Networks, Signals and Systems

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Lecture - 33

Synthesis of 2 - Port Network (Conti…)

Good morning friends, last time we were discussing about LC synthesis we got struck in a little problem. See we had $z_{11}(s)$ those are slip we made, we had something like this S squared plus 16 plus K_3 by S.

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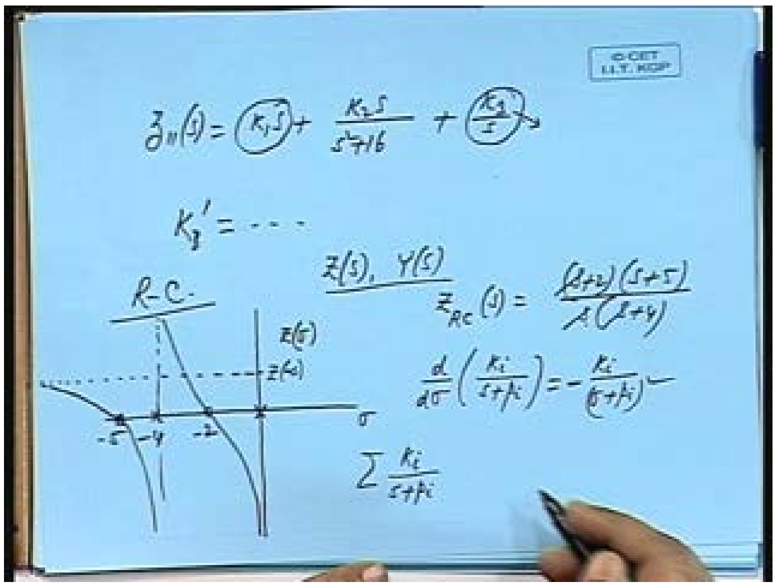

So while removing the pole partially we are concentrating on $K_1(s)$ instead of that it should have been in $K_3(s)$ okay and from there we will get the value of K_1 dashed corresponding to the one that is to be removed K_3 dashed okay and we will get the pole shifted. So I would leave it to you for completion of this after that it is a very straight forward method. We will take up today RC networks all right, RL is not used so often because of the imperfection in the inductance L.

So RC is a very commonly used network so will concentrate on RC network before you go to RC network in details you would like see the properties of Z(s) and Y(s), some of the properties of Z(s) and Y(s) which we did not study earlier. We will see what would be their plot in the S domain. Suppose you consider the Z(s) function it may be s plus 2, let me take a very simple example, S plus 5 divided by s into s plus 4 the pole is at the origin so 2, 4, 5, what would be the impedance diagram, Z, sigma, if I put S is equal to sigma that is minus 2, minus 4, minus 5 these are the poles in 0s and if I put any other value of sigma what would be the nature of variation at least near this poles and 0s. It will be a pole here passing through 0, this is a pole. So it will be from infinity passing through 0 will be going to infinity okay again from here will be going like this at S equal to infinity it is finite okay.

Let us see if you put S is equal to infinity it is a s squared by s squared that is 1 in this particular case it is 1 and had there been a constant here it would have been that constant, so this is Z infinity at S equal to infinity, why should the slope be negative, slope should it be negative. Let us find out d, d sigma of see this can be written in a general term some K_i by S plus p_i okay summation of this p_i may be 0, in that case the pole is at the origin otherwise, the poles are at points like4 there can be many more poles. So this is a general term, so it will differentiate any of the general terms and see what will be the nature S equal to sigma okay we are putting S equal to sigma.

So we will find this will be giving me minus K_i by sigma plus p_i whole squared which will be always giving me a negatives slope all right, this is a respective of the value of sigma. So here it has to pass through 0 with a negative slope, so the curve has to be this way all right. So this is the nature of Z in case of an RC network and there been a pole somewhere other than the origin and so on, what will be the nature of this? This is a pole all right, this is a pole, this is a 0, this is a pole okay, this is a 0, what about this one? So it may cross at a point Z at 0 all right. Let us have a function like Z(s) equal to so this a minus 1 here so S plus 1 into S plus 2, S plus 3 I am just obviously taking some points okay.

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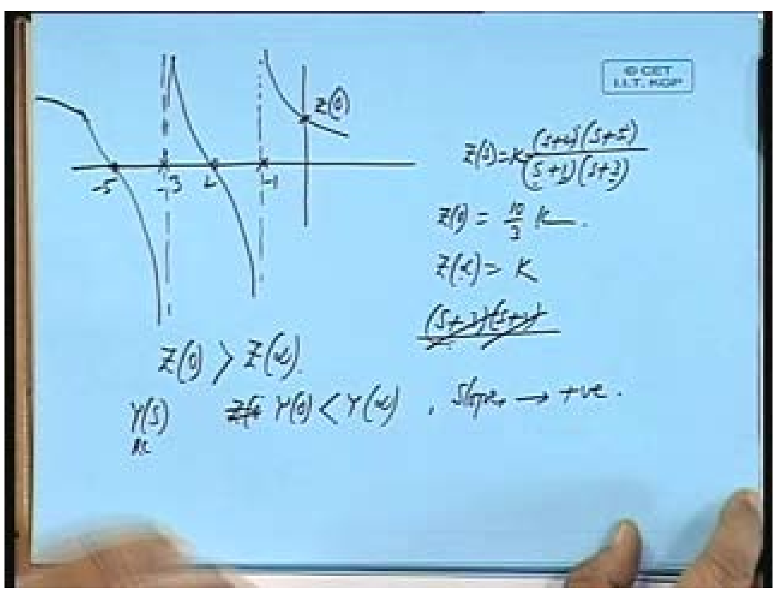

So this is 1, this is 3, this is 2, this is 5, you may have a have a function like this, what will be Z_0 if I put a S equal to 0, so it is 10 by 3, what is Z infinity. So Z_0 is always greater than Z infinity are you convinced this is there any logic for it when I put S is equal to 0, see these are poles and 0s starting with a lower value a pole first that means 1 then the 0 corresponding 0 will be at higher point so 1, 2 the ratio is always greater than 1, 0 is always above the pole all right here it is 5 by 3 and so on.

So Z_0, Z_0 will be always more than Z infinity it can be under certain situation okay may be equal to, s plus 3, s plus 2, s plus 6, s plus 1 okay let us see S plus 3 into S plus 2 then the poles and 0s are not interlacing it will be an RLC circuit it will not be a RC circuit. So because of the property that RC networks will have poles and 0s coming alternately starting with a pole that means a lowest value is a pole then a 0 then a pole a 0, 0 is always at higher point than a pole. So the ratio is always greater than1 so the overall ratio is more than 1 and if you take a S_{10} to infinity that gives me Z infinity which will be a S squared by s squared that is 1 at the most all right otherwise it will be 0, no for an RC network it cannot be otherwise, it cannot be otherwise.

So Z infinity is 1 in this particular case otherwise if you have a K both of them will be multiplied by K okay. So this is an important conclusion Z naught is always greater than Z infinity in case of an RC network. For Y(s) it will be just the other way round, so for Y(s) for an RC network Z_0 sorry Y_0 is less than Y infinity and the slopes will be positive okay. So if we take a take an admittance function it will look like this. So Y(s) is once again I can put it s minus 1 minus 3 okay s plus 4.

