Circuit Theory
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Lecture - 27
Two-Port Interconnections

This is the twenty-seventh lecture and we are going to discuss 2 port interconnections. Before we do that we would like to consider the most general situation of a 2 port which is terminated at both ports. That is we have network N which is driven by source of resistance, let us say R1 this is Vg terminated at both ports pins.

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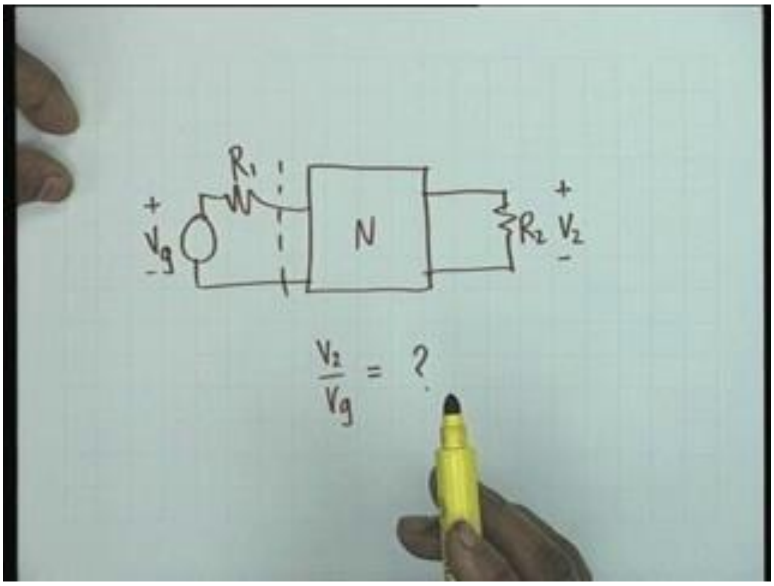

Terminated at one of the ports with a source perhaps the other port has a load. This is the usual situation, usual situation, because we cannot have an ideal voltage generator, we cannot have a current generator. A source a voltage source in series with a resistance is equivalent to a current source in parallel with a resistance which represents a practical source, a practical source and usually power is required to be transmitted through a 2 port in to a load.

So, this is the load, R2 is the load and this is the usual situation we would like to found out the voltage transfer function V2 by Vg, we would like to find out V2 by Vg of this network in terms of the 2 port parameters. We can use any of the 2 port parameters for simplicity we shall use the z parameters. Now, in order to be able to use z parameters w replace N there are many ways that this can be done. Let me, first show you an alternative way, then I will go through the routine calculations.

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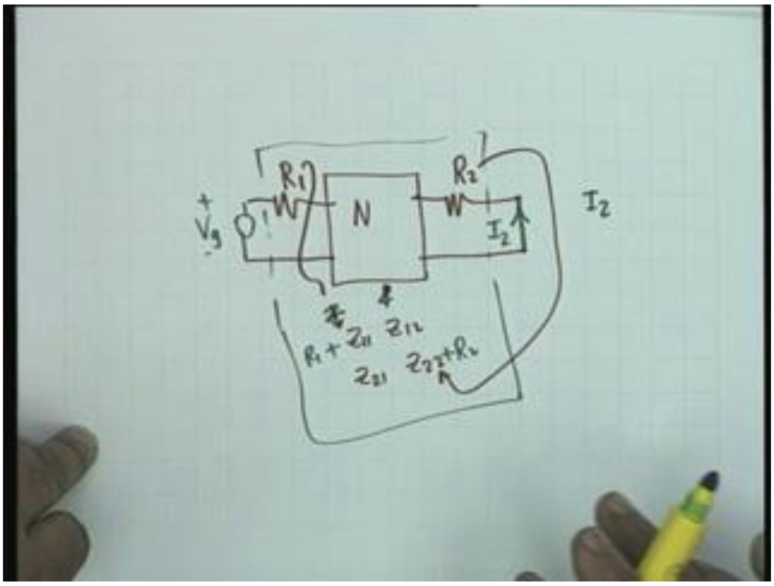

As far as this network is concerned if the z parameters of this network are z11 z12 z21 and z22 if these are z parameters. Then, adding a resistance R1 here simply affects the z11 parameter R1 affects z11 parameter. And what we have is, we have a resistance R2 at the other end. Let us included R2 has a series connection, then R2 shall affect z22.

Then, what we are doing is what we are doing is we are connecting a voltage source here I call it Vg this is my overall 2 port the green covered 1. So, my overall 2 port has z11 plus R1 and z22 plus R2; that is all the modification is, and then what I have is, I have short circuited this is the original network the network that you wanted to analyze. So, if I can found out I2, if I can find out the short circuit current, then the voltage V2 shall be minus I2 R2.

So, all that you are required to find out now is I2 in terms of Vg by considering a simple 2 port terminated in a short circuit. And therefore, the circuit can be solved in terms of either Z parameters or perhaps a better situation would be Y parameters, because there is a short circuit. We can also, do it this is an alternative way: 1 way of looking at the problem. The other way: would be simply you write down the equivalent circuit that is I have Vg R1.

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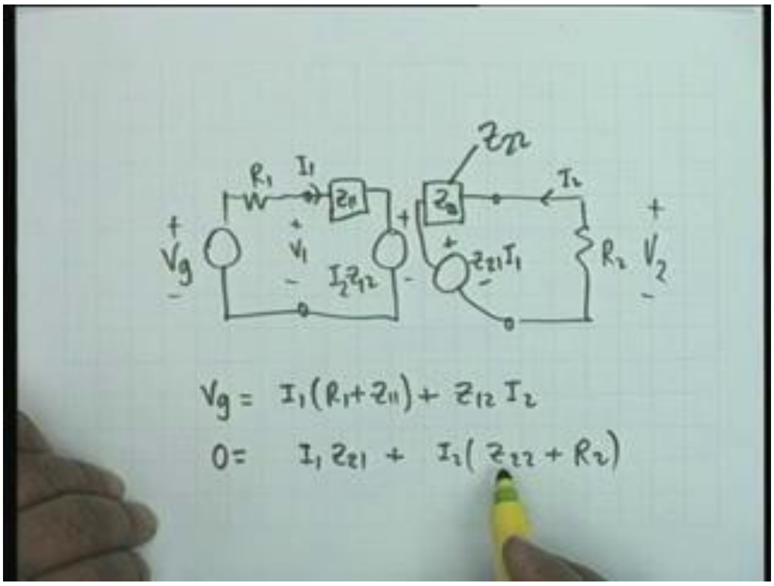

And, then the 2 port, the 2 port, and then we have the R2 and this voltage is V2.The 2 port if you recall has a z11 I1 z11 V1 is equal to I1 z11 plus I2 z12. So, we had used a voltage source which is I2 z12.Similarly, V2 if this current is I2 is equal to z22 I2, z22 I2 this is z22 plus z21 I1, so plus minus z21 I1, is it ok? I have replaced this by it is equivalent circuit, this is a truly 4 terminal equivalent circuit it does not assume that the lower 2 terminals are connected it's a general equivalent circuit.

And, then what I do is I write the 2 loop equations there are 2 distinct loops which are: the decoupled physically from each other, but not electrically. Do you see that? The current I2 affects the voltage here; the current I1 affects the voltage here. So, they are not electrically decoupled, there are physically decoupled. So, I can write down the loop equation as I V's of g equal to I1 R1 plus z11 plus Z12 I2, which also shows that, the only parameter that is affected by R1 is the Z1 it adds to Z11.

