Basic Electrical Circuits
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Lecture - 13
Two port parameters-y parameters

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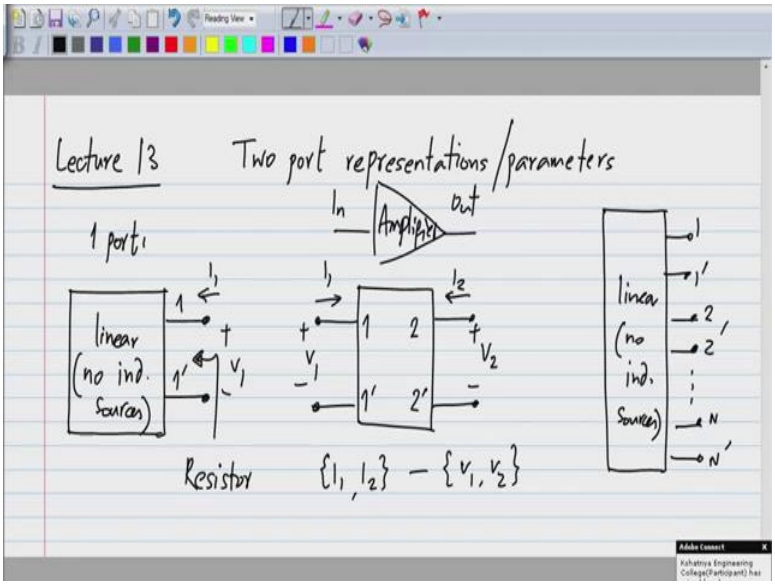

As I mentioned in the previous class, when you have a circuit with single pair of terminals that is a linear circuit with a single pair of terminals, it looks like a resistor and considering circuits without any independent sources inside. Now, when you have a circuit with two pairs of terminals, we have to find the right representation for it. We know that in a linear circuit every quantity will be a linear combination of the sources that are applied to the circuit. When I say every quantity I mean every branch and every branch, so this linear combination can be represented indifferent ways and they give rise to different sets of two port parameters.

That is a single terminal pair one prime and I have a two terminal pair, we have to relate V 1 I 1 to V 2 I 2, so that relationship let us say you relate I 1 to I 2 to b 1 and b 2, it gives you a set of two port parameters as I mentioned in the previous classes. Unfortunately, the setup we have is such that I cannot take questions by audio, so please ask your questions on the chat window. Now, this also can be further generalized to many ports we will not consider that, but I will just show you here if you have let us say

n terminal pairs, you can relate what are currents at these terminals. Now, particular reason for considering two ports is that many amplifiers many systems, we know have one input and one output.

They correspond to this two ports that is they are well described by these two port representation. For instance, amplifiers if you have an amplifier, there are an input and an output and are described by this representation. So, that is why they are represented by two ports, so that is why we will study the two port parameters in some detail. I think participants are raising hands to ask questions. As I mentioned, I will not be able to take questions by audio, so please use the chat window to ask any questions you have.

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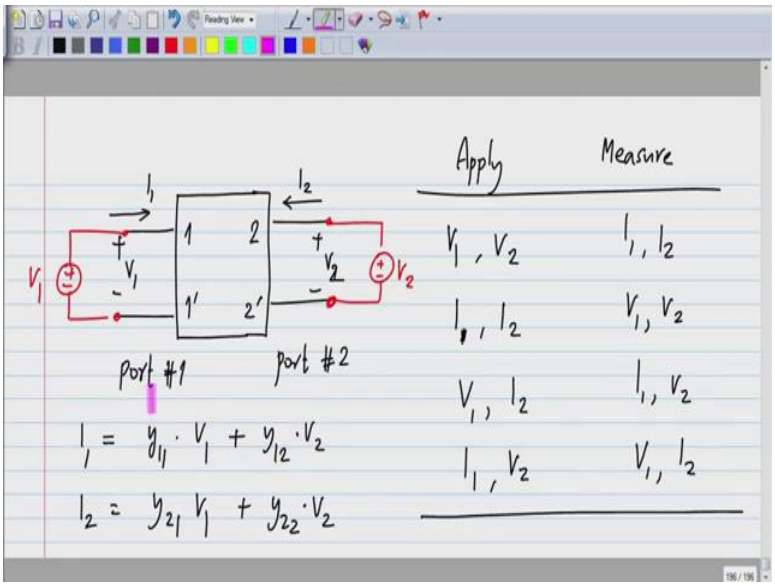

Now, I also took an example of a simple circuit and showed that quantities will be linear combinations. So, let me take this example where I have two terminal pairs of each terminal pair is called a port this is port number one this is port number two and each port has a voltage and a current. These voltages and currents are defined in directions consistent with the passive sign convention that is V 1 is with the plus 1 top into the upper terminal. Similarly, for V 2, sorry this is V 2, now we can apply either voltage sources or current sources to either side and measure the remaining two quantities. So, for instance we can apply V 1 and V 2 and measure I 1 and I 2, when I say measure what I mean is I write I 1 and I 2 in terms of V 1 and V 2.

Alternatively, I could apply I 1 and I 2 and measure V 1 and V 2 and I could also apply V 1 and I 2 and measure I 1 and V 2 or I apply I 1 and V 2 and measure V 1 and I 2. So, all these are possible, so for each of these there is a set of two port parameters to describe the relationship, so what do I mean by when I say I apply V 1 and V 2 and measure I 1 and V 2. It means that I have voltage sources connected to the two ports and then I will write I 1 and I 2 in terms of V 1 and V 2, now clearly I 1 can be written some number one one times V 1 plus some other number y 1 2 times V 2. Similarly, I 2 can be written as some third number y 2 1 times V 1 plus a fourth number y 22 times V 2.

So, we discuss this in the previous lecture, now these numbers y 1 1, y 1 2 and y 2 2, these are numbers with dimensions of conductance. Now, the numbers that appear here will depend on the parameters that we choose in this case we are writing currents as something proportional to voltages.