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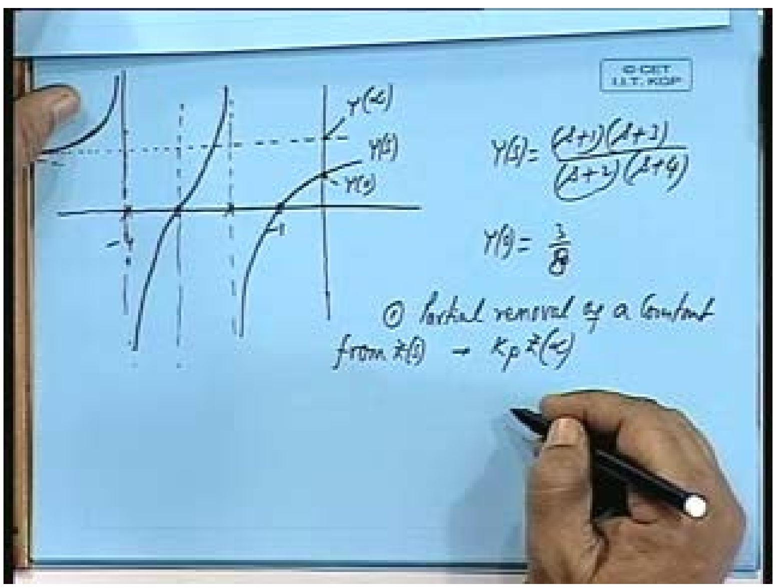

So this is an admittance function of an RC network okay, what will be Y_0, 3 by 10, 3 by 8, sorry 3 by 8, 3 by 8 so will be somewhere here then from here and so on then at S equal to infinity it is 1, this is much above this point. So how will it move, it will be going to infinity like this asymptotically it will go to Y infinity that is equal to 1 is it all right.

Now suppose there are these following steps of removal of poles okay part removal I can have a partial removal of a constant from Z if you are given the specification in terms of Z(s) you remove a constant Z(s) which will be some Kp times Z at infinity okay. So for Z, for Z, Z infinity was like this okay.

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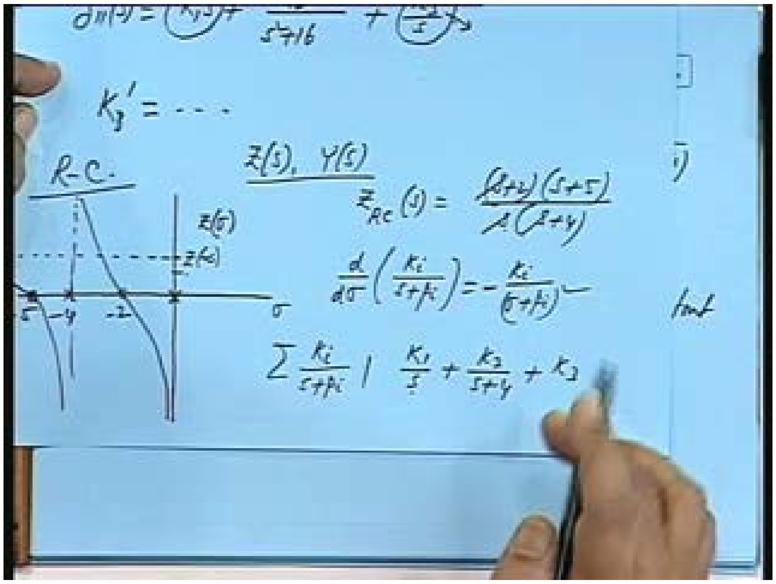

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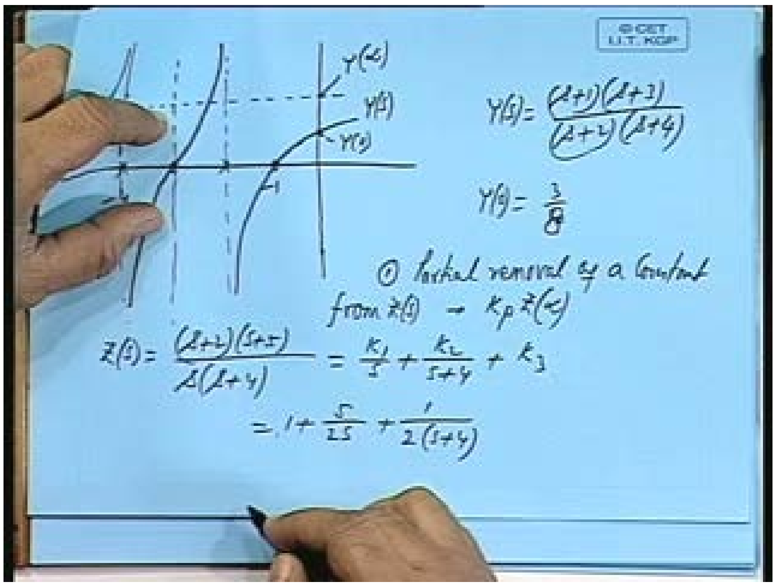

So some fraction of it I can remove, I do not remove Z infinity totally, what is Z infinity? Z infinity what will it give me here. Now in this particular example it is 1 if I make partial fraction of this, it is K_1 by S plus K_2 by S plus 4 plus a constant K_3, so at S equal to infinity this will vanish, this will vanish, it is this term all right, it is this term which is partly removed that means whatever is that constant I do not remove it totally I retain a part of it all right. So if I remove a part of it what happens to the 0s, what happens to the 0s. So let us go back to that very example, Z(s) is s plus 2 into S plus 5 divided by s into s plus 4. So if you make a partial fraction K_1 by S plus K_2 by S plus 4 plus K_3 that gives me 1 plus 5 by 2S plus 1 by 2 into S plus 4, you can calculate K_1, K_2, K_3 as 1, 5 by 2 and half all right.

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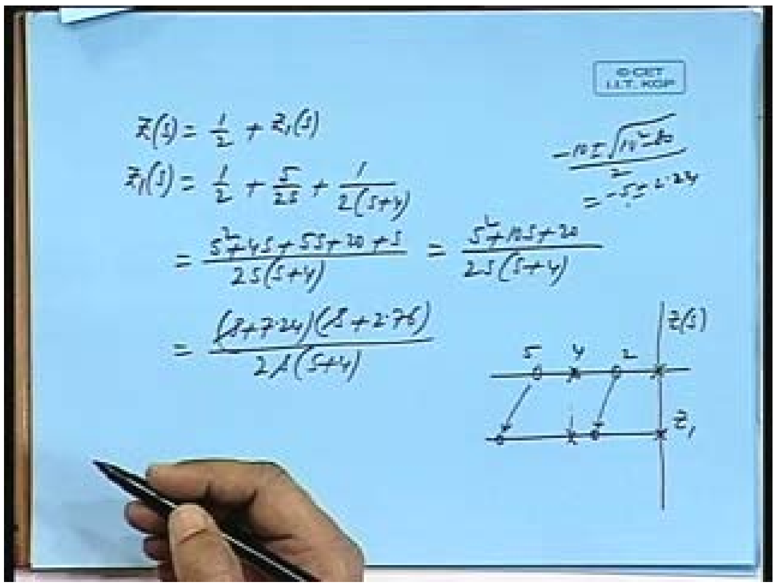

Suppose I remove only a part of it half of it 50 percent then what will be my new Z(s) is half plus some Z_1(s), what will be the Z_1(s), it will be the balance half plus 5 by 2 S plus 1 by 2 into S plus 4 okay. Now can you see the result and that gives me just check up your calculations 1 by 2S, so S into S plus 4, S squared plus 4, S plus 5 into S plus 4, so5 S plus 20 plus S, so that gives me 5 plus 4, 9 plus 1, 10S, S squared plus 10S plus 20 by 2 S into S plus 4 okay. So that gives me minus 10 plus minus root over 10 square minus 80, so by 2 so that gives me minus 5 plus minus root 20 by 2, root 20 is how much root 5, so 2.24 okay.