And the other would be there is a no source here, therefore it would be 0 equal to I1 z21 this voltage plus I2 z22 plus R2 agreed. And all that 1 is required to do now, is to eliminate I1 from here and find out I2.

This is the same equations yes. So, what we do is, I am required to find out I2, because the voltage V2 is of concern. So, from the second equation I find I1 as equal to minus I2 z22 plus R2 divided by z21 is that from the second of those equations i find I1 in terms of I 2 and I substitute in the first equation, therefore I get I2 z12 from the second term I2 z12.

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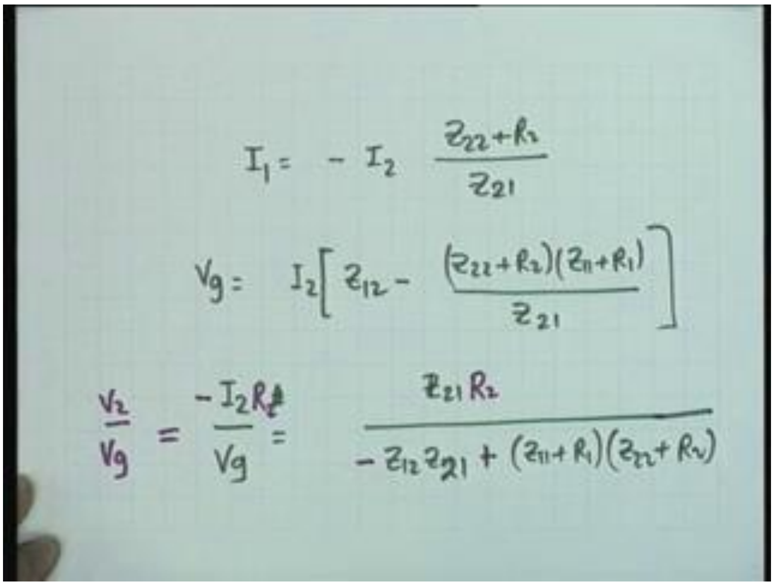

Then, the first term I substitute for I1, so I get a negative sign minus z22 plus R2 multiplied by z11 plus R1 divided by z21 agreed is this ok? And my therefore, I get my I2, I2 as equal to I2 by Vg I2 by Vg shall be simply equal to 1 over well. Let me, simplifies this no 1 aver this whole expression let me, simplify this I bring z21 at the top, and then z12 z21 minus z11 plus R1 multiplied by z22 plus R2.

Then, I make some modifications what I want is V2 by Vg, what I want is V2 by Vg. How do I get V2. I multiply I2 by minus R2, because I2 and V2 do not agreed. So, i multiply this by minus R2, so I shall have R2 here and I change the sign in the denominational right. You see what have I done? I have multiplied I2 by minus R2 to get V2 this is what I want .And therefore, I finally, get V2 by Vg as equal to z21 R2 divided by…

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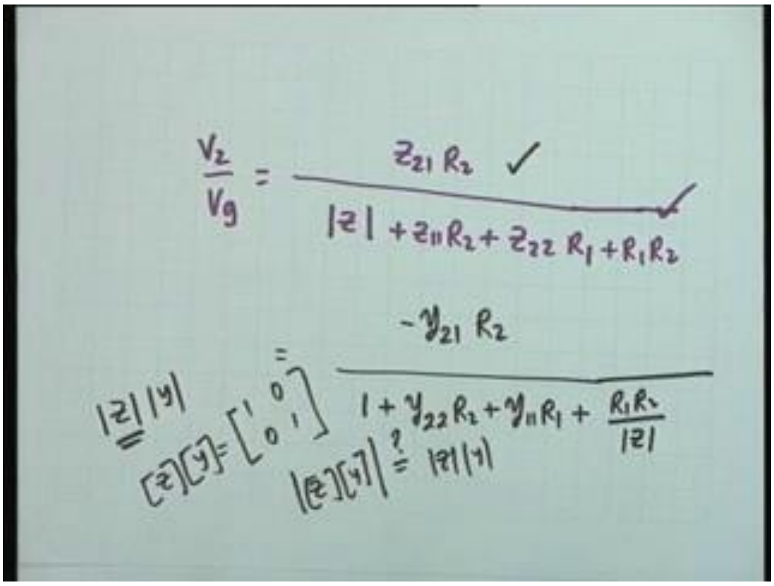

If you notice in the denominator z11 we shall have the z matrix determinant, because I have the product Z11 Z22 minus z12 Z21. So, this is the determinant plus z11 R2 plus Z22 R1 this is the final result, which 1 is R2 Z11 no I have done.

There is an R1 R2 yes, same yes.

As I said the alternative was to look upon the terminated, double terminated network as a single network whose z parameters are simply the augmented 1s that is z1 is augmented by R1 Z22 is augmented by R2. Then, you find the short circuit current and multiply the short circuit current by minus R2 which is precisely, what we have done the neighbor would not have been anything less.

But 1 thing that is interesting is that if you divide both numerator and denominator by the determinant of z, then you can see that this result could be put in this form. Can you tell me what the result would be If you divide both numerator and denominator by the determinant of z?

Do I get Y21 or minus Y21?

That is correct you must not make this mistake minus Y21 R2.

In the denominator I shall have 1 plus.

Y no, Y22 R2 plus Y11 R1 plus.

What shall I have here? R1 R2 divided by determinant z.

What is the relationship?

What is the relationship between the determinant of z and the determinant of y?

Is the product 1? It is an identity matrix.

No, determinant is a scalar this is a product of z y is an identity matrix that is it 1001. Therefore, the determinant of the matrix is that equal to the product of the 2 determinants determinant of these product is it equal to this?

Okay.

Then, I can write 1 by determinant z as determinant of y alright. So, the transfer function can be expressed in terms of z parameters can also be expressed in terms of y parameter. And if you now look at the table and we place the z parameters by let’s say the transmission parameter. You can express the transfer function in terms of ABCD parameters also any set of parameters in fact. And this is the most general case, so no other case showed bad result all other cases will follow as a special case of the general case.

Of course, we you could introduce more generality by replacing resistance by general impedances R2 could be Z L and R1 could be Z sub Z. We next consider interconnections of networks, interconnections of 2 ports. And we shall consider 3 kinds of interconnections: one is so called cascade interconnection that is if 1 2 port feeds in to another.

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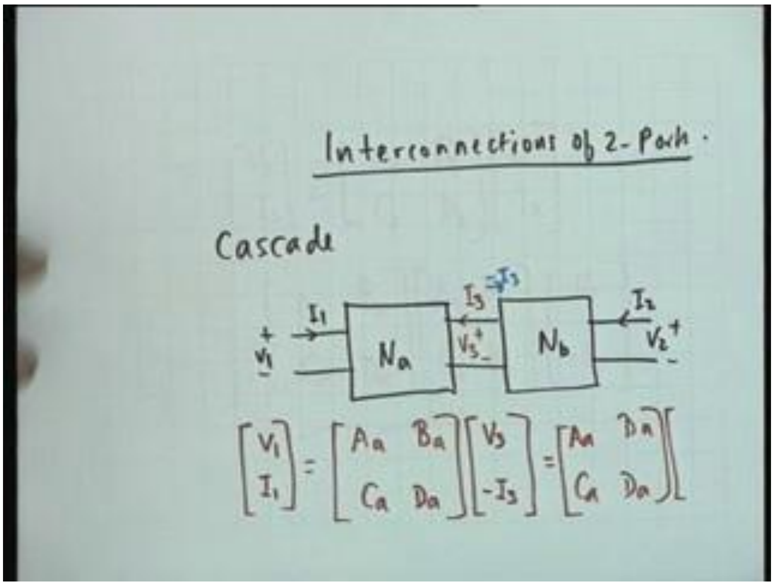

Let us say Na feeds in to another 2 port Nb this is called a cascade interconnection. In the cascade interconnection, the output of one of the networks acts as the input of the succeeding network. And the most familiar example is that of a cascade of amplifiers, but the gain of a single amplifier inadequate you put another amplifier in cascade. Now, let us consider the composite network V1 I1 V2 I2.

