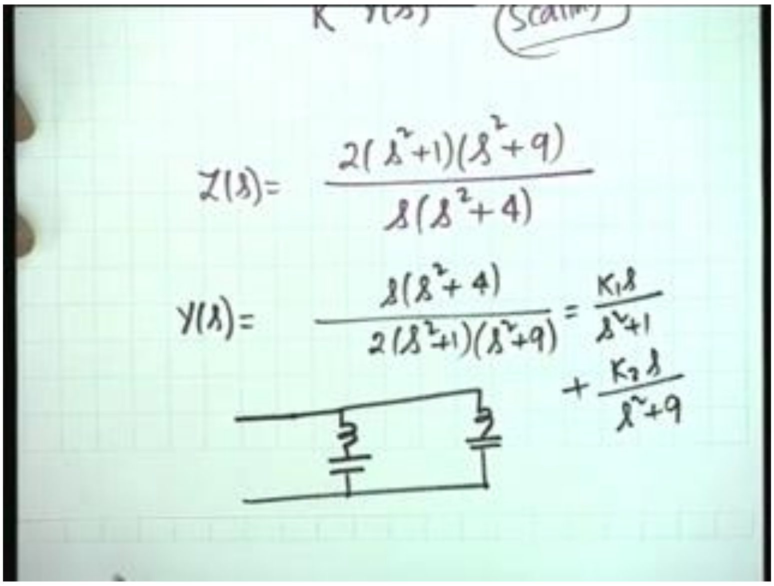


Suppose, if know the synthesis of Y of s some admittance and I want to find out the synthesis of K Y of s. All that I do now

Student: (Refer Time: 29:31)

Multiply the capacitors by K, divide the inductors by K and resistors if there are any, divide by K. This is called as scaling. And many a times in the numerical calculations, particular in very complicated functions 1 does that. 1 takes out a constant, takes out a constant such that the rest of the numbers are nice number to deal with. And then finally, change the element valves. Do it once only, do not make your life miserable throughout the calculations.

Now, let us look at foster 2. Our function was Z of s equal to twice s square plus 1 s square plus 9 divided by s times s square plus 4. For foster 2, we have to take the admittance; foster 2 is a parallel connections. So, we take the admittance Y of s is equal to s s square plus 4 divide by 2 s square plus 1 s square plus 9. The admittance fortunately or unfortunately, has no poles either at either external critical frequency. You see at s equal to 0 its 0, at s is equal to infinity it is also a 0. And therefore, I can immediately draw the form of the network. What will be the form of the network? Just 2 LC networks 2 series LC networks in parallel. Isn't that right? Is this ok?

Student: (Refer Time: 31:16)

How do I get that?

This function has no pole at infinity, so there is no shunt capacitor. This function has no pole at the origin, so there is no shunt inductor. And there are 4 specifications; there must be 4 elements, the partial fraction expansion of this would be K 1 s divided s square plus 1 plush K 2 s divided by s square plus 9. And each of them will give you a series LC circuit and therefore, there are 2 LC circuits in parallel. No single inductor no single capacitor.

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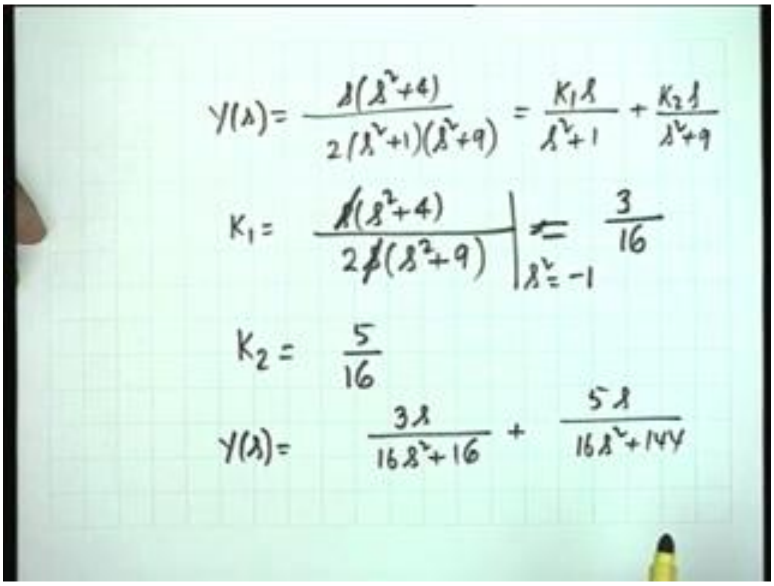


To find out K, Y of s is s times s square plus 4 divided by 2 s square plus 1 s square plus 9, this is equal to K 1 s divided by s square plus 1 plus K 2 s divided by s square plus 9.. So, K 1 we multiply by s square plus. So, little little bit of practice, you do not even have to write this or you write agitated form. For example I do not write this function again, what I done is s times s the numerator shall remain the same.