So it is s plus 7.24 into approximately s plus 2.76 divided by 2s into S plus 4. So what will be the pole 0 configuration earlier we are having a pole okay at 2 there was a 0, at 4 there was a pole, at 5 there was a 0. Now this is for Z(s) I am not drawing the entire sketch I am just showing the pole 0 configuration and at Z_1, now we have got a pole here a 0 at 2.76 here, pole here and a 0 at 7.26 you see the shift in the 0 positions, is it all right. So if you weaken the what you have done is, you have partly removed this, what is this part removal part removal of Y at infinity, a Z at infinity, Z at infinity, Z at infinity this has been partly removed.

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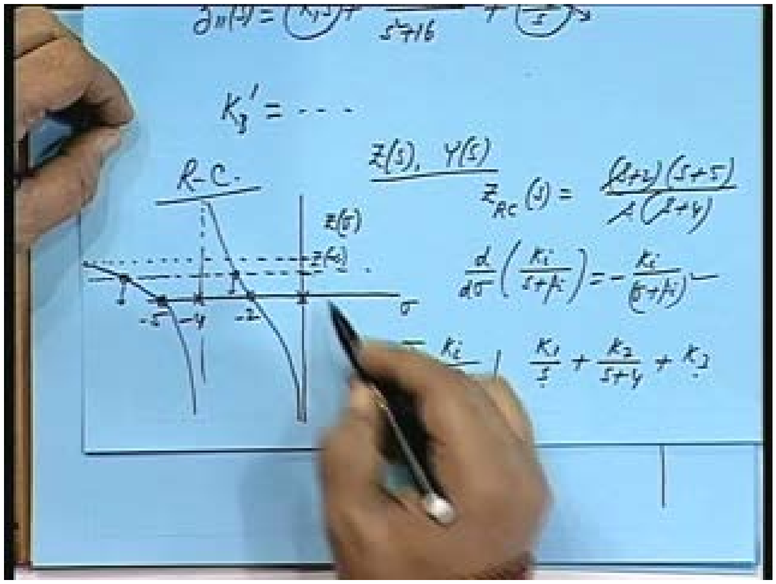

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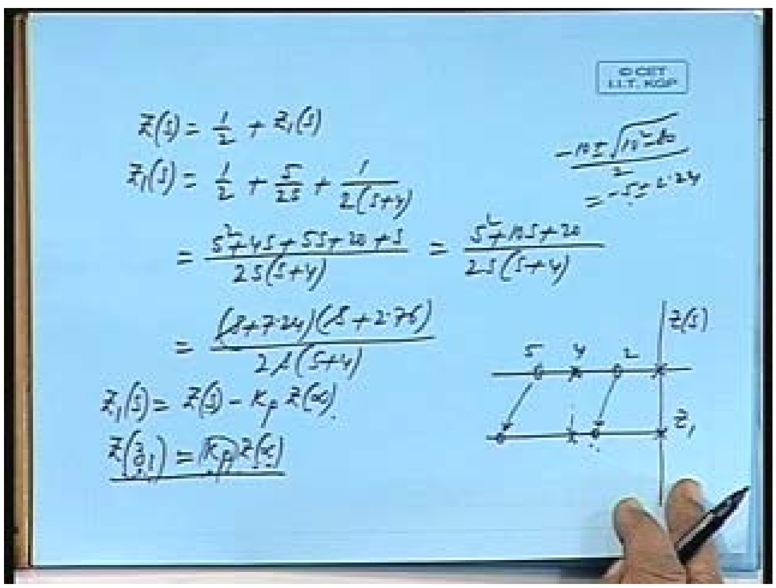

So if I remove it partly this is the intersection of this is now taking place here, intersection of this is taking place here. So this is the new shifted position of the 0s all right if I remove it partly then if I draw line these are the new 0s okay, not convinced $Z_1(s)$, let me write Z(s) minus K_p into Z at infinity you all agree. So we are suppose this is the new location of the 0 at that location Z at that location new 0, I call it $z_1(s)$, z_1, z_2 okay and so on this is 0, so this is 0, so Z at that point should be equal to K_p into Z at infinity.

So K_p into Z at infinity, K_p into Z at infinity is this that value should match with this function at various points at those 0s, so this is the shift wherever this condition is satisfied those 1s will be z_1 or z_2 or z_3, so these are the z_1's z_2's etcetera, is it all right. So this is the condition to be made to determine what should be the value of K_p to get a particular location of z_1 or z_2 that means the desired 0 the shift in the position of the 0 at the desired position at z_1, z_2 we can achieve by equating z at that point equal to K_p into Z at infinity. So that gives me the values of K_p the fraction of this to be removed okay if instead you remove okay we had once again I will start from the same function Z(s) is equal to 1 plus 5 by 2S plus 1 by 2 into S plus 4.

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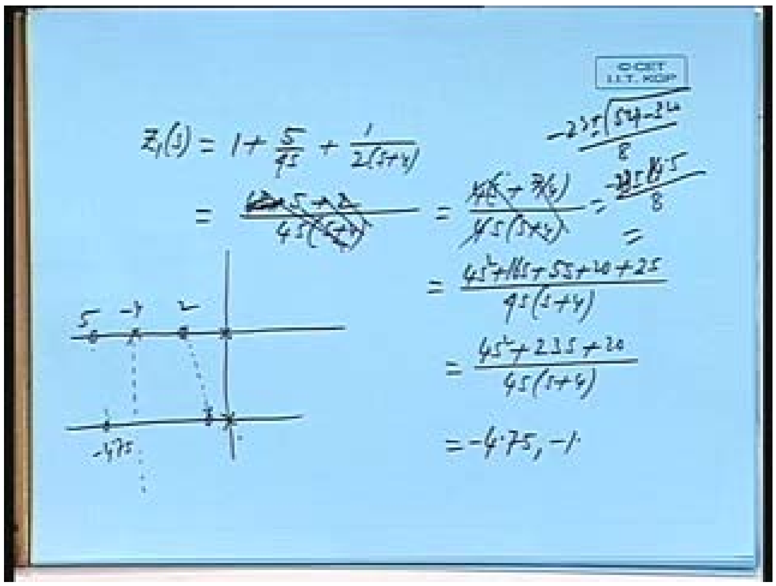

Suppose we get this one partly this pole what happens so $Z_1(s)$ will be 1 plus suppose we remove 50 percent of it. So 5 by 4 retain plus 1 by 2 into S plus 4 okay if you take 50 percent of it 5 by 4 S and remaining 5 by 4S is here. So it will be 4S into S plus 4, 4 S plus5 plus 2, correct me if I am wrong 4 into S plus 7 by 4 divided by 4 into S into S plus 4, so 4 get cancel, cancelled. So once again if we sketch the poles and 0s, 4S plus sorry this totally wrong yes, this is 4S into S plus 4 thank you, this is all right, now nothing is right okay. Let me work it out 4S into S plus 4, so 1 is 4S into S plus 4 so 4 S squared plus 16 S plus 4 S squared plus 16 S plus 5 into S plus 4 so 5S plus 20 plus 2S, is it all right.