And in cascade connection the most convenient parameters 2 port parameters are the transmission parameters. Because, what is transmitted through Na becomes: input to Nb and transmits to Nb. Let us, say that the voltage and current here are V3 and let say I3 alright. Then, you see for Na, for the network Na V1 I1 would be equal to the ABCD parameters of Na by definition that is that is Aa Ba Ca Da multiplied by the output voltage and the negative of the current going in that is minus I3.

Now, do not you see that V3 is the input voltage of Nb and minus I3 is the input current of Nb. Therefore, this can be written as Aa, Ba, Ca, Da multiplied by. V3 let me put it another paperV3 minus I3 is the input voltage and input current of the network Nb this should be equal to Ab, B sub b, C sub b, D sub b multiplied by V2 minus I2.

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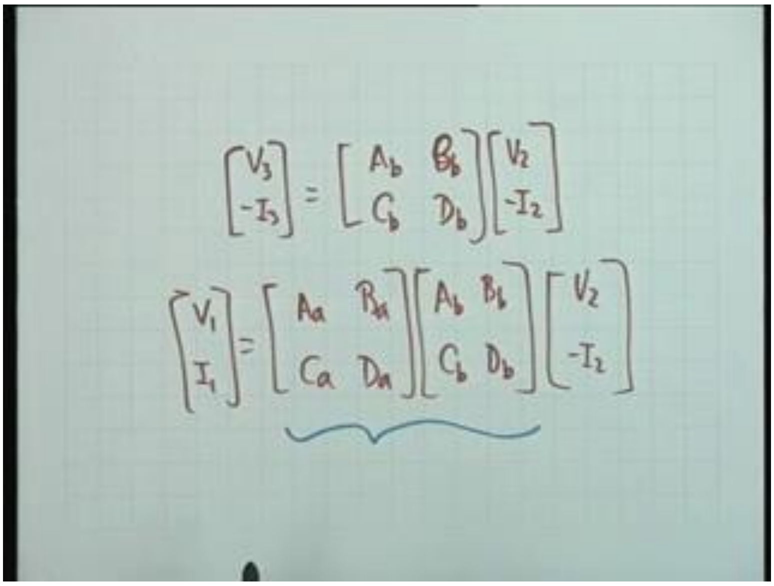

So, therefore if I replace this in the previous equation, then I shall have V1 I1 as equal to Aa, Ba, Ca, Da multiplied by Ab, Bb, Cb, Db multiplied by V2 minus I2.And therefore, in the cascade interconnection the ABCD matrices simply multiply each other alright ABCD matrices get multiplied.

V3 minus I3 this is the input parameters of Nb.

Minus I3, because I have to take the current going in.

You see V1, I1 current is going in was Aa Ba Ca Da multiplied by V3 minus I three that is the convention. Now, V3 minus I3 is precisely minus I3 is the current going in to Nb and this is being replaced by the b transmission parameters multiplied by V2 minus I2 that is simply multiply each other. We shall take an example to illustrate, this and one of the simplest examples this has also in problems at 6 I think.

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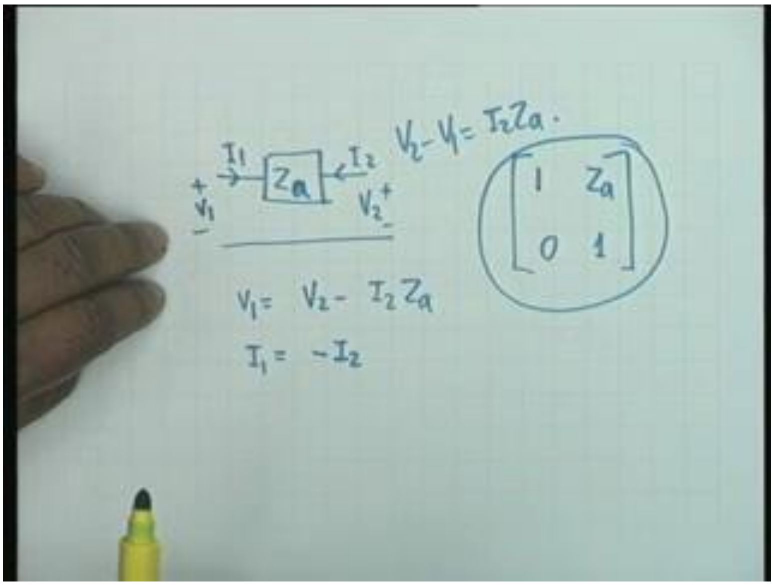

If we have let us say an impedance Za, a simple impedance Za alright what are the ABCD parameters? The currents voltage are this V1 V2 V2 I2 and you notice that V1 what is the relation between V1 and V2? V1 is equal to V2 minus I2 Za is that ok? And what is the relation between I1 and I2 they are simply negative of each other. So, what is the ABCD parameter of this? ABCD parameters of this network this is 1 V2 a V2 minus VI2therefore, Za then CV2 C is 0, minus D I2, so this is 1.

First equation, V1 is equal to V2 plus the drop in Za.

Itdoes not matter I1 and I2 we I1 and I2 are equal and opposite of each other. Ido not have to consider I1.You see, what I do is V2 plus the drop in Za that must be equal to V1. Or you can say, V2 minus V1 equal to I2 Za V2 minus V1 is equal to I2 Za. So, V1 is V2 minus I2 Za is that ok? So, this the ABCD parameters the transmission matrix of this network. Does this network have Z parameters?

No.

Does it have Y parameters?

Yes, it has Y parameter.

Now, what about the ABCD? This ABCD matrix is this a reciprocal network?

Yes Ab minus Bc is equal to 1. Let us, consider another network. Suppose, I have Z sub b here only a shunt element. The currents and voltages are this V1, V2, I1, I2. You notice here that V1 is equal to V2 agreed, but I1 plus I2 the 2 currents going in is equal to V2 divided by Zb.