Student: (Refer Time: 32:39)

This would be twice s times s square plus 9 and that the condition s square is equal to minus 1. So, 3 by 16, K 1 is 3 by 16 and K 2

Student: (Refer Time: 33:00)

5 by 16. And therefore, write this Y of s; 3s by 16s square. Now, I am giving you a trick, I am this denominator 16s square plus 16 so that my element valves are obvious and this plus 5s divide by 16 s square plus 144.

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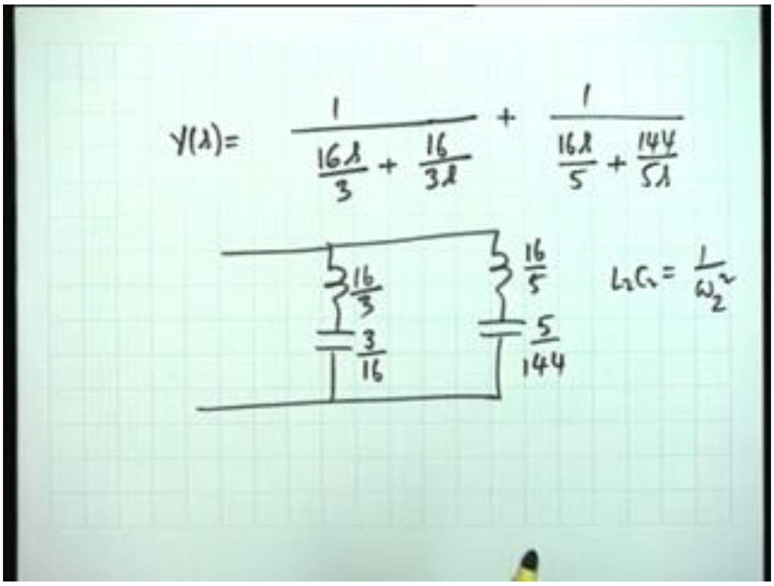


And therefore, I can write Y of s with a little practice you do not have to do this, but to start with it’s not a bad idea to do this. I divide both by s 3s that is; I make the numerator as 1. Then, I get 16s by 5 plus 144 divided by 5s and the element values should be obvious.

Student: (Refer Time: 34:12)

This is 16 by 3 s l and 1 by s c, so this is 3 by 16. 1 of the verifying features 1 of is; that the product of this 2 must be the reciprocal of omega 1 squared. It is a series resonant circuit and this is the frequency of resonance omega 1 squared is 1; here the product should be equal to 1. And here 16 by 5 and this should be 5 by 144. The product L 2 C 2 must be 1 over omega 2 squared and omega 2 squared is 9.

Therefore, the product of these 2 is indeed one-ninth. That takes care of foster 2, there are exactly 4 elements. You have a question?

Student: (Refer Time: 35:16)

No for any, even in the parallel LC foster 1 in foster 1 the product of the 2 inductance and capacitance shall be 1 by omega naught square. That is a verifying feature.