So that gives me 4S squared plus 21 plus 1 to 2, 23 S is that so plus 20 divided by 4S into S plus 4 then why have you left the factorization for me tell me the values it will be minus 23 plus minus root over 23 square 529 minus 4 into 4 into 20, 320 okay divided by 8, so minus 23 plus minus 529 minus 320, so 209, 14.5 divided by 8 approximately. So 23 and 14 how much 37.85 by 8 so this is one route, so 4.775 approximately and the other one is 23, so this is approximately 8 okay say little more than 1. Okay, so let us take as minus 1 and minus 1, .1 or 2 whatever it is this was 1, 2 then 4 then 5. Now it is minus 1 minus 4.75 we have weakened this pole, pole at the origin, is it not, so this 0 is drifting to this side this 0 is also drifts towards this side that means all the 0s will be gravitating towards the 0, towards the pole which you are weakening all right. Here both of them will be shifting towards origin, let us weaken the third1 and then see what happens $Z_1(s)$ is equal to 1 plus 5 by 2 S plus1 by 4 into S plus 4 half of this is removed, so14th I have taken out, so14th is retained.

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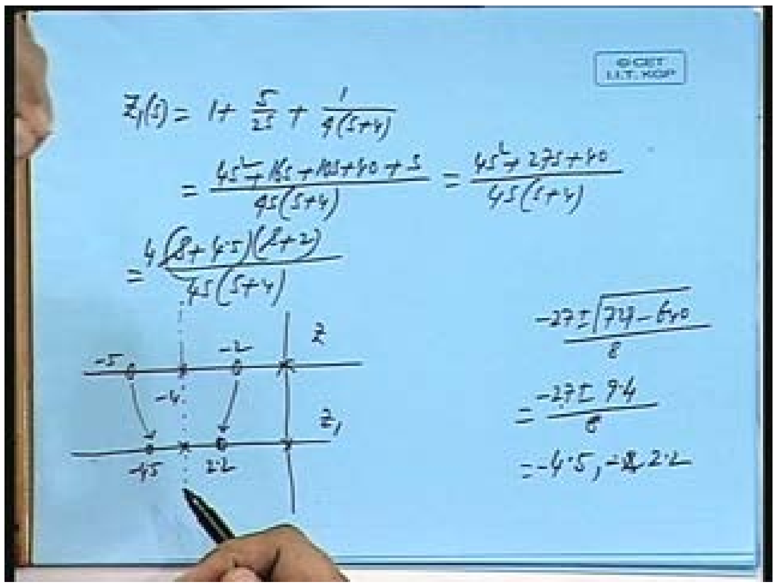

So this will be how much 4S squared plus 16 S plus 5 into 25 into 2S so10S plus 40 plus S, so that gives me 4 S squared plus 26 plus 27S plus 40 divided by 4S into S plus 4. So that gives me minus 27 plus minus 27 square 729 minus 4 into 4 into 4, 640 okay divided by 8 that is sure 729 and 40, so this is 81, 89, so this will be 9 point how much 9.4 divided by 8. So 36.4 by 8 say 4.5, 4.5 to this is one route, the other one is 27 minus 9, 18 by 8 little less than 2 little more than 2 okay approximately minus 2, is in approximation, little less than 2. So it will be s plus the poles and 0s these are somewhat approximate, this is the minus 2 point you should tell me this is a little less than 27 minus9 18 okay 2.2 minus 2.2.

Let me see I hope this calculations are all right then what was the pole at minus 4 then it was at 5, this was Z and Z_1, this is a pole, this is a pole, so 2 becomes 2.2 and this 5 becomes 4.5 you see now both are them are coming towards this pole, so the shifts are in opposite direction but they are towards the pole this is what I wanted to do stress that means the pole that you are weakening will be attracting the 0s from their earlier positions towards that particular pole itself . So the movement of the 0s are known, so once you know this then the problem is simplified you know which 0 is to be created by weakening which pole yes please any question, no well 0s become poles means 0s will be merging with a pole and they will vanish.

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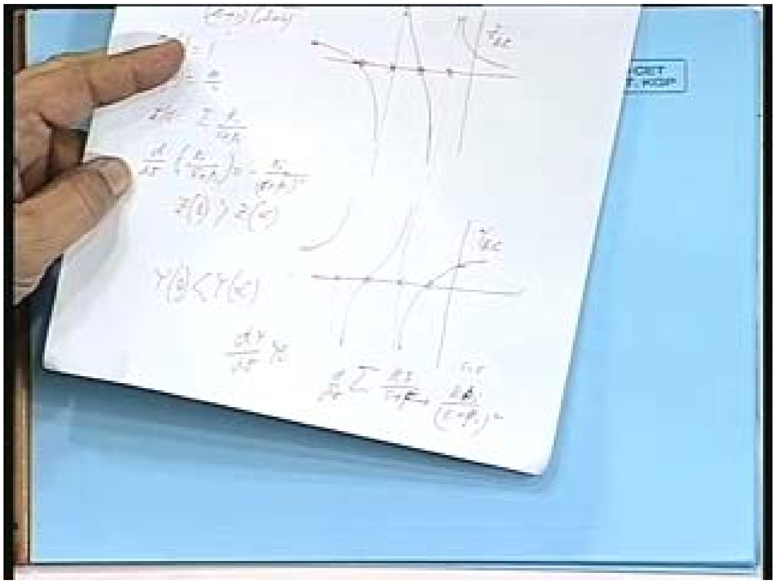

So that is the total removal that is what you precisely do, when you take out that pole totally there is no trace of that pole in the remaining part all right. So it is like a positive charge and negative charge when they joined together that becomes neutral. So when the 0 merges with the pole means the pole is totally removed. So we have seen the 3 cases of removal of partial removal of a pole at at the origin or at any definite location or removing the constant.

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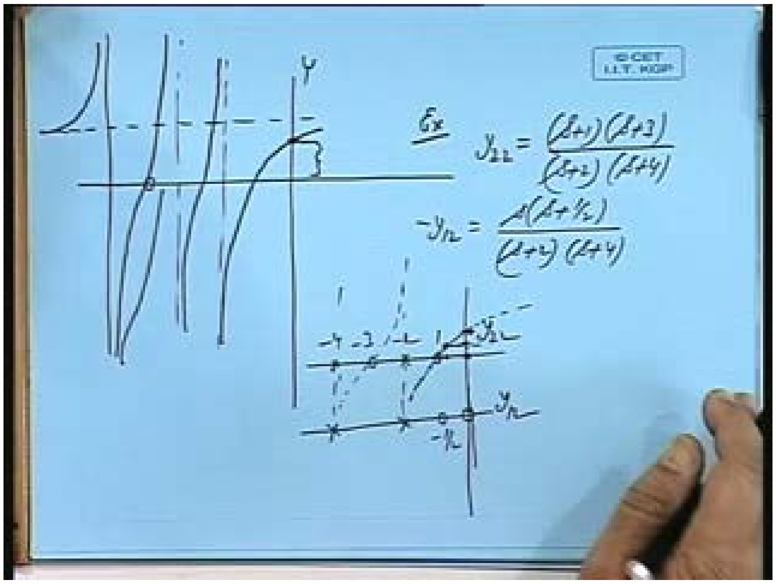

In case of Y what would be the effect on partial removal of say any pole or constant in case of Y where will be this value, this value is more or less than this infinite value sorry that can be many more such elements and so on. This value is always greater than this value, so here you remove a part of this part of this this constant all right. Earlier case you removed part of this constant and then again you will get 0s shifted. Let us take up an example, you are given y_{22}, y_{22} as s plus 1 into s plus 3 divided by s plus 2 into s plus 4 okay minus y_{12} is given as s into s plus half divided by s plus 2 into s plus 4 all right.