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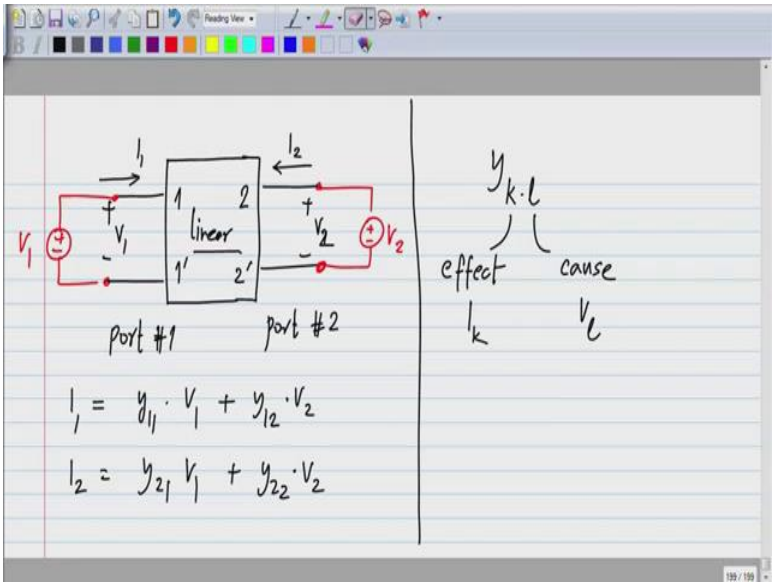

So, these will have dimensions of conductance, now we also said this kind of relationship comes about because this whole thing is a linear circuit that denotes the effect and the second one the cause. What I mean is this y 1 1 relates I 1 two V 1, so this I 1 means the first subscript is one and this is due to V 1 means the second subscript is also one. In this case, y 2 1 relates I 2 V 1, so in general y k l will relate I k two V l, so this is the convention that is used.

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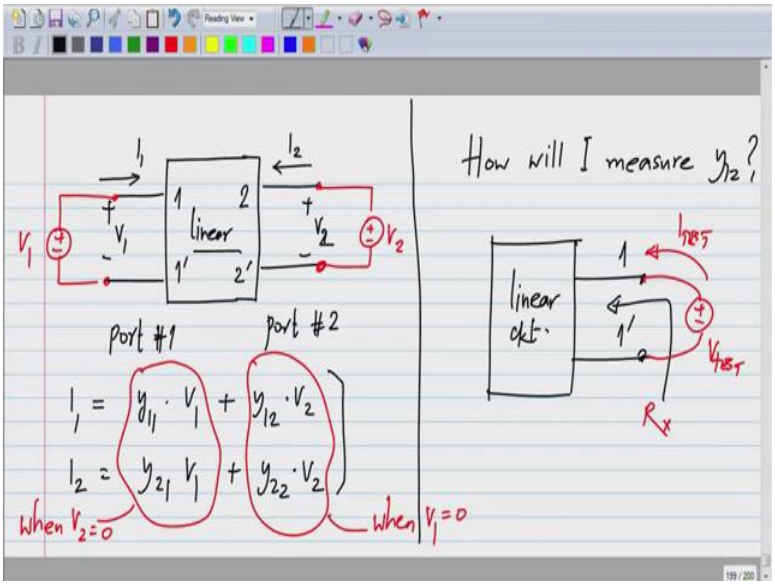

So, again let me if you want to try to understand how these relationships come about first of all it is a linear circuit, so linear circuit means super position will apply. So, you can think of this as super position of two cases where V 1 is zero and other one V 2 is zero, if V 2 is zero, both these currents will be proportional to V 1. So, we will get this part and if V 1 is zero both of these currents will be proportional to V 2 we will get that part and if you have both of them non zero. Then, you get the sum of the two, so this part comes about when V 2 equals zero and this part comes about when V 1 equals zero. So, now let us say you are given a circuit with two ports and you are asked to determine the values of these parameters what will you do how will you measure it.

Let us say how will I measure the value y 1 2, you can relate this to earlier examples we did many times that is we have one port. Then, you want to find out what it looks like looking into this terminal pair what we did was to apply some test voltage and measure the current. So, taking the ratio of voltage to current we get the resistance looking into this one similarly, now in this case I want to measure y 1 2, what should I do what is it that I can do to measure the value of y 1 2. So, in general to measure any of these things you have to set some voltages to zero and apply only one voltage, so instead of applying both voltages simultaneously, you have to apply just one of them.

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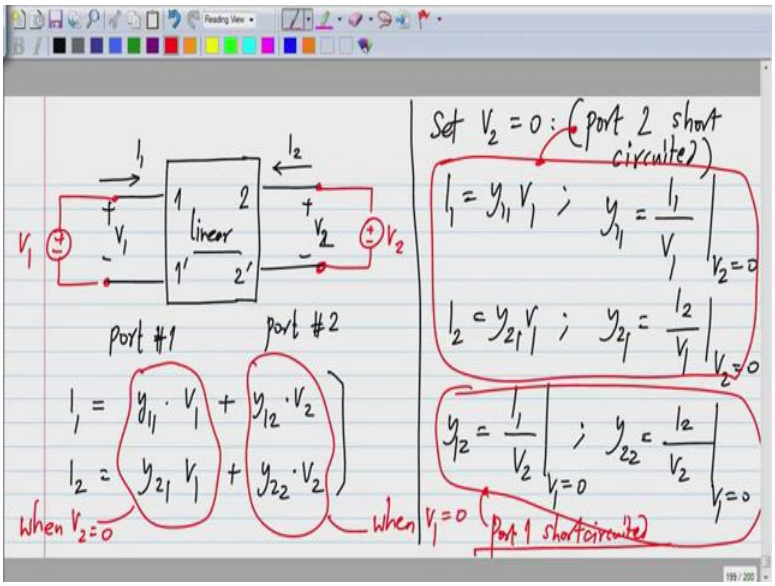

So, let us see now first of all let us set V 2 to zero, if I set V 2 to zero it is the same as saying that port two is short circuited. So, if I substituted that V 2 equal to zero what I will get is I 1 as y 1 1 V 1, so y 1 1 is nothing but I 1 by V 1 with V 2 set to zero. Similarly, I 2 would be y 2 1 V 1 and y 2 1 is y two by V 1 with V to set to zero, so to measure y 1 1 and y 2 1 you have to apply V 1 short circuit port two and measure the currents in port one and port two. So, I think this is pretty obvious from the equation if I set V 2 equal to zero the second part of these things go away and you will be left with only this and then you can find each parameter individually by measuring I 1.

You can measure y 1 1 by measuring I 2, you will measure y 2 1, similarly it is also very clear that y 1 2 can be measured by setting V 1 to zero and measuring I 1, you measure I 1 by V 2 with V 1 equal to zero. When V 1 equals zero, this part goes away and y 1 2 will be I 1 divided by V 2 and similarly, y 2 2 will be I 2 divided by V 2 with V 1 set to 0. Now, I hope this is clear soy one one and y 2 1 these are measured with port two short circuited and y 1 2 1 and y 2 2 these are measured with port one short circuited.