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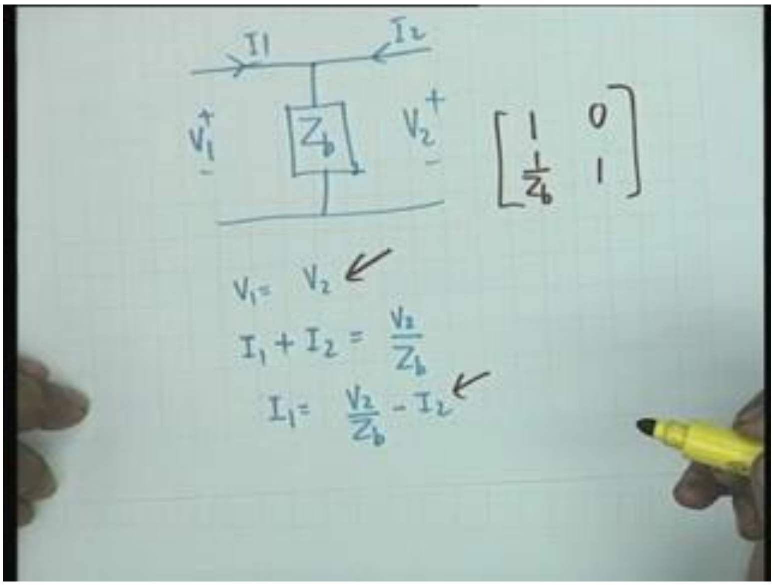

The 2 currents going in must be equal to the current leaving which is V2 by Zb I could also have written V1 by Zb, but I have written V2 intentionally. Because, I want to write I1 in terms of V2 and I2, so V2 by Zb minus I2.And it is obvious, that the ABCD parameters if you look at these 2 equations, these 2 equations it is obvious that the ABCD parameters are 1 0 1 by Zb 1.

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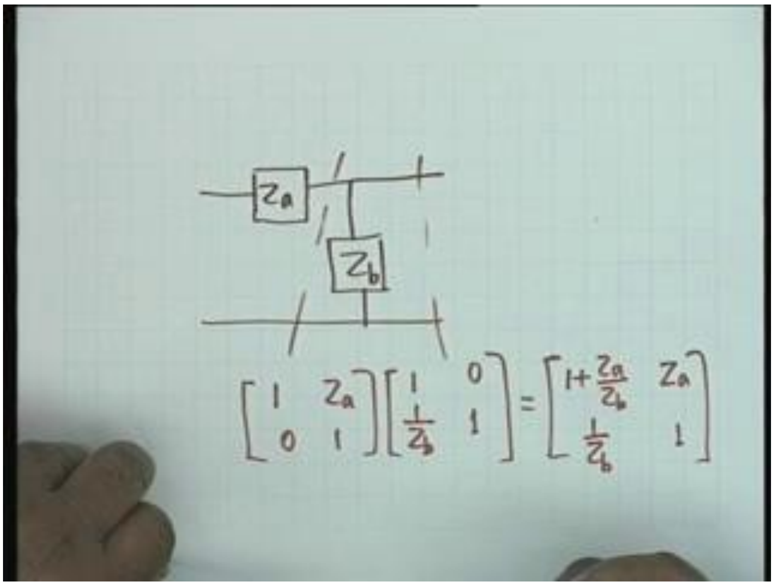

Now, let us consider an interconnection of this 2 that is I have Za and Zb. This can be considered as the cascade connection of first 2 port is: this 1 and the second 2 port which is this 1.And I found out the ABCD parameters of each of them individually. Therefore, the overall the ABCD parameter shall be for Za it is 1, Za 0 1 and for Zb it is 1 0 1 over Zb 1 agreed?

So, the overall ABCD parameters of this network shall be now you make the matrix multiplication 1 plus Za by Zb, Next 1 is Za simply this multiplies this, then 1 by Zb 1. What is the AD minus BC for this? It is still 1, because this is reciprocal. So, the total is reciprocal. Suppose, now we complicate the situation and we have let us say a Za a Zb and a Zc. Now, we shall have the product of 3 ABCD matrices.

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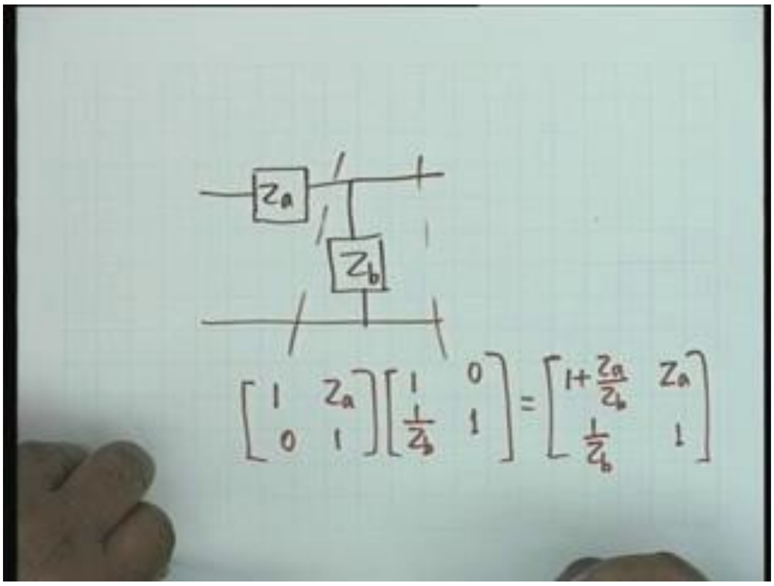

We shall have 1 Za 0 1 1 0 1 over Zb 1 and 1 Zc 0 1this the overall ABCD parameters of the t network. Now, which sequence shall I go in multiplication shall I multiply these 2, and then this or these 2 and then this does it matter?

It does not matter I could combine this 2 in to a 2 by 2 matrix and multiply by this. Since, I have already combined this 2 I can substitute this and multiply it by this. I shall not go in to the algebra I will only write down the final result. The final result for this t network Za Zb Zc the final result for the ABCD parameters is Za plus Zb divided by Zb.

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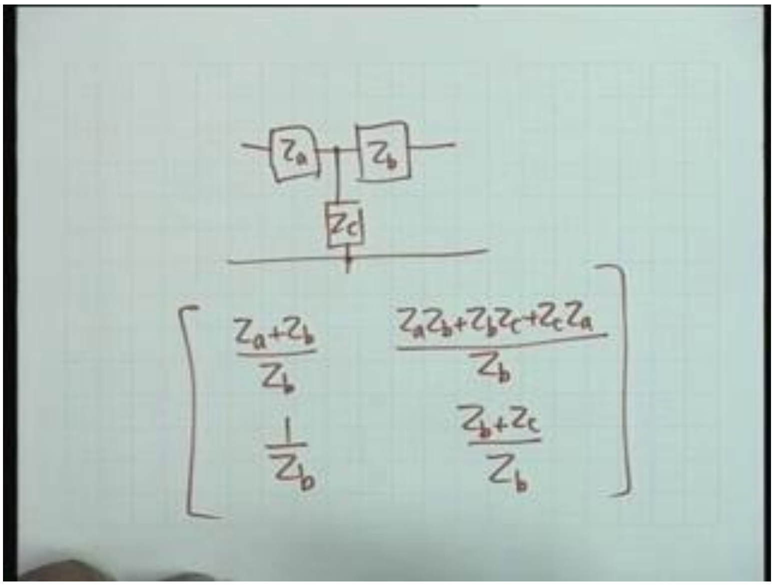

Then I have Za Zb plus Zb Zc plus Zc Za divided by Zb 1 over Zb and Zb plus Zc divided by Zb. There is a certain symmetry in this which you should notice, there is certain symmetry this is ABCD parameters. And you can again verify that multiplication of these 2, minus multiplication of these 2 is exactly equal to 1, it has to be there is no other way. This is one example of cascade connection of 3 networks we consider these has a cascade of 3 networks.