So if you look at the poles and 0s I will just sketch it here only the poles and 0s at 1 you have 0 this is for y_{22} then at 2 you have a pole at number 3 you have a 0 at minus 4 you have a pole and you want y for y_{12} there is a 0 at the origin, there is a pole sorry 0 at half there is a pole at this point, there is a pole at this point okay in the original one, this will be the nature of pole 0, this is the impedance diagram is it not admittance diagram for y_{22}.

So it is part of this that I am going to remove part of this may be this much I remove, if I remove this much then this will be the new 0 location, is it all right, if I remove it totally then this 0 will come here, is it true mind you there is no pole I am weakening it is removal of a constant. I can remove part of a constant or weaken any pole all right that pole depending on the network function that pole can be at a finite point or at infinity or at 0 depending on whether it is an admittance function or an impedance function. For an impedance function RC, impedance function the pole can be at the origin but there cannot be any pole at infinity. Similarly for an admittance function whole can be at infinity but not at 0, first one has to be a 0, so I can remove a part of that constant value okay whenever it hits the S equal to 0 line all right a part of that is removed. So if I remove that wherever it hits this curve that is the shifted 0 position I can remove it totally and then this 0 can be brought here.

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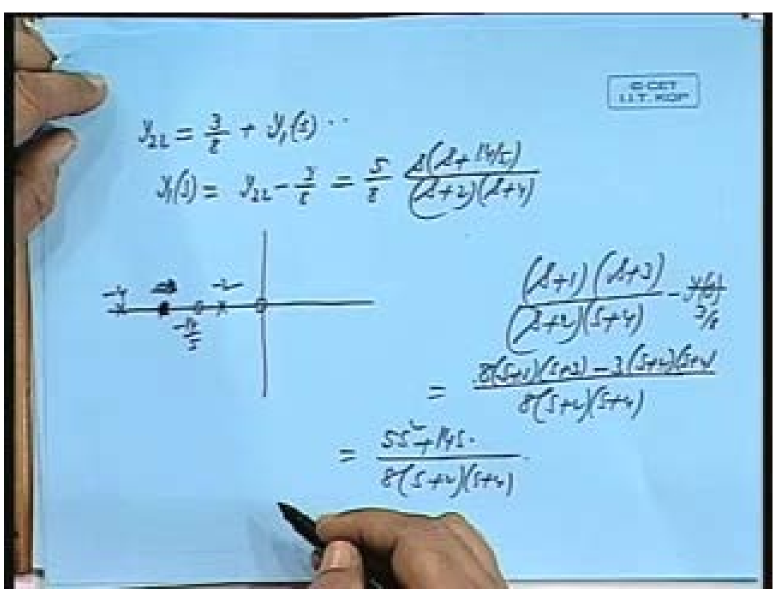

So let us take up this particular problem, so y_{22} if you make a partial fraction, if you make a partial fraction it gives me 3 by 8 plus dot dot dot dot plus $y_1(s)$, let us call it $y_1(s)$ the remaining part i am interested only in the constant but I am playing with this portion. So what will be $y_1(s)$, $y_1(s)$ is y_{22} minus 3 by 8, so that gives me 5 by 8, y_{22} is this much s plus 1, s plus 3 by s plus 2 into s plus 4. So I am subtracting 3 by 8 from here 3 by 8 is actually the constant value suppose I remove that constant then what is left $y_1(s)$ becomes 5 by 8 into you can make partial fraction and then add also rest of the terms or subtract directly s into s plus 14 by 5 divided by just, what it out here s plus 1 into s plus 3 by s plus 2 into s plus 4 and I am subtracting that y at 0 value which is equal to 3 by 8, so minus 3 by 8.

So that gives me 8 into S plus 2 into S plus 4 okay, so 8 how much is it if I subtract it by 8 are you getting the minus sign 8 into S plus 1 into S plus 3 minus 3 into S plus 2 into S plus 4 so that gives me 8S squared minus 3S squared 5S squared plus 3 plus 1, 4 into 8, 32, 4 plus 2, 6 into 3, 18, 32 minus 18, 14 S plus 3 into 8 and 3 into 8 okay divided by 8 into S plus 2 into S plus 4 which gives me this 15 by 8 if it is a common it will be S plus 14 by 5, is it okay. So what will be the 0s for this $y_1(s)$ I have realized 10 I will removed it completely. So this will be if I remove it completely this will be hitting here only, is it not. So I will get a 0 here and that is one of the desired 0s I could have realized partly and got into this 0 okay either you realize this 0 first or this 0 first you take 1 at a time okay. So if I remove it partly I could have got at minus half this one it I remove it totally that is this part 5 by 8, 3 by 8 then you can go here. Can you tell me what will be the value of that partial removal of this constant 3 by 8 such that I realize this 0 then you all try, let us see that also.

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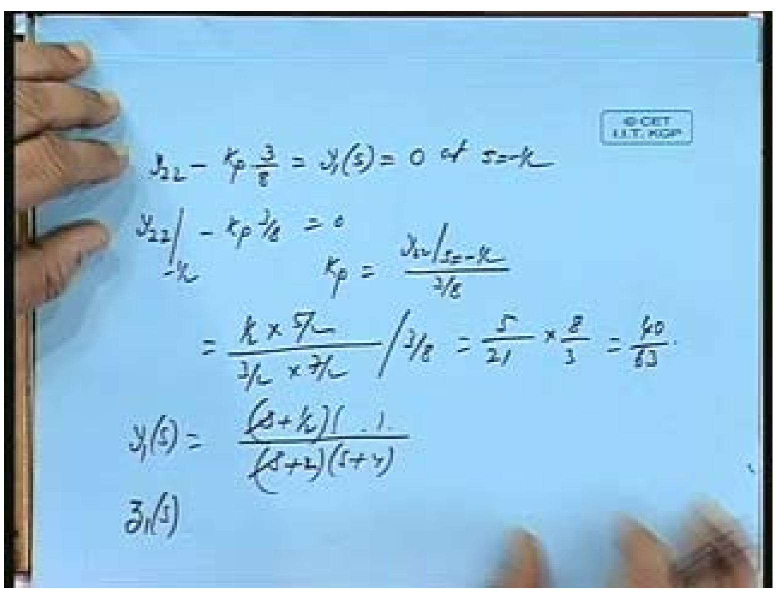

So now I have got 0 here,0 here and 0 at minus 14 by 5 and a pole at 2 then pole at 3 minus 2 minus 3 and sorry 0 pole at minus 4 no 0 here okay this is my new distribution of the pole 0 for the balance function y_1 if instead of realizing $y_1(s)$ like this suppose we take 50 percent of it or a certain percentage of it so that we get the 0 at S equal to half minus half then what would be that value of the removed material okay. So y_{22} minus some K_p times this is partially removed constant which is less than 1 times the actual value is 3 by 8 that should be equal to my new one $y_1(s)$ and this must be equal to 0 at S equal to minus half. So y_{22} at minus half how much is it that means y_{22} at minus half minus K_p into 3 by 8 should be equal to 0 so K_p is y_{22} at minus half divided by 3 by 8. So how much is that y_{22} at minus half y_{22} at minus half is half into 5 by 2 divided by 3 by 2 into 7 by 2 divided by 3 by 8.