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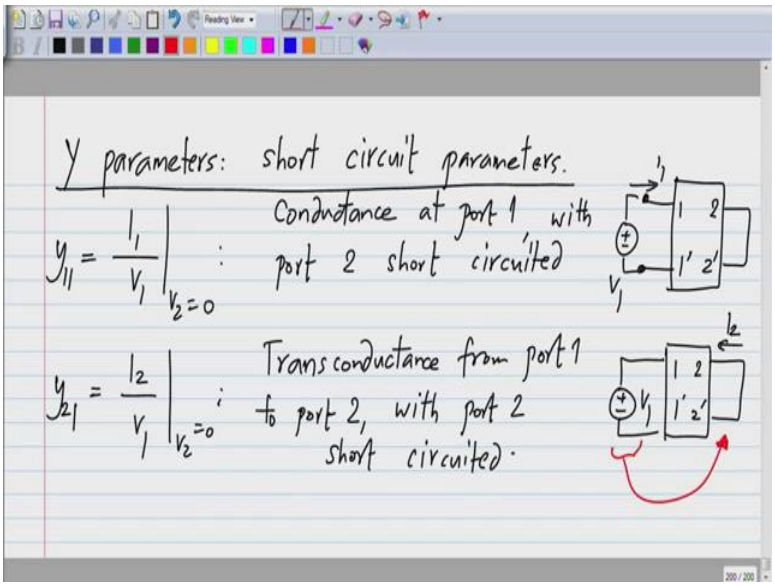

So, that is why these y parameters are also called short circuit parameters, so y 1 1 which is y one by V 1 with V 2 set to zero and what is y 1 by V 1, it is current going into port one divided by the voltage of same port. So, if you apply voltage between some pair of terminals and measure a current through the same pair of terminals it is like measuring the resistance or conductance across that pair of terminals. So, this is nothing but conductance at port one with port two short circuited, so if you imagine the picture you will have it like this, so this is how we are measuring y 1 1. So, it is pretty clear that once you have short circuited this, you can think of this as single port network when you are measuring I 1.

So, you are applying V 1 measuring I 1 taking the ratio of the two I 1 by V 1, so it is like measuring the conductance between this terminal and that terminal is this clear. Now, if you look at y 2 1 it is I 2 by V 1 with V 2 equal to zero the picture is the same except that you are not measuring I 1, but you are measuring I 2. Now, you are applying voltage to port one and measuring the current in port two, so this one is not a conductance is when you apply voltage to some pair of terminals and measure the current going into the same pair of terminals.

Here, we are applying the voltage, but measuring the current on the other side, so this kind of a thing has dimensions of conductance I 2 by V 1, but it is a different ports and this is known as trans conductance port one to port two with port two short circuited. So,

y 1 1 is like a conductance and y 2 1 is like a trans conductance from port one to port two trans conductance means that something that you apply here has an effect on that port.

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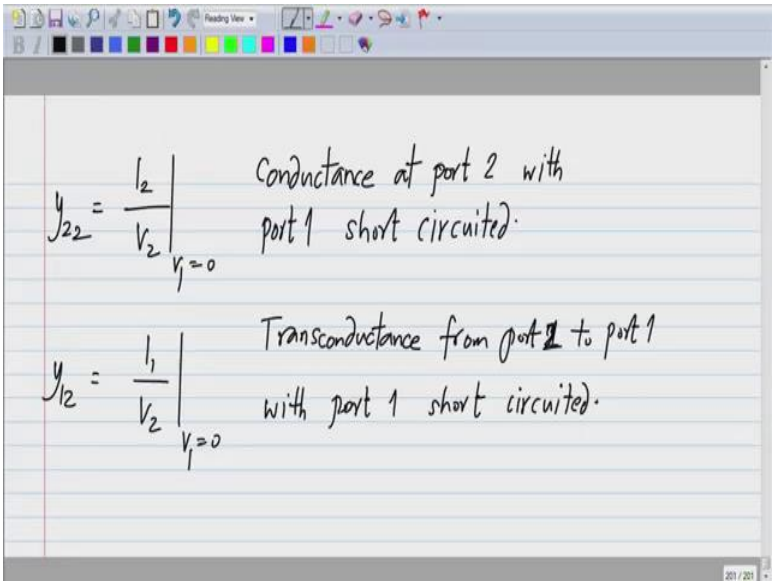

So, now please give me the interpretation of y 2 2, what is y 2 2, we know that it is I 2 by V 2 with V 1 equal to zero. So, please give a sort of a verbal interpretation what this parameter is y 2 2, so that is exactly right, this is conductance at port two with port one short circuited. Similarly, y 1 2, which is I 1 by V 2 with V 1 being zero is trans conductance from port two to port one with port one short circuited.

Now, when I say measure it also applies to calculations, so when you are given a circuit and you are asked to calculate the y parameters this is how you have to do it to calculate y 1 1. You have short circuited port two measure I 1 and divided by one to get y 1 1 and so on, so we will take an example of this later.

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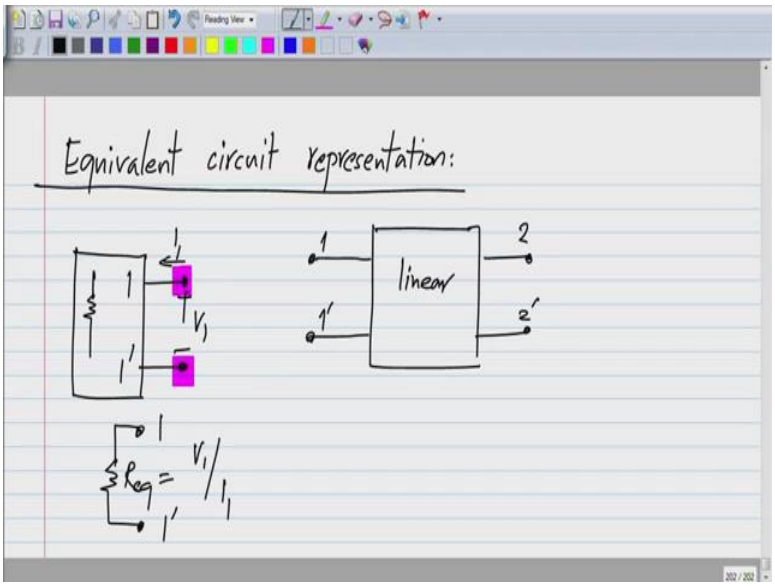

Now, another thing is equivalent circuit equivalent circuit representation, what do you mean by this again let us go back to one port. So, if you have a single pair of terminals, then we know that this I 1 will be linearly related to V 1 and at these two terminals we can always represent any linear one port with an equivalent resistance. This R eq will be nothing but V 1 by I 1 and we can also find the conductance if you want. So, my question is now we have to do similar things for two port that is this circuit, this is very simple circuit is the equivalent of this whole box whatever complicated circuit be inside as far as these two terminals are concerned.

That is very important that is when we say is equivalent we should find out where is the equivalence these two terminals the voltage current behavior will be the same as in this complicated circuit. Inside this, you could have hundreds of resistors and linear control sources and so on, so all of them will finally reduce to this linear relationship between V 1 and I 1. So, similarly, for a two port we have to come up with a relationship that is we now have equations which describe the behavior. Now, I would like to have a circuit representation of this sort, so what is that going to be, so let me copy over this part of it.