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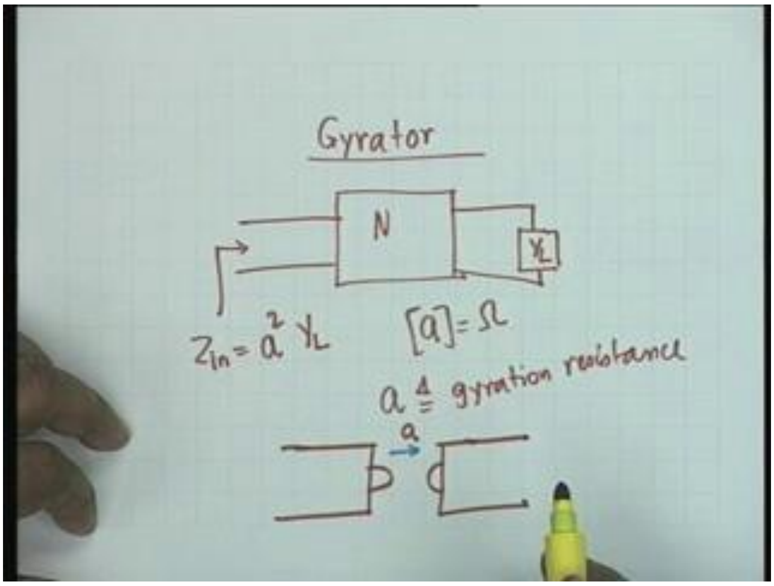

Now, let us make this a little more complicated by introducing a Non-reciprocal element called a Gyrator, a Non-reciprocal element called a Gyrator. A property of a gyrator is gyrator is a 2 port having the property that, if you terminate this in YL a termination in an admittance YL the input impedance Zin is proportional to YL input impedance is proportional to YL. Obviously, the proportionality constant will have to have the dimension of.

Ohm square resistant or impedance square isn’t that right?

So, we represent this by a squared, where a has the dimension of ohms alright.

a in practice, a is design to be a real quantity therefore, a is called has the Gyration resistance. Gyration resistance and the usual symbol for a Gyrator is like this. This is the symbol for a gyrator with the gyration resistance denoted here exactly like a transformer you indicate Tran’s ratio N is to 1. Here the gyration resistance is indicated and the direction of the gyration is indicated by an arrow. That means, you have to terminate here to get an input impedance here alright. The gyration is in this direction. Why is the direction important? Because, as you will see this is a Non-reciprocal device. Which way you transmit is important. A forward transmission and the reverse transmission are not identical, they do not transmit equally well in both directions alright. And therefore, the direction of gyration is important.

That is I understand this denotes the direction of power transmission, power transmission or energy transmission. Now, before I go in to this let me indicate why it is important? Why it is gyrator an important network. Zin is; Zin is equal to a squared YL notice that if the load is capacitance, then the input impedance is that of an inductor and this is the major use of a Gyrator.

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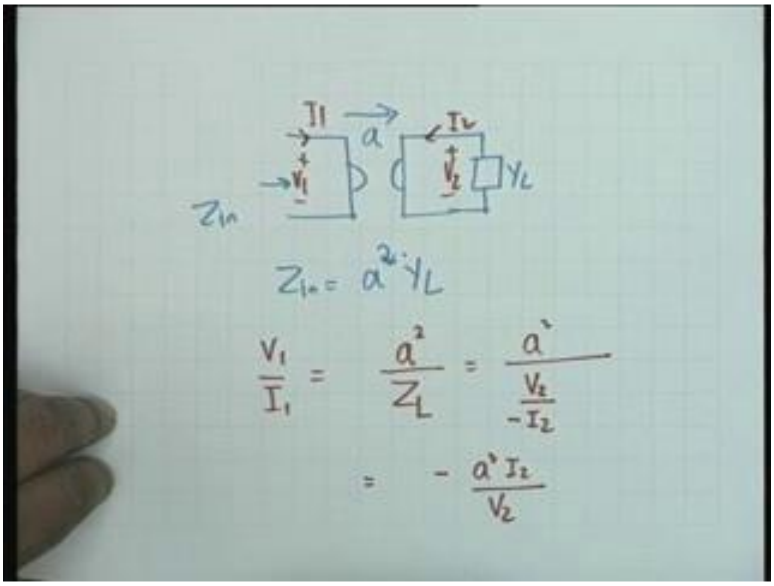

This is indicated circuits as you know in IC chips it is extremely difficult to use an inductance. So, inductance has to be simulated. Inductance it is used if you use to realize in the usual manner by flux linkage per unit current. Then, flux linkage would be extremely small, because of the volume, because of the extremely small volume and therefore, it is very difficult to use an ordinary inductor in an integrated circuit and therefore, what 1 does is one simulates an inductor.

The Gyrator can be can be made by op-amps and resistances, op-amps and resistances, and therefore if you terminate the Gyrator in the capacitance you got an inductor. And almost a very high value of inductor is possible within very small volumes. Because, op - amp can be fabricated in a chip, so can be the resistances alright this is the major views.

Now, let us try to characterize a Gyrator if this is consider is a 2 port network, 2 port network these are the voltages and currents.

Then, you see Zin can be written as V1 by I1 and this can be written as a squared by ZL and this can be written as a squared by ZL is V2 divided by minus I2 is that clear? V2 divided by minus I2 you understand why minus? Because, V2 and I2 do not agree with each other. They are in opposite direction they oppose each other, so V2 by minus I2. Which I can write as minus a squared I2 divided by V2 agreed a that is simple simply different ways of writing the same thing. So, what I get is V1 by I1 as equal to minus a squared I2 divided by V2.

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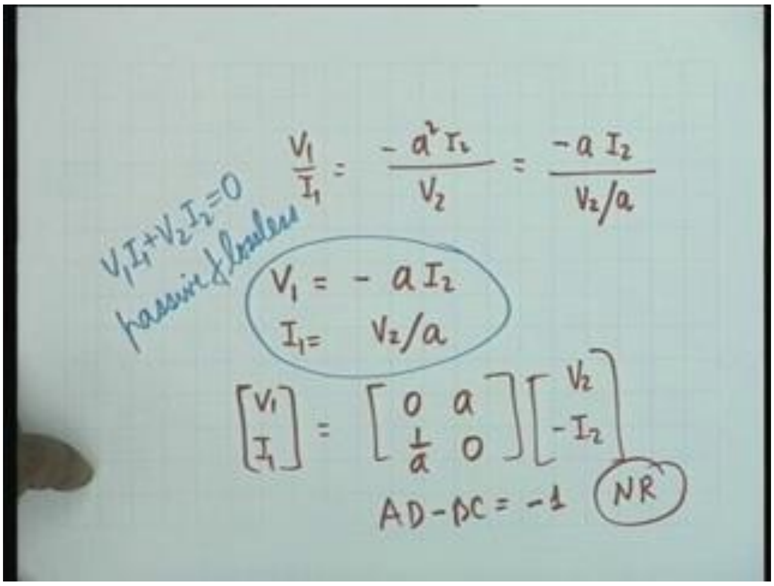

I write this as minus aI2 divided by instead of a squared I write minus aI2 divided by V2 by a alright. And practical circuits are usually realized, according to this relation that is V1 equals to minus aI2 and I1 as equal to V2 by a there are many other ways of identification, but this is one of the, one of the convenient ways this is how Gyrators are designed in practice.