So 22 goes so 5 by 21 into 8 by 3 how come here 40 by 63 this is K_p, is it all right. So if this fraction of 3 by 8 that means 5 by 21 could have been removed I would have got a 0 created at minus half, once you have realized the 0 then what would have been the factor of y_1, $y_1(s)$ would have been s plus half as a factor 0 created there multiplied by are you know that you have to calculate out but I am sure s plus half will be one of the factor and the denominator as it is s plus 2 into s plus 4 okay. So after you have realized the 0 at particular location, how to realize the network elements, how to get it of it whenever there is a 0, how do you remove that 0 invert it create a pole make partial fraction and remove that is it not so from Y(s) you have to go to corresponding Z(s).

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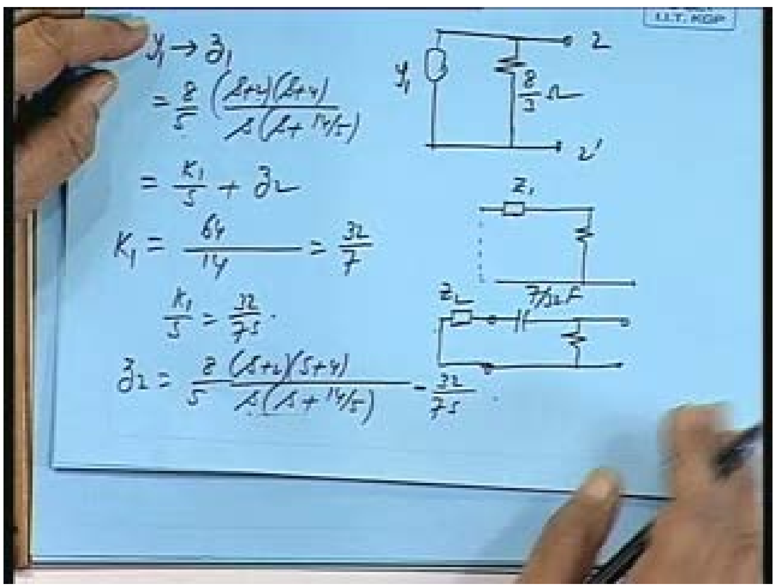

So $Z_1(s)$, so let us go back to the first realization when you have shifted the 0 to the origin that is totally removed that factor 5, 3 by8 all right, 3 by8 is removed from y what does it mean you have started from the terminal 2, 2 dashed okay, you have started from the terminal 2, 2 dashed and then we have started from here. We have started with the first element which is a resistor 3 by 8 is a constant all right that I have removed y_{22} is equal to 3 by 8 plus $y_1(s)$, so 3 by 8 is admittance so 8 by 3 ohms resistance I have put and this is the balance $y_1(s)$ okay, yet to be realized. Now you have seen that there is a 0 at the origin so from y_1 we go to the corresponding z_1 because we want to realize that 0.

So what will be corresponding z_1 this was our after removal of that constant this was our y_1, so z_1 corresponding z_1 will be 8 by 5, s plus 2, s plus 4 by s into s plus 14 by 5 okay. So remove this as K_1 by S plus whatever is left over I will call it z_2 okay. So get it of this 0 which has been realized as a pole, so how much is K_1 multiply by S make S equal to 0, so 64 divided by 5 into 14 by 5, so 14, 64 by 14, 32 by 7 all right. So 32 by 7 this y, I have converted to a Z all right I am writing in the form a Z whose series element is 32 by 7 what, sorry this is K_1, so 32 by 7S, K_1 by S means 32 by 7S, so what is it a capacitor 7 by 32 farads okay whatever is remaining I will call this as Z_2 all right this Z_2 I have to finally calculate z_2. So how much is z_2 once you have written 32 by 7S from z_1.

So 8 by 5 into s plus 2 into S plus 4 divided by s into s plus 14 by 5 minus 32 by 7S. If I remove this I will get the balance other alternative is you can make partial fraction since there is only 2 poles you can make partial fractions remove that one of them will be 32 by 7S, so remove that whatever is remaining will be our z_2 okay. So how much is it, how much is it coming to okay. Let us compute I have got 8 by 5, Z_1 as 8 by 5 into S plus 2 into S plus 4 divided by s into S plus 14 by 5 I could have written as K_1 by S this is the one which I have removed K_2 by S plus 14 by 5 plus K_3 okay and that gives 14, 14 by 5 so 8 by 5, 8 by 5 S plus 14 by 5 so 4 by 5 minus 4 by 5, correct me if I am wrong, 14 by 5 and 4, 20 minus 14, 6 by 5 divided by minus 14 by 5. So that gives me 8 by 25 is that so 24 by 14.

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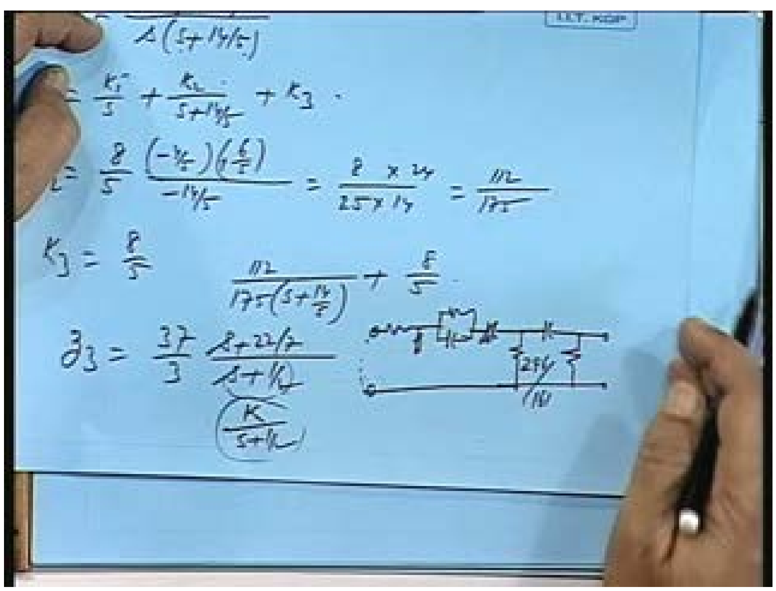

So 112 by 175 okay so it is 100 and this K_2 is this much how much is K_3, K_3 make S_{10} into infinity so it will be 8 by 5. So basically 112 by 175 into S plus 14 by 5 plus 8 by 5 this total sum will be your Z_2 is it not this will be equal to Z_2, is it all right. So from Z_2 what should I do from Z_2 what you do again go back to Y_2 then again weaken a pole so as to realize the other 0, so as to realize the other 0 that is at minus half.

So if you keep on doing it so you have to remove partly one of the poles so that the 0 shifts to minus half again realizing it by taking a factor 1 by S plus half by inverting it and making the partial fraction. So if you keep on doing it you finally get I will give you only the final result you can work it out this procedure is same alternately you have to go for imp impedance and admittance. So you get next stage you will get Z_3 as 37 by 3 after removal of this s plus 22 by 7 by s plus half okay means in the next stage after realizing that new 0 invert it you get the pole and then again make partial fractions.