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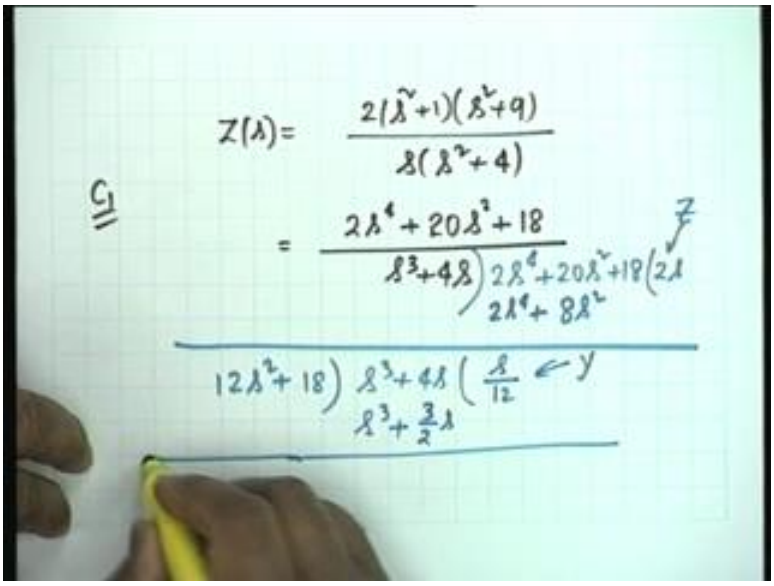


Let us go back to the impedance function Z of s is equal to 2 s square plus 1 s square plus 9 divided by s into s square plus 4. Now, we are asking for cover 1 the question, this is a crucial step and 1 must be very careful. First you ask the question, does the function have a pole at infinity? Yes it has. So, we can start continue fraction of Z of s. If, it does not and you start blindly, you shall get nonsense results and immediately you should you should go back and correct yourself.

Now, here this factored form is of no use now, so you must reduce it to a polynomial form. And you can easily see that this is s cube plus 4 and in the numerator it’s twice s to the 4 plus

Student: (Refer Time: 36:34)

s cube plus 4s all right. In the numerator?

Student: (Refer Time: 36:42)

20s squared plus 18. We could have done away with 2 we could have, but 2 is a nice number it does not really affect us so let us keep it. Now, we start continued fraction expansion; 2s to the 4 plus 20s square plus 18 and as I said to avoid going like this we will bring the reminders here. And the first quotient is 2s and this is an impedance, you must go ahead and identify the dimension 2s. So, we get 2s 4 plus 8s squared. And you bring here 12s squared plus 18, that divides s cube plus 4s, the quotient is s by 12 and this is in admittance Y.

So, s cubed plus 18 by 12, that is 9 by

Student: (Refer Time: 37:44).

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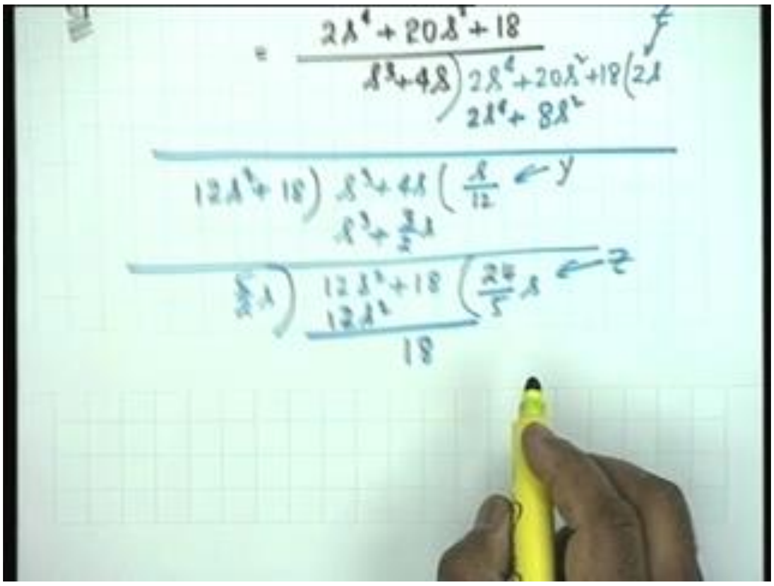


3 by 2 s 3 by 2 s. The remainder is 5 by 2 s that, divides 12s squared plus 18. So, the quotient would be 24 by 5 s and this is impedance 12s squared remainder is 18.