V1 is equal to minus aI2 No, I have not changed anything, I have simply identified the numerator with the numerator. Now, a has the dimensional of resistance, so resistance multiplied by current should be a voltage. You must see that, its dimensionally correct. You could not identify V1 to minus a squared I2 that would have been wrong correct. So, it has to be minus aI2. Now therefore, you see that the matrix V1 I1 can be written as V2 minus I2.

0 a 1 by a and 0and you notice that, AD minus BC this is the transmission matrix AD minus BC is minus 1 and therefore, the device is Non-reciprocal. AD minus BC has to we plus 1 for a reciprocity and therefore, the Gyrator is a Non-reciprocal device alright. Question is the Gyrator passive or active? That answer do not be too quick in answering this question that answer is embedded here.

This is the total power going in as v. It is passive and loss less total power going in is 0. And therefore, it is passive and loss less. If this was greater than 0then, it would have been a Lossy Gyrator if this quantity was greater than 0.If it is less than 0the, it is active all right, it is active period. Active means, it can generate energy it is possible to make a active generators it is also possible to make passive generators.

In other words, these 2 need not necessarily be reciprocals of each other, need not necessarily, therefore it is possible to make active directors, it is also possible to make passive. One usually, makes passive generator, because the active generators have attendant problems of stability alright.

Why cannot V1 be minus a squared I2?

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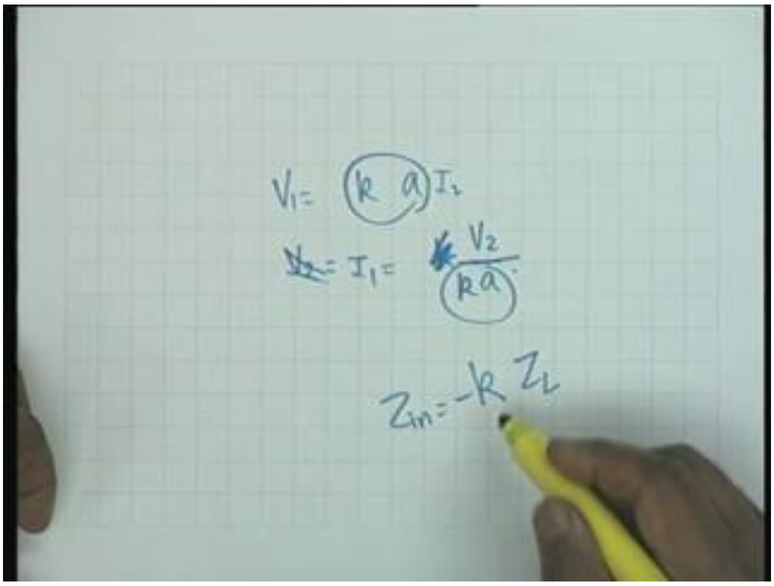

V1 equal to k times aI2.

I1 equal to k times V2 by a yes it is possible.

What whatever you are doing? See the it is simply ka and this is ka. So, it's another constant. This is one way of satisfying this relation, this is 1 way and this is the way that usually, statistics are made you can do it some other ways also.

It can be active, passive it can be plosive also passive etcetera.

There are many variation I have introduced you to 1simple circuit 1 simple way of realizing a Gyrator.

NIC can also be realized in various ways.

NIC I see the question is Zin should be equal should be proportional to the negative of the load. That means, it should be is let us say some k multiplied by ZL minus K ZL. And if K is 1; that is the unity conversion constant. If K is not 1then, you say K is the NIC constant.

That is Non-reciprocating both are Non-reciprocal. Now, let us see a cascade connection of a Gyrator and the passive network like this. And suppose we have the previous network that is Za Zb Zc. We are required to characterize this network V1 I1 V2 I2. All that we have to do is to replace each 2 port by its corresponding ABCD parameters. This is 1 2 port and this is the other 2 port. So, we have what is the it is 0 a 1 by a 0 and for the other 1 as we have already, found out it is a Za plus Zb divided by Zb and so on.

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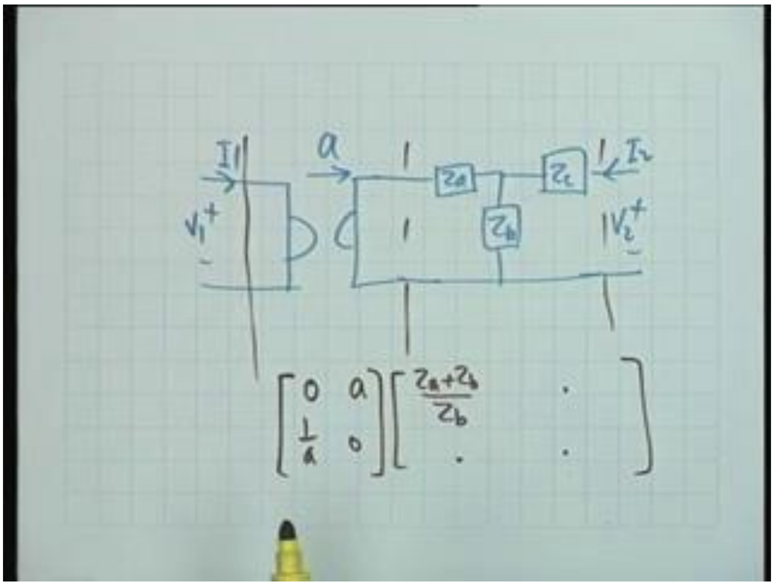

And all that, all that you have to do is to multiply the 2 matrices to get the ABCD parameters any question. Absolutely, if the reciprocity is not a precondition for connection or finding parameters. It can be active also, it can be passive, it can be active, it can be reciprocal, it can be Non-reciprocal no problem.

ABCD parameter is multiplied, always multiply irrespective of any condition, this is not, so in other interconnections. For example look at a parallel interconnection. Suppose you have 2 networks Na and Nb. First let me, show you the difficulty and the condition that are, the condition that is required. Suppose, you have another networks Nb and you want to connect them in parallel alright.

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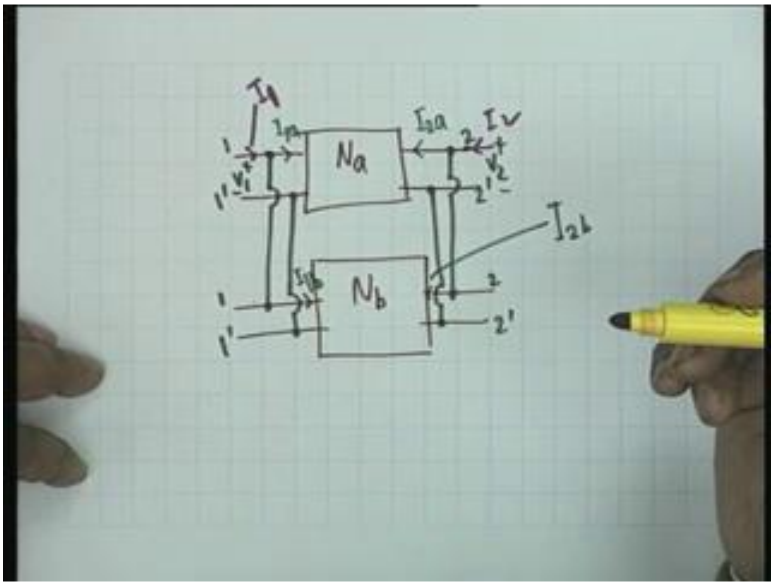

What you do in parallel connection is that this terminal you connect to this terminal and this 1 you connect to the lower terminal. Similarly, this 1 you connect to the upper terminal and this 1 you connect to the lower terminal. Then, they are parallel interconnected. You call this 1 1 prime 2 2 prime. Similarly, this is 1 1 prime 2 2 prime, the prime has the significance that this is the reference for measuring the potential of 1.