So the final values will be like this which is 296 by 161 okay then a capacitor in the final stage you may have since it is going to be realized as S plus half, K by S plus half, it is an RC combination all right. Earlier, we are getting a factor like K by S, we remove 32 by 7S is it not. So that was a capacitor now it is an RC combination so you will get something like this okay that will give you S plus half then because that Z this one will be this RC combination and a constant that is all Y_{22} is an open circuit parameter or short circuit parameter, it is a short circuit parameter, it will be shorting this. So measuring the impedance from here we will get the same impedance that I will be doing so okay is this point clear the last1 last one is from Y_3, I have got z_3 so from Y_3 where we have got some factors here divided by some factors here and you want to remove that much of a constant. So that you get in the next stage say Y_4 something like S plus half realized here.

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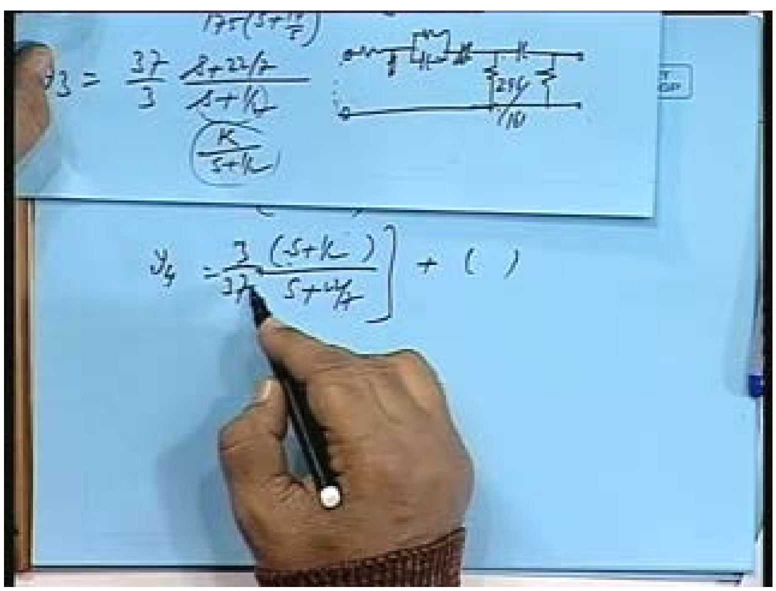

Okay so you have removed Y_3 as Y_4 plus a constant which was 296 by 161 this constant was decided so as to realize S plus half in Y_4 is it not the other 0. Once you have realized that that factor became if I invert it that factor became this is it all right, this part this was basically S plus half into S plus 22 by 7 into 3 by 37 it is this one which was inverted and you got this.

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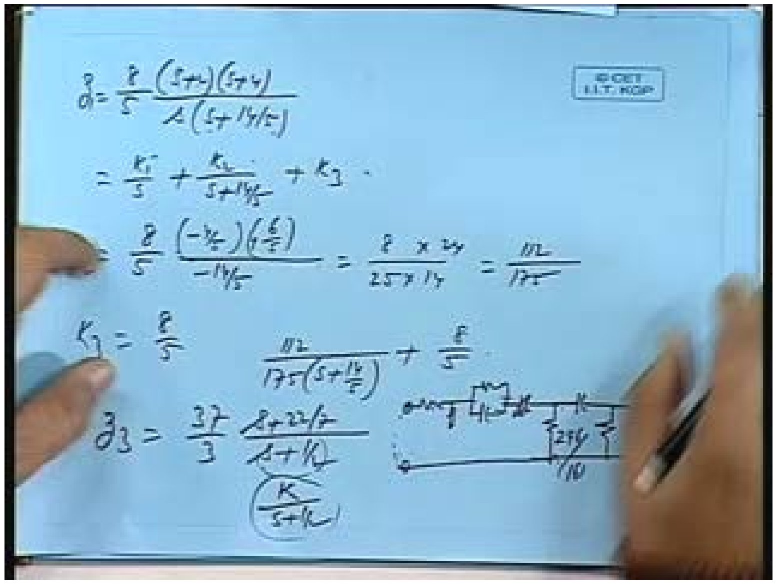

So after realizing this resistance whatever is left over you invert it that will be the Z and that is just a simple RC and R combination. So leave it there, so this will be your Y_{22} and Y_{12} specification met. Obviously, Y_{11} can be anything there is no unique choice I could have removed that 0 at minus half earlier. So I could have got something else this RC combination could have been at the beginning itself do you get my point. So we will stop here for today next time we will take up Lattice synthesis okay.

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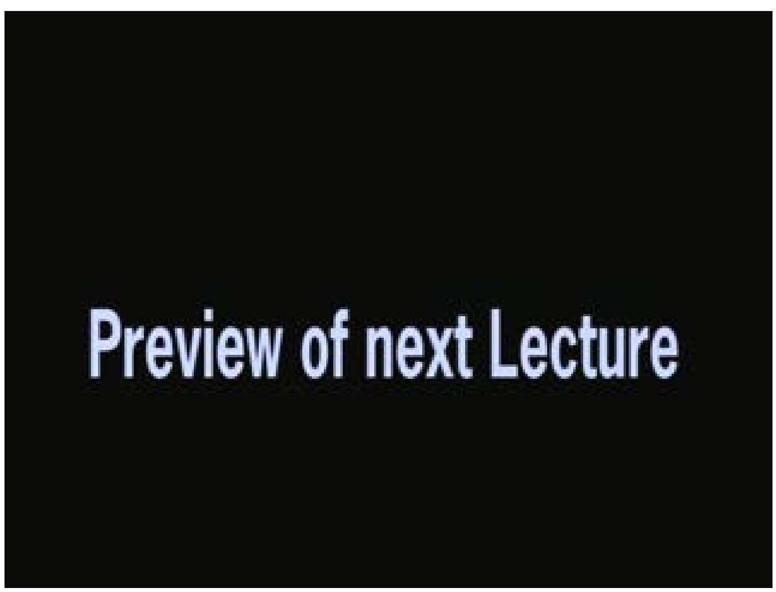

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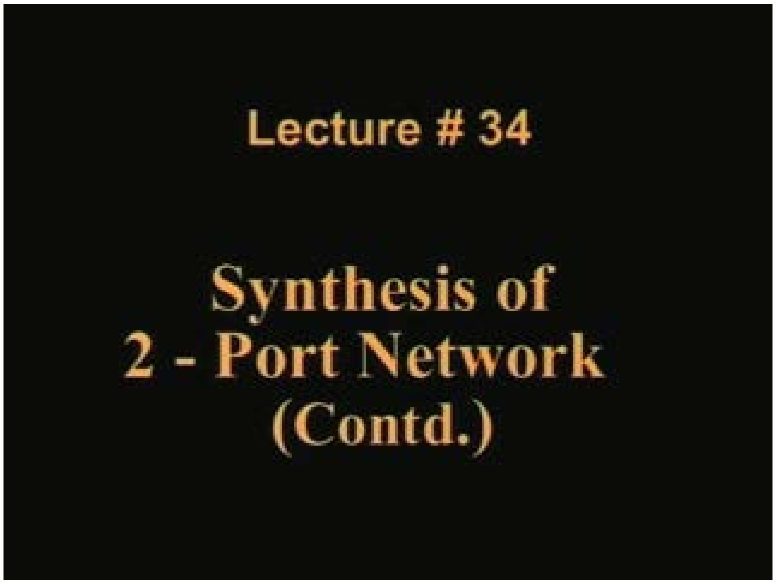

Good afternoon friends, today we shall be discussing about symmetrical network, symmetrical Lattice network for two port synthesis.