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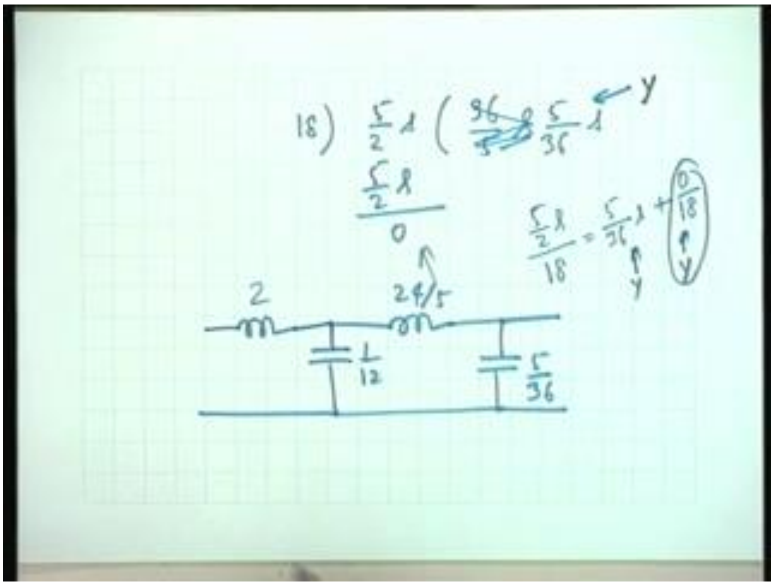



And all that you have to do now is 18 divides 5 by 2 s. So, you get 36 by 5 s.

Student: (Refer Time: 38:27)

Oh! 5 by 36 s 5 by 2 s and 0, this is admittance. What is the dimension of this?

Student: (Refer Time: 38:43)

No, 0 by 18 is isn’t it. This quotient plus remainder divided by the divisor, this must be admittance it has to be, if it was impedance then 0 impedance means: short circuit. So, the last element, what is the last element here? Capacitor it is an admittance. So, our network becomes this; I have a 2 Henry inductor because we started then impedance,, then one-twelfth capacitor, then 24 by 5 and finally, 5 by 36. The rest is 0 admittance which means: infinite impedance; that means, open circuit all right, it as to be that way there is no another way. There are exactly 4 elements and the last element is a capacitor because, what is the reason this is a capacitor? Because, the function had pole at the origin.

Student: (Refer Time: 40:04)

Why we have open circuit? You see the last device the last remainder this is 0 and, so 5 by 2 by 18 5 by 2 s divided by eighteen this is the division that we have performed here. This is equal to 5 by 36 s plus 0 by 18. If, this is admittance this must also be an admittance. And this 0 admittance means: an open circuit, have it been an impedance then it will have been a short circuits. The point that I mention in is the question that I was putting you why is the last 1 a capacitor?

Student: (Refer Time: 40:48)

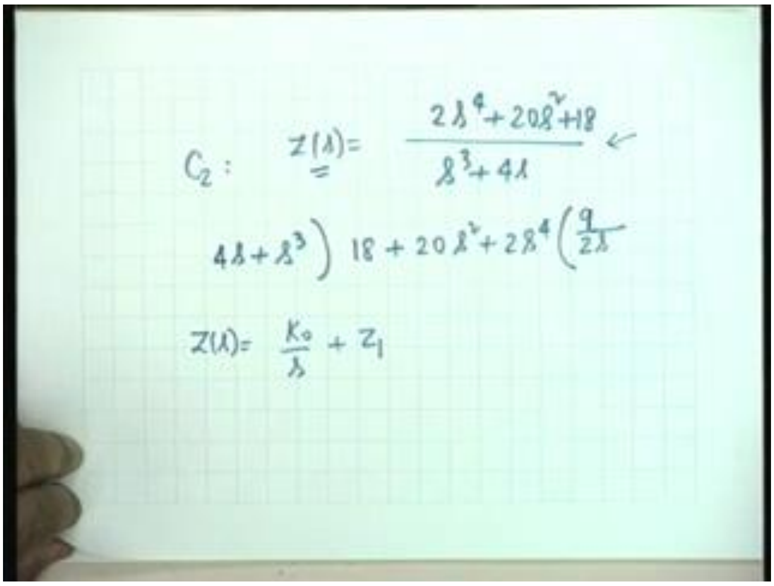
Pardon me.

Student: (Refer Time: 40:51).

Of course, it could have ended in a impedance 0, then you have to put a short circuit. For example, if the function to start with, there is a pole at the origin, that is why the last element was a capacitor. If it did not have a pole at the origin, then the last element would have been the short circuit that is a last element would have been inductor; that means; instead of a capacitor we will have a short circuit. It is important to understand this. After a while it will become routine, after a while, but you require a little bit of practice.

Now, let us go to cover 2.