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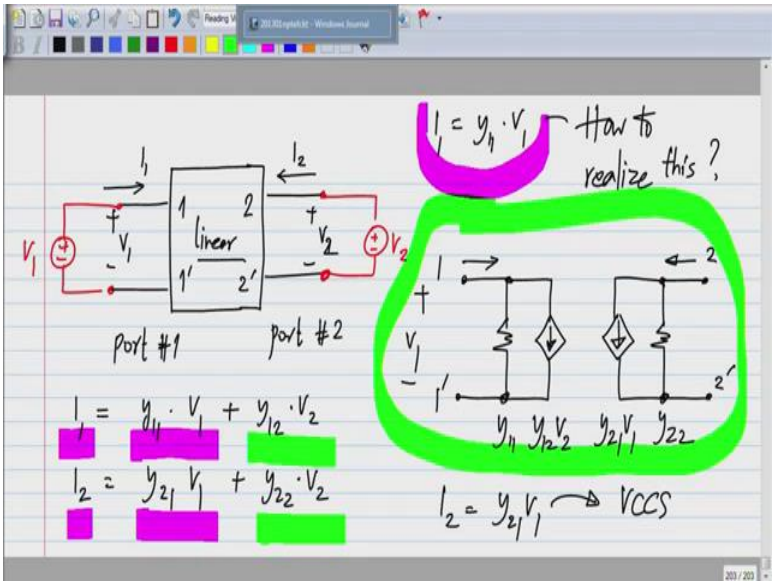

So, let me take each term one by one and then try to make a representation, so first of all I will take this part I 1 and I will take the first terms of that I 1 times V 1. So, if I have I 1 equals y 1 1 times V 1 and let me draw the two port here. So, I should have some circuit element, which will realize this relationship I want I 1 to be proportional to V 1 with this constant y 1 1. So, what is the circuit element that realize this relationship and where should I connect it in the circuit that is I have four terminals here one one prime two two prime. So, what is the circuit element that will realize just this relationship where I have taken only the first term I 1 and how do I connect it.

So, I get just this relationship in fact you can very easily see that it is more or less equivalent to one port network. So, again I think you were able to get the answer quite quickly, so this you see is just a conductance y 1 1 connected between I 1 and V 1. So, when I write y 1 1, y 1 1 has dimensions of conductance, so when I write a resistor and then write y 1 1 next to it. So, that means that the conductance of this resistor is y 1 1, so this will clearly realize if I write V 1 here, a current will flow which is equal to y 1 1 times V 1. So, now let me take the first term of the second equation, the equation for I 2 now what is an element that will realize this that is I want to now realize I 2 equals y 2 1 V 1.

So, what is the element that we will realize this and how do I connect this to circuit here it says that the current in two prime is proportional to the voltage across one prime. So,

what is an element going to realize this relationship, I think one of you answered this if you have a current somewhere depending on the voltage elsewhere. Clearly, it is a voltage controlled current source, so this is voltage control current source says that a current going into port two in this direction this is I 2. So, always keep in mind that I 1 and I 2 are currents flowing into the ports, it is a voltage controlled current source which is controlled by V 1, so this I will write y 2 1 V 1.

So, it is a voltage controlled current source V 1 and connected across two prime in this direction, now similarly if I take the other terms y 1 2 V 2 the current in port one is dependent on voltage at port two. So, clearly here also we need dependent source and finally in this term the current in port two is dependent on voltage at port two, so current and voltage are at the same port, so we can use a conductance which is y 2 2. So, this is an equivalent circuit representation of a two port network, any linear two port can be represented like this. That is the advantage of this see the point of having all these representations is that I think I have repeated this many times before you will end up designing very complex circuits which have lots of components.

Now, the person who is using that may not need to know all the internal leaders, so that is why you have this black box, which has a hundred of resistors and control sources and what not, but it has only two pairs of terminals. So, someone who is using this does not need to know all the intricacies of the circuits inside, they only need to know the current voltage behavior at the terminals. So, as long as you have only two ports exposed to the outside world they can be represented by just four numbers y 1 1 y 1 2 y 2 1 y 2 2 and anyone doing any analysis of this black box or any other system. Using this black box can use those four numbers to do the analysis or equivalently they can use this two port circuit, this thing I have shown here to do the analysis. So, how ever complicated the circuit is inside, it can be replaced by this much, of course, you have to find the value of y 1 1, y 1 2, y 2 1 and y 2 2 is this clear, any questions on this?

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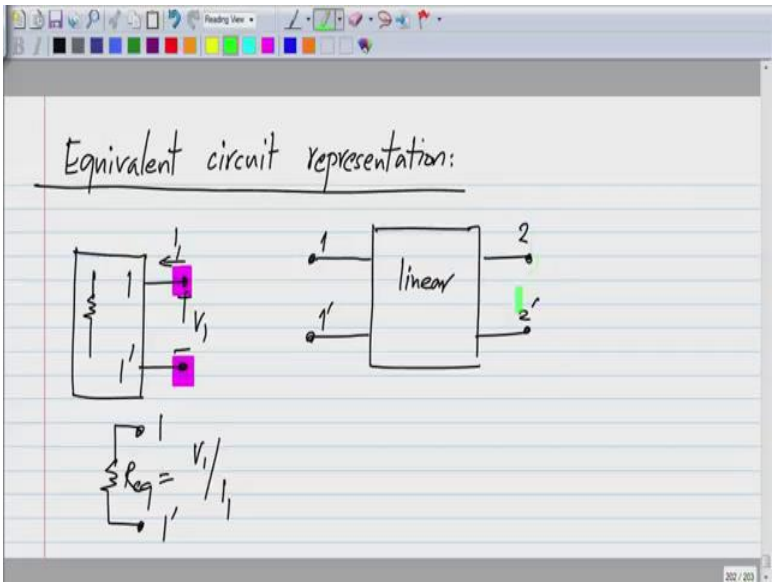

So, this is analogous to in case of one port I can always represent it by single resistor in case of two ports I need four parameters because there is a resistance across one prime there is a resistance across two prime. Also, if you apply something to one prime, it affects something at two prime, similarly you apply something to two prime, it affects something at one prime. So, with all these interactions we will need four parameters to describe a two port network, any questions about this?