When, you say that the voltage here is V1 this is the plus here minus here. Similarly, when you say the voltage is V2 here it is 22 the potential of 2 is measured with respect to 2 prime is the reference. And the 2 currents let us say are I1a and I1b the currents going in at the input port and let the currents going in at the output port, at the port number 2 be I2a and I have exhausted space I2b.

Then, you notice that the overall current let me, use another column. The overall current I1 here is the sum of I1a and I1b by and the overall current I2 is equal to the sum of I2 a and I2b. The voltages are the same V2 V2 V1 V1. And therefore, it is very easy to conclude that the Y parameters shall add, but be aware they do not always add, there are problems.

Let me, take let me illustrate the problem case the Y parameters do not always add, the Y parameters let me take a very simple example. Suppose, I have a network like this; a 3 terminal network and another network which is truly 4 terminal, now if I connect them in parallel, if I connect them in parallel, what I am going to do is to connect this to this? Similarly, this to this no problem and I am going to connect this terminal.

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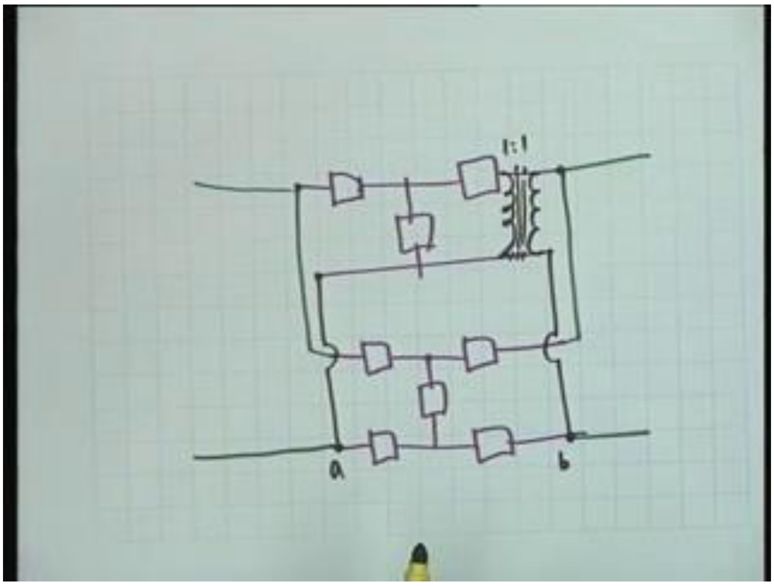

Let me use another color I am going to connect this terminal to this terminal and this terminal to this terminal. My overall network would be, this would be input port and this would be output port, but in the process you see I have destroyed the character of this network. Isn’t that right? I have connected this 2 points a and b and I have short circuited a and b, this is a short circuit it’s a 3 terminal network.

And therefore, the Y parameters of the other network, second network had been disturbed the character of this network has been spoiled and therefore, Y parameter shall not add here.

That is it not? Then you do not we cannot draw a circuit. We can find the Vicky. You cannot do that, even that is do not permitted why? Because, the Y parameters of this the pi circuit will contain Y parameters of this truly 4 terminal network and by this connection you have destroyed you have we have disturbed the Y parameters. As long as, a parallel interconnection you see in the cascade interconnection there is no question it is always valid.

The output of 1 network is the input of the other here, this is not the case you must be careful. So, long as the 2 networks the parallel connection does not interfere with the character of either network your parallel connection is valid and Y parameters shall add. One of the is that clear.

You can go back to the definition.

It is not the calculation this connection shall not be valid, you calculate, but that overall Y parameter calculated in any manner shall not be the true Y parameters of this, because you have disturbed the character of this. What you are saying is I take Na and Nb, I take the Y parameters and I add them no.

But that would be of a new network what you wanted is to add the 2 Y parameters. You cannot do that now. One of the ways that this problem can be avoided is to use a transformer. For example: if Na if this network has a was the 3 terminal 1 we connect at the input alright, but at the output we do not connect straight away. What we do is we connect a transformer here a 1 is to 1 transformer.

Then, you see what we have done is, what we have done is we have converted this is a truly 4 terminal network. This is the voltage and current here if it is 1 is to 1 ratio the identical with this if it is 1 is to 1 and therefore, we have not disturbed the terminal voltages in currents, but we have made this in to a truly 4 terminal network. Now, do i require this from both of them?

No just 1 just 1.

Suppose both of them where 3 terminal 1then there is absolutely no problem in interconnection. So, the problem comes when 1 is a 3 terminal 1 and the other is a 4 terminal 1 alright, and then you require a transformer. Let us look at this type of interconnection. That is I have an Na and Na I use a 1 is to 1 ideal transformer it has to be ideal transformer.

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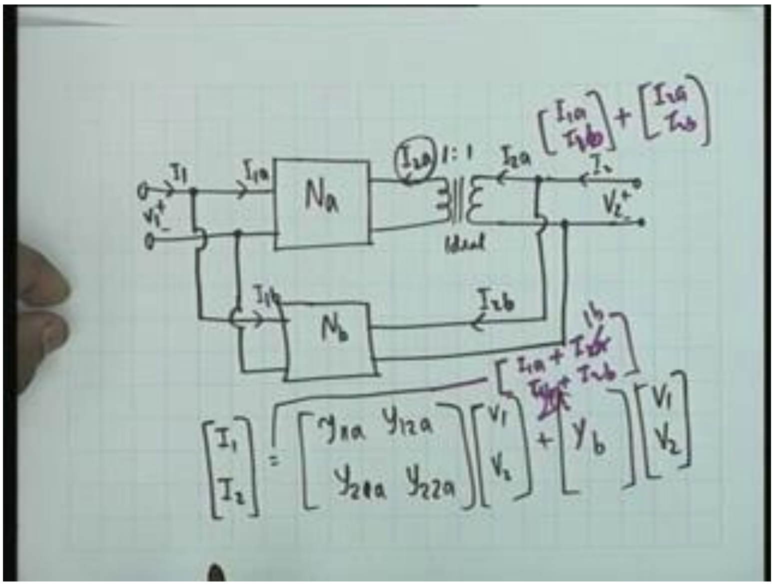

Because, I do not want to disturb the voltages and currents, then I have an Nb, Nb does not require an ideal transformer. So, what I can do is I connect this and I connect this. Similarly, I connect this I should have done it the other way round never the less. The 2 voltages are equal V1 and V2 they are equal this is also V2 and this is also V2. The voltages are equal the currents add that is if the overall current is i1then, a part of it goes in to Na and the other part goes in to Nb.

Similarly, if this current is I2, so will this current be this current would be I2a I2 shall consists of 2 parts: I2a and I2b. Then, this current will also be I2a. So, that we are not disturbing the terminal conditions of Na. And you notice now, that I1 I2 can be written as y11a y12a y21a y22a multiplied by V1 V2.this gives you I1a and I2a plus the b parameters the Y parameters of the b network multiplied by the same voltage is carried voltage vector V1 V2. And therefore, obviously the y parameters add, obviously, the Y parameters add.