(Refer Slide Time: 41:39)




Now, cover 2: our function is Z of s equals to s cubed plus 4s 2 s 4 plus 24s squared plus 18. Cover 2, as I said focuses attention on the point at infinity, it focuses attention on the point at the origin. Cover 2 focuses attention on the origin. And therefore, what we do is we remove terms like K 0 by s. In other words our focus now, shall be on the lowest powers not on the highest powers. And to be able to remove a term like K 0 by s; obviously, continued fraction expansion, has to be started with lowest powers not highest powers. Highest powers gives cover 1, lowest powers gives cover 2.

The question that 1 should ask is; does the given impedance given function had a pole at the origin? If it has, then you start continue fraction expand. If it does not have, then you take the reciprocal and then start continue fraction. Here we shall write, we shall have to write it like this; starting with the lowest powers. And the numerator 18 plus 20s squared plus 2s to the 4 and we have to continue.

Student: (Refer Time: 43:09)

Pole at origin.

Before starting any continued fraction expansion, you have to ask; is the function prepared for that particular continued fraction expansion? For example, in cover 1 we ask the question, does Z of s have a pole at infinity? If it does not have, then you cannot start continue fraction expansion of Z of s, you have to take it reciprocal and then start. Here also we ask the question, does Z of s have a pole at the origin?

Student: (Refer Time: 43:41)

Yes, it does.

Student: (Refer Time: 43:44)

It has a pole at the origin. That is why; we could start continued fraction expansion of Z of s.

Student: (Refer Time: 43:55)

Function is infinity.

Student: (Refer Time: 44:00)

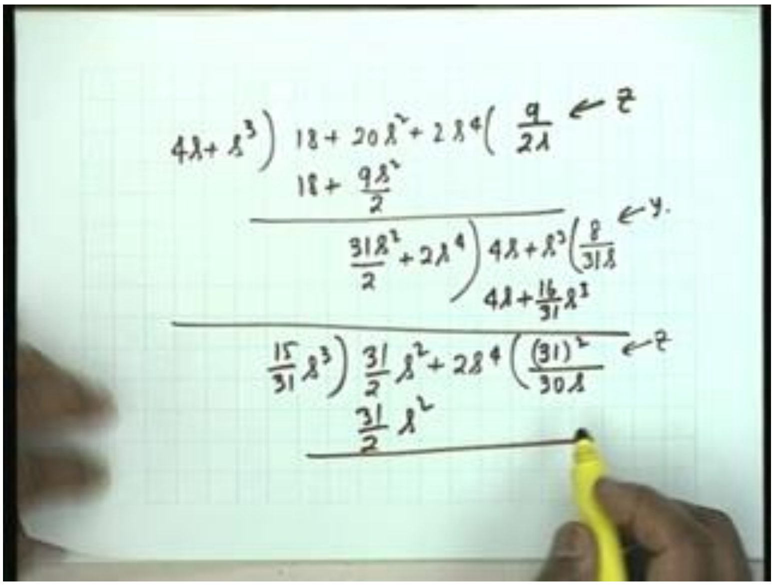
That is precisely the point. Therefore, we can start continued fraction expansion with Z of s, but now since it is cover 2 our point of attention is the point at the origin, we start with the lowest powers. And our first quotient becomes e18 by 4 which is 9 by 2s, s in the denominator now.

Student: (Refer Time: 44:27).

Why do we start with, because cover 2 in cover 2 we want to express this as K 0 by s plus some other function Z 1. How can, we get K 0 by s, unless we start continued fraction expansion with the lowest powers. You see highest powers always give you quotients of the form K time s. You have to get K by s and therefore, you must divide by a constant by the s term. This is the mechanization, but even if you do not know continue fraction, K 1 is not very difficult because it's simple means removal of poles at the origin.

If, the function as a pole; remove it. If, the function does not have the pole, take the reciprocal and remove it, but this is the mechanization.

(Refer Slide Time: 45:24)



Let us continue this continued fraction expansion 4s plus s cube 18 plus 20s square plus 2s to the fourth. The first quotient is 18 by 4s which is 9 by 2s and the dimension is impedance. I get 18 plus, what do I get here? 9s squared by 2, you must not forget the power s and s cubed so s square by 2. This should be 40 minus 9 that is, 31s square by 2 plus 2s to the 4 this divides 4s plus s cubed and I get

Student: (Refer Time: 46:07).