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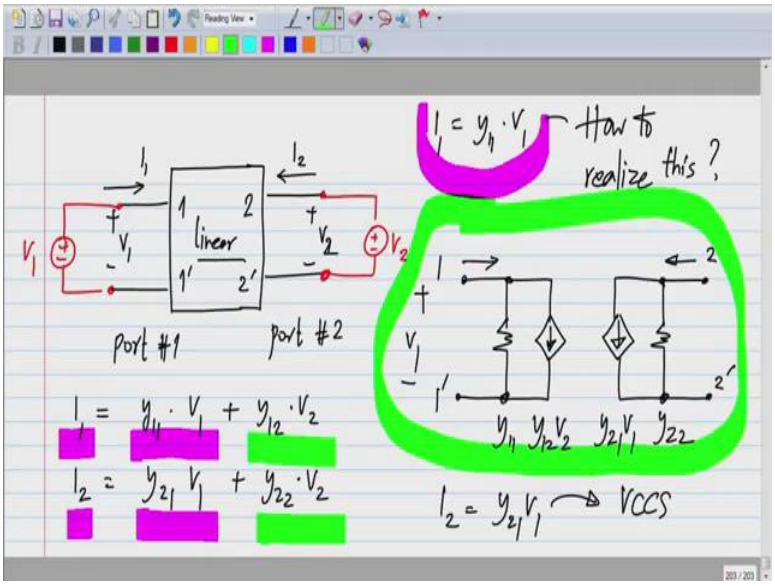

The question is how do you say it is a voltage controlled current source because the current is a function of a voltage. So, this is the input this is the output, so to speak is controlled by the voltage and gives you the current, so this is voltage controlled current source. So, now the question is what is the use of these parameters as I said you can describe a complicated circuit however complicated it is inside to with these four parameters that is the used. Basically, it is a representation and also you could have two different circuits inside, but let us say you have two black boxes each of them has two ports and the internal details are different, but if the y parameters are the same.

So, that means that they are the same equivalently, so you could have one circuit with one hundred resistors another one with 50 resistors and if you arrange it such that the y parameters are the same. Then, if you use this black box in other circuit they will behave identically, so basically it is a matter of representation and in terms of that in terms of that more complicated circuits like more complicated devices like resistors which you will encounter later. These are used to make amplifiers and so on can be represented using these y parameter or some of two port parameters. So, other question is why do we have a conductance here see if you have a current at some pair of terminals proportional to the voltage at same pair of terminals proportional to the voltage at same pair of terminals it has to be resistance right or resistance. So, if the picture looks like this if you have two terminals the voltage here is proportional to current here or the current there is proportional to the voltage here, so it means that it means that the equivalent thing is a conductance is the audio not clear?

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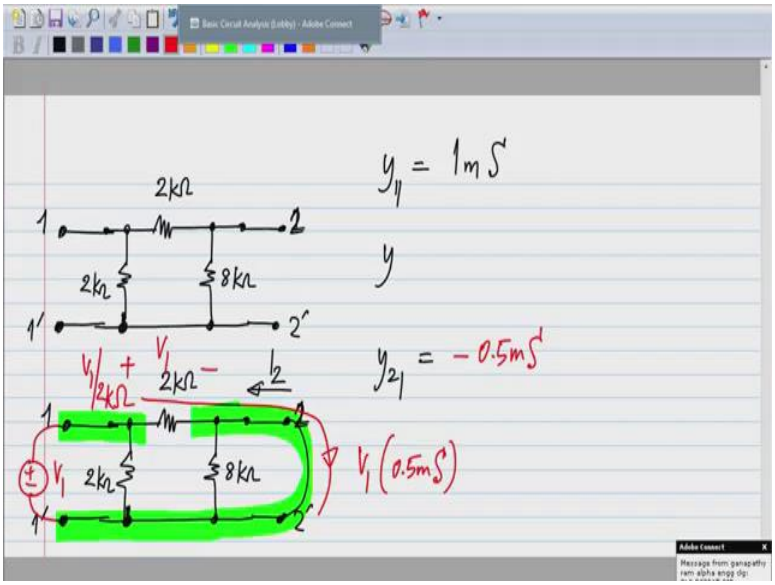

Now, let us take an example, let us take a simple example, so this is my circuit, this is port one and this is port two, so please find the parameter of this and then you can give me the answer by typing into the chat window. First of all, please find the value of y 1 1 again, to do this you can recall the definition, there are many ways of doing it, first of all you can apply voltage to both sides find all the currents and obviously it will be in this form and you can find these numbers. Alternatively, you can use the definition we came up with earlier that y 1 1 is conductance at port one with port two short circuited and y 2 1 is trans conductance from port one to port two with port two short circuited and so on.

So, first is please give me the value of y 1 1, there is an answer, seem to be correct, so please take note of the values correctly. So, this 2 kilo ohms and 8 kilo ohms and how will you find y 1 1 what will you do to port two and one more thing I have to find out which I have mentioned repeatedly that please try to get a feel for the numbers and always give numbers with units where applicable. We would never say that the distance between Chennai and Bangalore is 360 right, it is 360 kilometers.

So, similarly whenever you have quantities with dimensions you have to include the appropriate unit because if I just say 360 that is not clear if it is 360 kilometers or meters or whatever it is. So, always give the number with appropriate unit, so one for a the unit of conductance, so this is one, how do we get this you short circuit port two. Once you do that, it goes out of picture it is short circuited and you see that these 2 kilo ohms and

that 2 kilo ohms are parallel with each other. So, looking into one prime, we have 2 kilo ohm parallel to two kilo ohm which is a kilo ohm resistance, but y 1 1 is the conductance, so 1 divided by 1 kilo ohm.

Similarly, now what is y 2 1 please find the value of y 2 1 when I jumped to y 2 1 because it is also measured with port two short circuited. I think a couple of you gave the right answer immediately it is one milli once again, but one of you has said it is 1.6. I am not sure how you have got it, but that is not correct because if I apply V 1 here, now what I have to measure is first of all the current I 2 measured in this direction. So, keeping this in mind please give me the correct answer I 2 is measured going into the network by definition, so that is how I 1 and I 2 are. What is the value of y 2 1, so I need not only the correct magnitude, but also the sign.

So, let us look at this carefully, here this is short circuited so all of this V 1 appears across this two kilo ohms because port two is short circuited. So, the voltage here is V 1 so the current V 1 divided by two kilo ohm will flow in this direction now what is V 1 divided by two kilo ohm it is V 1 times 0.5. So, this is the eight kilo ohm is not in the picture, so this is short circuited, so if I apply V 1 here all of it appears across two kilo ohm and V 1 by two kilo ohm flows in this directional. So, this direction is opposite to that of the definition of I 2, so what is the value of y 2 1, it is minus zero point five. I hope this calculation is clear if not please let me know immediately so that I can repeat how to do that.