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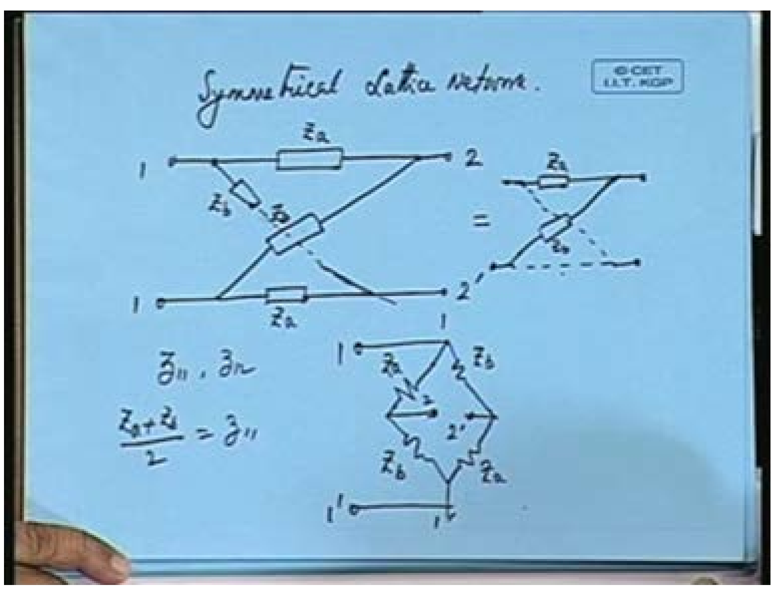

Let us take simple network function in this form Z_a is an impedance, Z_b is this impedance and similarly you have Z_a here and Z_b here. Now what will be for this network what will be Z_{11} and Z_{12} in terms of Z_a and Z_b you shall be see the symmetry, you shall be denoting this henceforth by an impedance Z_a and Z_b okay and it is understood by this dotted lines you denote the other

2counterparts, this is Z_a and this is Z_b so we shall be showing only the dotted lines and what will be Z_{11} and Z_{12}. If you look at this network see one side is Z_a and Z_b, so I can show from one say I can show it like this Z_a and Z_b okay. The junction is one Z_a and Z_b okay from Z_a the junction of Z_a and Z_b, this is 2 that is another branch Z_b and Z_a and that junction is 2 dashed.

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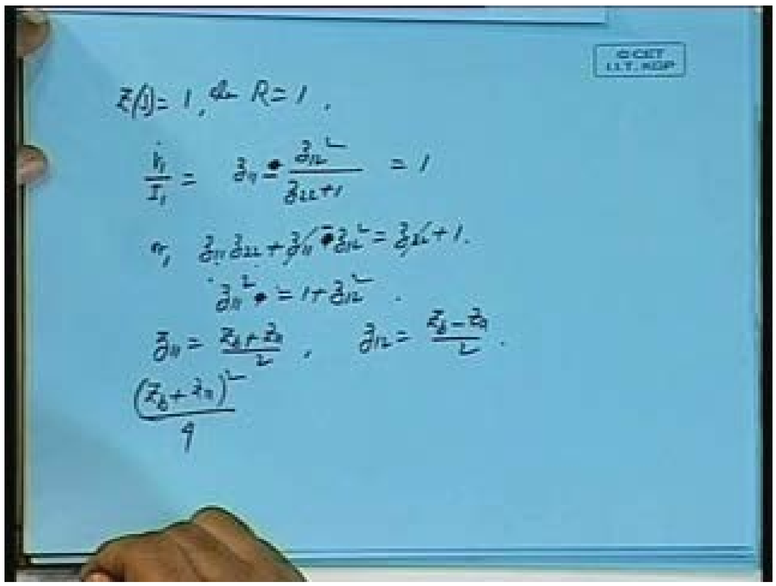

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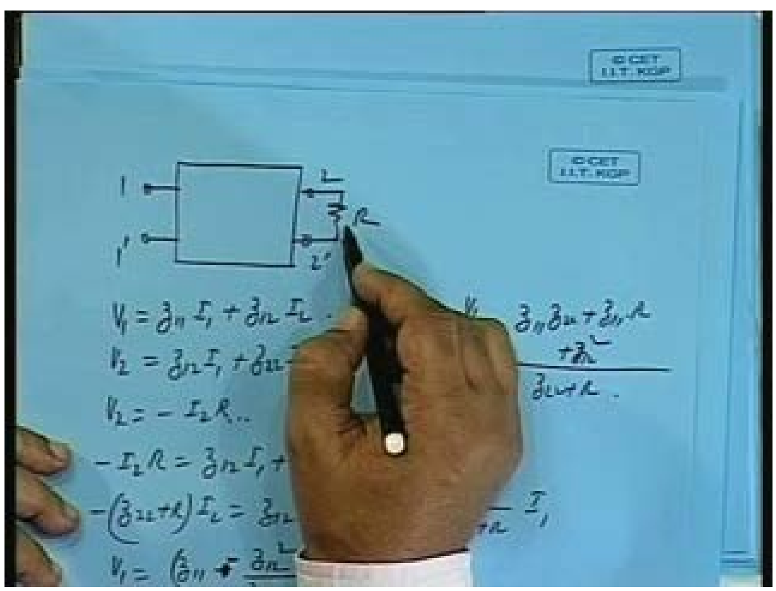

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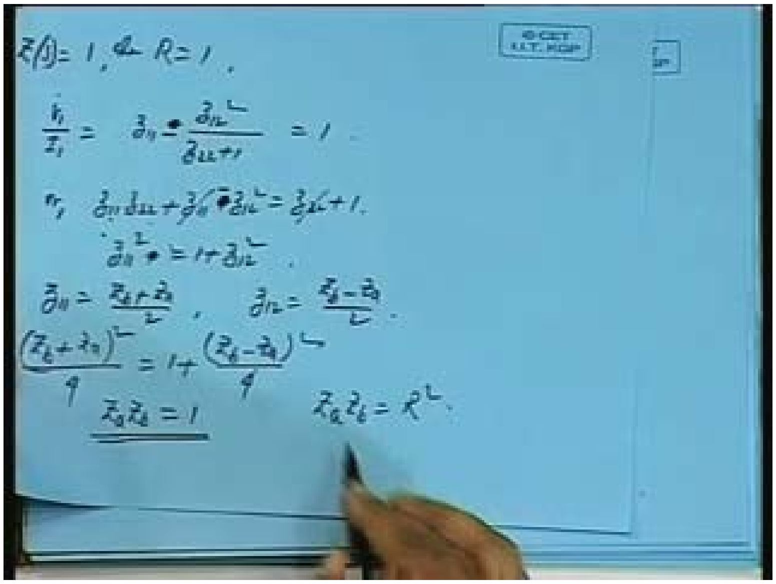

So basically this is 1 dashed if you look at it 1, 1 dashed by 4 is equal to 1 plus z_b minus z_a squared divided by 4 equate z_a squared z_b squared get cancelled then you are left with twice z_a, z_b by 2 okay if I bring to this side then a plus b whole square plus a minus b whole square is equal to 4ab that divided by 4 is just ab okay thank you z_a, z_b comes out to be therefore 1. So if you want that network, we are planning to have a network which if terminated by a register R, let us take a normalized situation 1 ohm, then the impedence seen from this side also 1 ohm, what will be that z_a and z_b. Now that z_a and z_b must be at this relation z_a, z_b equal to 1. So in the next class we will start from here this is for a normalized relation if it is equal to any R, so in general z_a z_b equal to R squared once you set z_a automatically z_b sets but such lattice networks terminating impedence R will generate an impedence of R from the looking side, thank you very much.