8 by 31 s this is an admittance. So, I get 4s plus 16 by 31s cube. So, I get 15 by 31 s cubed 31 by 2 s squared, numbers are getting nasty, but keep if as a fraction as long as you can all right, as long as you can. Because, as soon as you shift to decimals you are bound to ignore later part of the decimal and that will create errors. Finally, you may not get 0, you may get point you know, 10 to minus 4 or 10 to minus 5, depending on how much error you committed. So, in numerical calculation keep it as fractions as long as you can. What do we get here? 31 square divided by 30, s is in the denominator and this is a impedance.

So, 31 by 2 s squared, fortunately it is not too bad.

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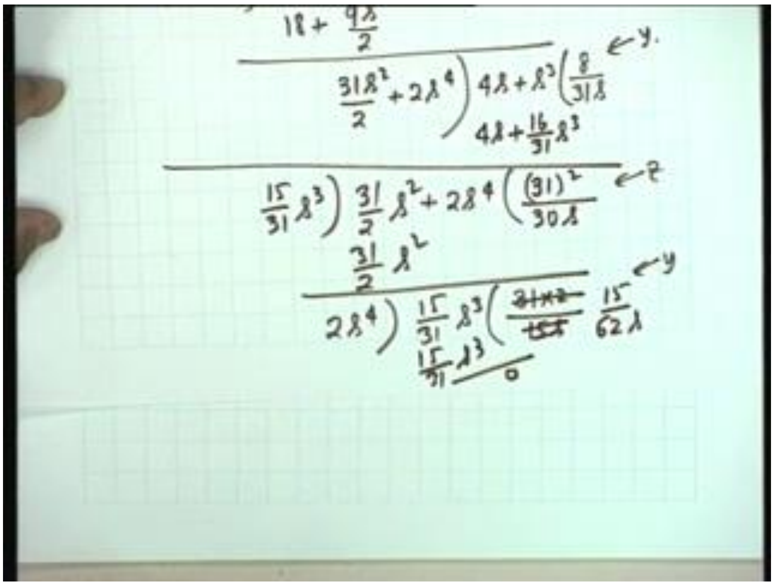
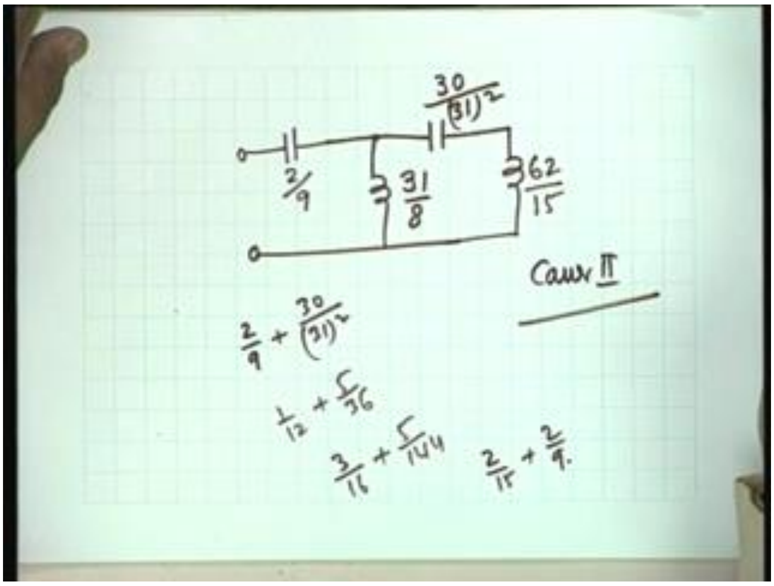


Now, last remainder is 2s 4 divides 15 by 31 s cube. So, I get 31 into 2 divided by 15s no.

Student: (Refer Time: 47:38)

15 by 62s and this is an admittance. So, 15 by 31 s cubed and the remainder is 0. This 0 is once again admittance.

(Refer Slide Time: 47:54)




So, my final network becomes; we start with a capacitor 2 by 9, the next 1 is an inductor valve is 31 by 8 1 by s l. The next 1 is a capacitor 30 by 31 square 961. And last 1 is a inductor 62 by 15 and that completes the job of cover 2. The rest is open circuit because; the remainder is an admittance which is equal to 0. Now, of these 4 networks that you have obtained, which 1 do you think you will prefer?