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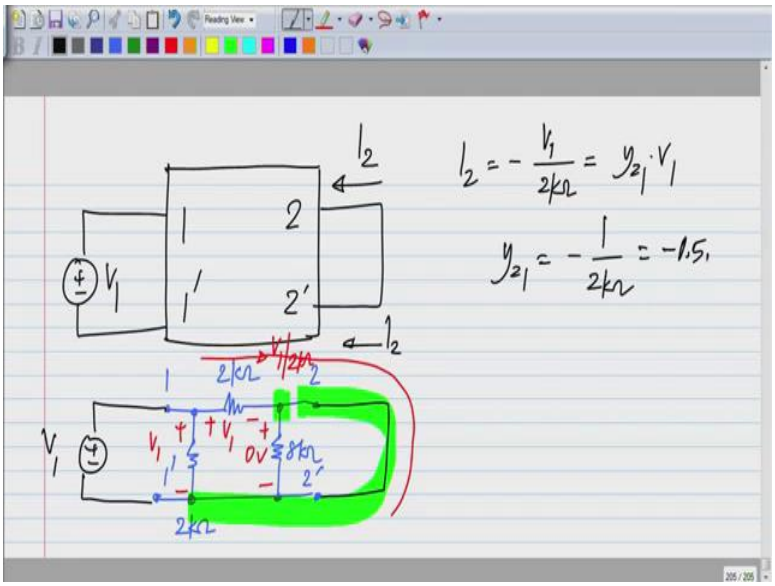

So, what is y 2 1 I apply V 1 two port one and I short circuit port two and I measure the current through the short circuit. So, that is the current in port two and in this direction going into this terminal two now what is the circuit I have inside this box. So, that is the two port network and these are the terminals and I apply V 1 here and this part is short circuited. So I hope it is very clear that V 1 is applied here, so voltage across this is V 1 and similarly, this is short circuited all the way through. So, the voltage across this is 0, 8 kilo ohm is connected in parallel with the short circuit and V 1 appears across this 2 kilo ohms.

So, V 1 appears across this two kilo ohms, now the current through this 2 kilo meter resistance is V 1 divided by 2 kilo ohms when it appears. At this note, it can go either through the 8 kilo ohm or the short circuit, obviously if you have something in parallel with the short circuit everything will go through the short circuit. This you can easily calculate this you can easily calculate I mean if you have something across a short circuit all of the current will go through the short circuit. So, this V 1 by 2 kilo ohm is what flows out like that and remember I 2 is what we are trying to measure going into the network. This I 2 is what we are trying to measure, so I 2 will be minus V 1 divided by 2 kilo ohms and this is nothing but y 2 1 V 1, so y 2 1 is minus one by two kilo ohms or minus 0.5.

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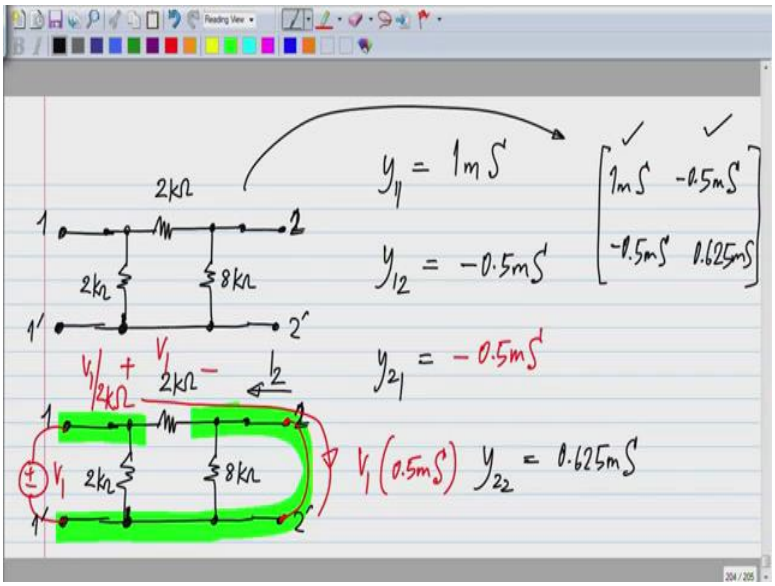

So, that is how I get the value of y 2 1 to be minus point five this is I think one of you has got the answer of minus 12.5, I think some simple numerical error, now there is a question what is the significance of negative. We are not looking at voltage at some port divided by current at the same port or current at the same port divided by voltage at the same port. So, that would mean something significant a negative resistance is there means it is generating power here if here we are talking about current at port two divided by voltage at port one, this being narrative does not have any particular significance.

Later I will show how easily we can make that positive, so with this background you should be able to calculate y 1 1 and y 2 2 quite easily as well so please give me the values y 1 2 and y 2 2. So, you have to be able to calculate this for any circuit, so again all this requires is a systematic circuit analysis you short circuit port two and apply V 1 to port one and calculate y 1 1 y 2 1 short circuit port one apply V 2 to port two. Then, you can calculate y 2 1 and y 2 2, so please give me the values of y 1 2 and y 2 2, please calculate y 1 1 y 1 2[FL], you have got 0.625.

Again, there is some calculation error, please make sure that you sorry with this one this is y 2 2 so yeah y 2 2 is 0.625, that is correct that is the correct answer what about the value of y 1 2 has got minus 0.13 not correct. Please check you answer remember y 1 2 is I 1 divided by V 2 with port one short circuited, no it is negative that is, but even the number is not correct.

The value of y 2 2 is 0.625 that is correct, what is the value of y 1 2, so to calculate y 1 2 you have to apply V 2 to port two and calculate this current flowing in port one. So, again I think [FL] has got it, so it is minus 0.5, so the y parameters of this networks are, so this and this we already discussed we will look at the other two.

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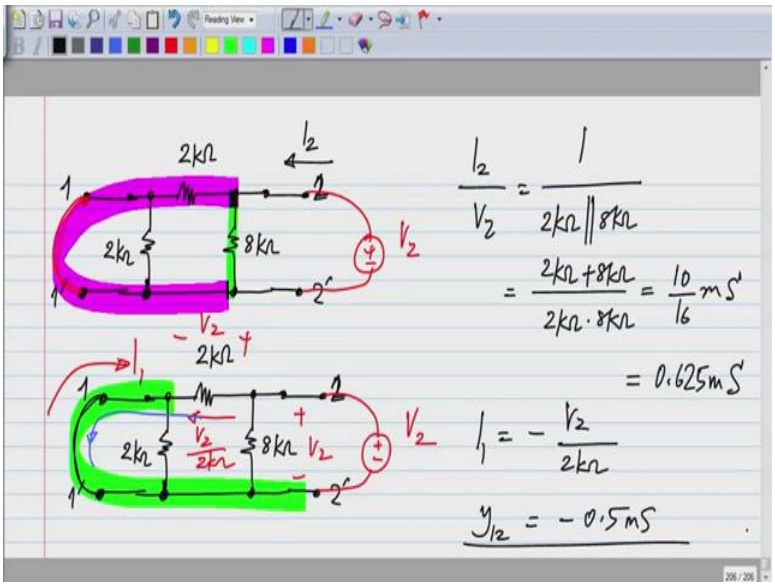

To calculate y 2 2 what we do is short circuit port one and apply V 2 here, now you see that this 2 kilo ohm is parallel with 8 kilo ohm because this is short circuited. So, this two kilo ohm is parallel with this 8 kilo ohms, so essentially you see a conductance corresponding to 2 kilo ohm and parallel with 8 kilo ohms I 2 by V 2 will be 1 by 2 kilo ohms, which is 2 kilo ohm times 8 kilo ohm 2 kilo ohm plus 8 kilo ohms. This is 10 by 16 and you have kilo ohms in the denominator, so this is 0.625 and 2, calculate y 1 2 what I have to do is to find this current sorry I 1 as a function of V 2.