Can I explain this again ok?

I what I omitted in between is let me, draw it in color I1 I2 is I1a plus I2a I1b plus I2bthe currents are sum of these 2 currents. And therefore, this is the sum of 2 vectors: 1 is I1a I2a I1a I1b plus I2a I2b and each of this I1a I1b is y11a y12a y21a y22a multiplied by V1 and V2 is that or shall we go back.

Wonderful, I1a plus I1b and this will be I2a plus I2b agreed. The currents add the currents, add and these 2 currents I1a I1b I1a I2a can be related to the Y parameters of this. The voltages are the same and therefore, you if you take this common and add the 2 Y parameters. Let me, in the few minutes that is left.

So, this is the Y parameters of the b network.

Yes.

If you only have DC currents let us have…

No if it is DC, then the transformer obviously is used.

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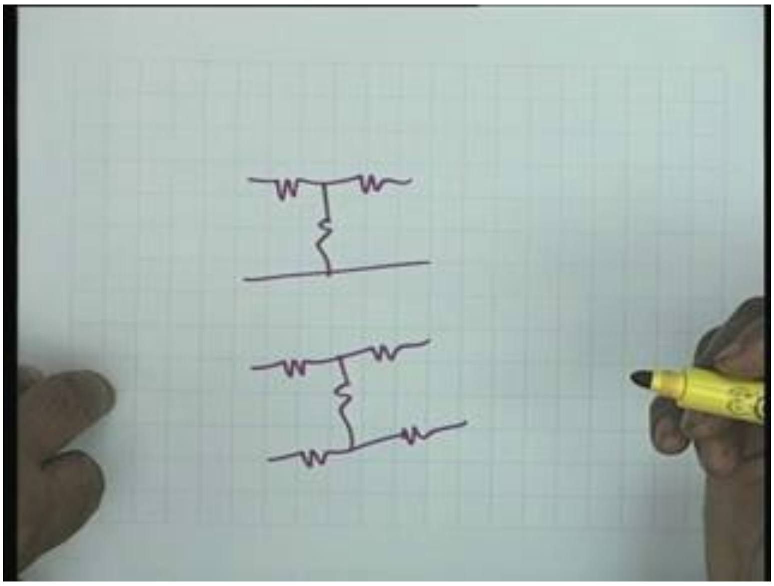

For example: if you connect a resisting network a 3 terminal, to another resistive network which is truly 4 terminal the transformer is useless. Then, you cannot make them, you cannot connect them in parallel.

There is no way out agreed you seeing the ideal transformer is a way out where did you get an ideal transformer. This is only 2 illustrate the fact that if 22 port networks are connected in parallel, the Y parameters do not always add underline not alright.

You have to be careful if look at the network and see if there is any interference with the character of the network, then you must give up.

If the 2 networks if by direct connection the character of 1 or both the network are disturbed. If that is, so then you have to use a a transformer Let me set a problem for you on parallel interconnections. This you may or may not work, out you may not work in the laboratory on this network, but it is a very interesting network.

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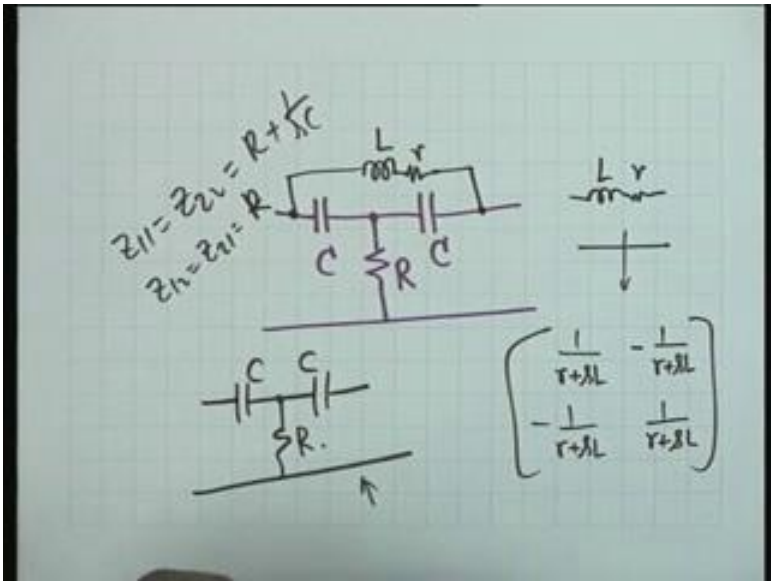

I have C C R and I have in parallel here and inductor L as you know an inductor cannot be made without a resistance and therefore, it has a small resistance r. This network can be looked upon as the parallel interconnection of 2 networks: 1 is the CRC network and the other is the Lr network this is the second network. And both are 3 terminal, both are 3 terminal. Therefore, in parallel interconnection the y parameter shall add is that ok? No transformer is needed.

Now, we can find out the Y parameters of this by inspection can you what are the Y parameters So, 1 by r plus SL minus 1 by r plus SL, minus 1 by r plus SL and plus r plus SL. These are the Y parameters of this network. The Y parameters of the pink network can also be obtained by inspection yes and no. What if you can convert it in to a pi, but i do not want you to waste your.

What is delta?

So, we have to find out for us now look, what I want you to do is reserve as much storage here as possible for new information. Thus it thus the point go in, do you understand what I am meaning I do not want you to memorize. If need be consult a handbook, consult your notes and get the formula in to that, but suppose you have nothing having nearby. You have no access you are in a in a place where there is no access to any of your class notes or your handbook or something. Suppose, I ask you to find the Y parameters of this what will you do?

What can you find out by inspection process? The z parameter isn't that right? z11 is z11 and z22 is simply R plus 1 by sc by inspection and zz12 equal to z21 is equal to 1 over simply R. So, you know the z parameter you can find out the determinant of the z parameter convert to y what is the relationship? No memorization z and y are inverses of each other and therefore, you can find out y11 and z22by determinant z similarly, all other parameters.

And if you know y11 y12 y21 and y22do not you know. Well you do not worry about the parameters. You can calculate the set without reference to any TPI conversion formula. I actually I advice that you do not use them unless you are absolutely sure that these are correct that these are correct and these are you have no time to to do this sort of calculation. And last statement shall I complete this example may I have a class now.

Then, I cannot complete this example, but I will do this next time on Thursday, but let me tell a small anecdote Leo Esaki, have you heard the name?

Leo Esaki is a noble laureate he discovered what is known as the tunnel diode, Esaki diode or tunnel diode. He discovered that, Esaki concept of tunneling can make a negative register this is what he got his noble prize for. Leo Esaki visited India very recently in the month of January. January seventh. In fact, he gave an address at the Ashoka hotel and he said that he is now vice-chancellor of a university in I forget the name of the university, he is not vice-chancellor they called it president. And he says the only way I reserved storage in my brain is that whenever I get a new attendance when, somebody comes to visit me he gives me a card and as soon as, the fellow goes out I through the card in the waste paper basket otherwise, I have read it and my storage in the brain shall be text.

I would like you to follow not literally that principle, but as far as, formulas are concerned do not try to memorize formulas. An engineer's life and engineer's like particularly 1 graduating from IIT he is required to do much more than memorizing formula and working out things he has to think of new things, and therefore as much storage as possible should be reserved.

Thank you.