Student: (Refer Time: 48:46)

Why?

Student: (Refer Time: 48:50)

Smallest capacitors? Now, 1 as to be careful. You see in fist in cover 2, the total capacitor is 2 by 9 plus 30 by 31 square. In cover 1 it is one-twelfth plus 5 by 36. In foster 1, let me say 3 by foster 2 3 by 16 plus 5 by 144. And what was foster

Student: (Refer Time: 49:32)

2 by 15 and 2 by 9. Now, before I get you involved in this calculation, let me point out that it is not just a total capacitor, capacitance large valve is not a problem. The problem lies in LC networks in particular. And almost all analog filters that are used in practice are required to be LC, required to be if, it is passive filter because, our very simple reason our power is very precious, we do not want to lose.

If, there are resistances they will absorb power and therefore, as it proceeds as the communication channel, as a signal proceeds on the communication channel it gets attenuated. Not only attenuated get distorted also all right. So, most of the telephone filter telephone channel filters for example, even if even a digital telephone filtering at crucial points, are done by analog means. And you require inductances and capacitances.

The point of state is not just the total capacitances because, capacitances is not a very crucial element. A crucial element is the inductor, particularly at low frequencies. At very high radio frequencies, broadcast frequencies or the short wave or the broadcast, work is not a problem. Capacitor inductance also is not much of the problem, but at low frequencies inductance is a problem. And there 1 as to bother more about the inductor queue because, you cannot make a large inductor without a large resistance. And as soon as we introduce a large resistance, well may current squared multiplied by that resistor, you just have no way to obviate that. That amount of power shall be disappeared.

Therefore, what I am saying is in the realization, it is not just the total capacitor, may be the total inductor is important or the individual valve of the inductor may be, in 1 of these realizations there is required a very large inductor. And you would not like not make that kind of that inductor because, you know to make let's say 1 Henry inductor, you require a very large space. The number of turns is required to very large and then 1 Henry inductor if you have, if you do not have iron as the core or ferrite as the core, then you might have to use this whole room to wind a 1 Henry inductor. And that is not a practicable solution.

So, you use cores, you use special kind of wires and other things. And if you use a core, then you have to bother about many other things, it not just ohmic loss, there are other losses AD loses. So, inductor is a nuisance as far as

Student: (Refer Time: 52:38)

There, that is another problem. As soon as you an inductor, a capacitor there are static problems; there is coupling in electric filed, but inductor coupling is more of a menace because, as soon as we have an inductor well it's creating flux and if this flux terminates, on the nearby equipment well, it going to destroy the functioning of that equipment. In addition, if there is a mutual inductance with the mutual with the neighboring machine and therefore, the performance of this particular machine is going to be Student: (Refer Time: 53:21)

So, it is not just inductor, it is not just capacitors. It is the total structure that is important and it depends on what you can realize in practice. Number 2 31 by 8 or 62 by 15 62 by 15 is more than 4 Henry, who is going to make a 4 Henry inductor for you? Well these are all normalized valves. You do not require a circuit in which the resonance frequency is 1 radian per second. It will possibly in the Kilo or Mega range. Then therefore, these valves shall also be staying down accordingly; an inductor of the range of 1 milli Henries, perhaps the highest that 1 uses in practice in filter.

Whereas, in machines and power systems, may be you you use larger inductance, but in communication telecommunication you do not use more than a milli Henries. Similarly, capacitor valves are limited to microfarads. If, you go beyond microfarads then there is a practical problem, what is a problem?

Student: (Refer Time: 54:26)

Size is 1 and leakage, the higher the valve of the capacitor the more is the leakage because, you see between 2 let us say, let us take an aluminum foil, which acts as the plate. Now, between aluminum foils you have to put a insulator, that insulator is not a perfect insulator, that is the leakage. And that, as the valve of the capacitor increases, the area through which leakage can occur also increases and therefore, the conductance Z decreases. No.

Student: (Refer Time: 55:08)

Increases; resistant is in shunt, so if it is increases its good. Conductance increases and therefore, resistance shunt resistance decreases. Now, these are the practical valves. And life is a compromise; electrical engineering is no exception you have to make compromises.

More, tomorrow at 10 clock.

Thank you.