I apply V 2 and find I 1, so again I see that V 2 appears directly here and also because this is short circuited V 2 appears here. So, the current flowing from right to left through it 2 kilo ohm resistance is V 2 by 2 kilo ohms and at this note you have a short circuit and two kilo ohm. So, obviously all of the current will go that way, so I 1 is minus V 2 by two kilo ohms, which says that y 1 2 is minus 0.5, so we end up getting this set of y parameters.

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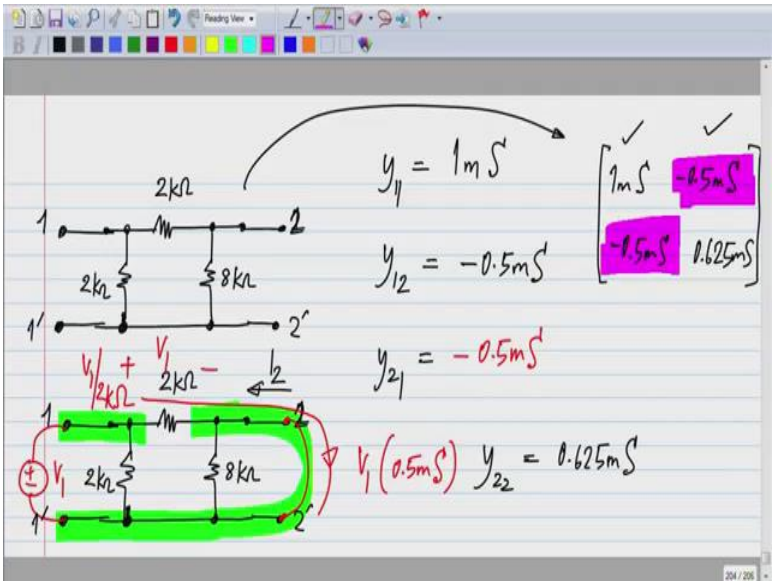

Now, first of all is the procedure clear to everybody I think many of you made mistakes while calculating please avoid that with a little bit practice. You will be able to avoid those things, so please mind the units like kilo ohms and so on and also please mind exactly where the current if flowing because when you short circuit it some of the components drop out of the picture. This is calculation of y parameters, now my question is y 1 2 and y 2 1 came out the way exactly equal minus 0.5.

Now, my question is this coincidence for this circuit or what do you think it is, so what I am asking is y 1 2 and y 2 1 are the same. Now, is this a coincidence for the same circuit or what is it, one of the answer is because it is this kilo ohms. Now, that is how we calculated it this is a fundamental property of resistive network, it does not have anything to do with this particular policy because we already saw and one of you answered.

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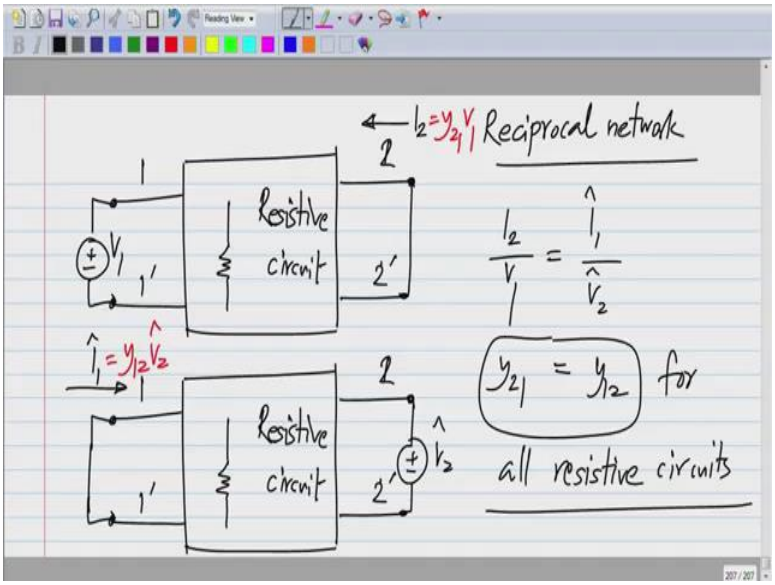

If you have only resistance that is not just a linear circuit, but something that has only resistors in it says reciprocity theorem or it is a reciprocal network and reciprocity can be thought of in different ways. When we apply a voltages to the two sides or current to the two sides or voltage to one side or current two other side, so if you recall this is the terminology we had used. So, this is how we evaluate reciprocity now the reciprocity result was that I 2 by V 1 that is you apply stimulus to the left find the cause on the right side. It will be exactly same as I 1 at divided by V 2 at where you apply stimulus to the right side and find the effect on the left side.

Now, if you look at this picture this port two is short circuited and we are applying V 1 and measuring I 2, so clearly this is nothing but y 2 1. So, this is basically measuring y 2 1 here and similarly, here you are short circuiting V 1 and applying V 2 hat. So, this I 1 that will be nothing but y 1 2 V 2 hat and this number will be y 1 2, so y 2 1 will be equal to y 1 2.

So, this y 1 2 being y 2 1 is a fundamental property of all resistive circuits because if you have a circuit containing all the resistors it is going to be reciprocal and y 2 1 will be equal to y 1 2. In fact, you can also look at that as a statement of reciprocity if you are given the two port parameter and if y 2 1 equals y 1 2. You call it a reciprocal network and if it is not equal it is not equal, there is a question if the cause and effect of the same that is current and voltage can be reciprocity.

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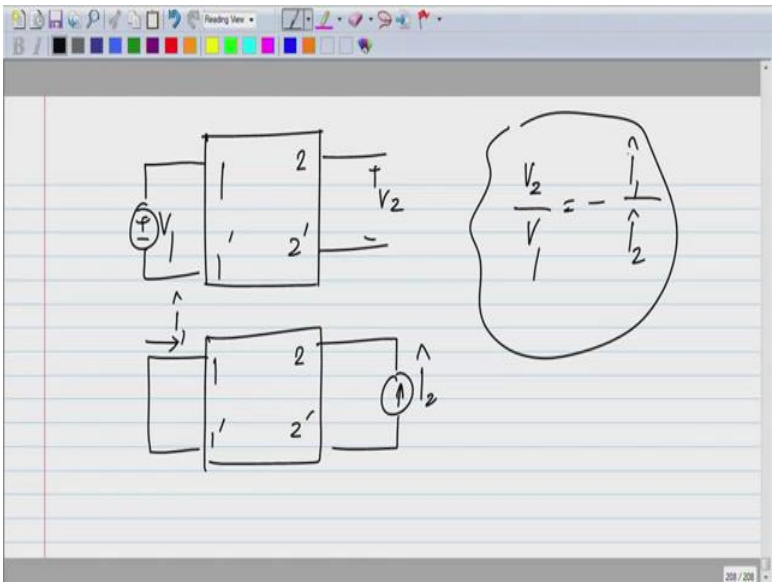

Now, yeah we have evaluated that, so if you consider the case where we evaluated reciprocity with the right side open circuited. This corresponds to applying a voltage on the left side measuring the voltage on the right side or applying the current on the right side and measuring the current on the left side. In this case also reciprocity is true and we saw that V 2 by V 1 equals minus y one hat by I 2 hat. Now, this will have implication on another set of two port parameters, so I hope this is clear, now let me quickly extend the example, so let me copy this whole thing over here.

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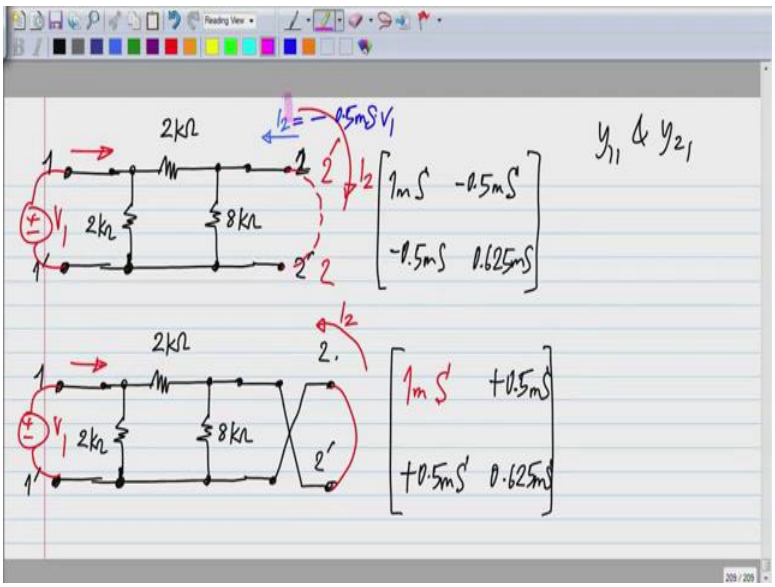

So, this is the result we have got and we will slightly modify this is just to make sure that you have understood what we have done that means I have crossed these wires and got this two one two prime. So, which parameters will change and how will they change we have four y parameters y 1 1 y 1 2 y 2 1 y 2 2. Now, I have the same circuit, but I cross these wires, so this is the new circuit I have taken the old circuit and modified this slightly. So, what will be the y parameters of this, so one of the answers is that it is exactly the same as before, now I have changed I mean I have changed the terminals two one two prime.

It will not make any difference another way to think about this is now this is two prime, there is an answer that the diagonal elements will change why is that. So, that means that y 1 1 will become y 2 2 and y 2 2 will become y 1 1, why will that happen. Another answer says diagonal will be 0 again why is that, so you actually do the short circuiting and calculate the parameters and then you see immediately what the answer is and another answer says that y 2 1 equals y 1 2. Now, this is not really possible right because for any resistive network we just said that they are reciprocal.

So, y 2 1 has to be equal to y 1 2 they could be different from what it was for the original circuit, but even for the new circuit which consists of only resistors y 2 1 has to be equal to y 1 2. There is another answer that says signs change, but sign change parameters all of them some of them which ones those which are associated with port two know that is not correct so y 1 2 and y 2 1 will change sign. So, first of all let us calculate y 1 1 and y two and y 2 1, so how do you calculate y 1 1 and y 2 1 you short circuit this which is the same as short circuiting this one and you apply V 1.

Now, whether you short circuit this way or that way it is exactly the same circuit so the current flowing here cannot possibly change you can do the calculation completely and then verify ahead, but the current flowing here. There has to be exactly the same because it is the same circuit after all and we are measuring the same current, so this will be now for y 1 2, sorry y 2 1 I have to measure I 2. So, that is two prime to two if you compare to the previous situation all that has happened is previously I was measuring the current going this way and now I have to measure current flowing that way because of the definition of two one two prime.

The current will be exactly the same because the circuit is exactly the same, so I 2 this blue current I have marked will be minus 0.5 times V 1, but in this case the I 2 I am interested in the opposite direction. So, this will become plus 0.5, now similarly you can verify yourself, first of all for a resistor circuit y 2 1 and y 1 2 have to be exactly the same. So, this is 0.5 and this you can verify for yourself that it remains the same for it is 0.625, now one of the things you would observe even a purely resistive circuit y 1 2 has to be equal to y 2 1.

This you can even use for sanity check if you calculate them separately and you find that y 1 2 has become different from y 2 1 that means you have made a mistake in calculation. By the way, this is for circuits which have only resistors if you have controlled sources the game is different and y 1 2 and y 2 1 can be different from each other. So, that is one thing and secondly I have only the resistors both y one and y 2 2 will be positive, so again let me look at this picture, here where calculating y 1 to calculate y 1 1 we take the ratio of this to that one.

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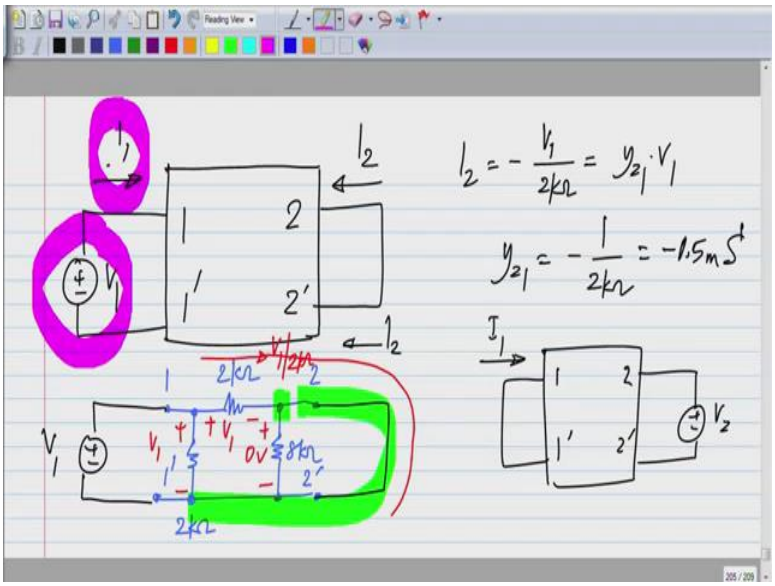

Now, let us say inside you have only the resistors so that means there will be a power loss, now if I 1 by V 1 happens to be negative that means that looking in to one one prime you have a negative resistance which generates power that is not possible. So, if you have only resistors in the circuit, it can only dissipate power and it has to be positive similarly, y 2 2 has to be positive.

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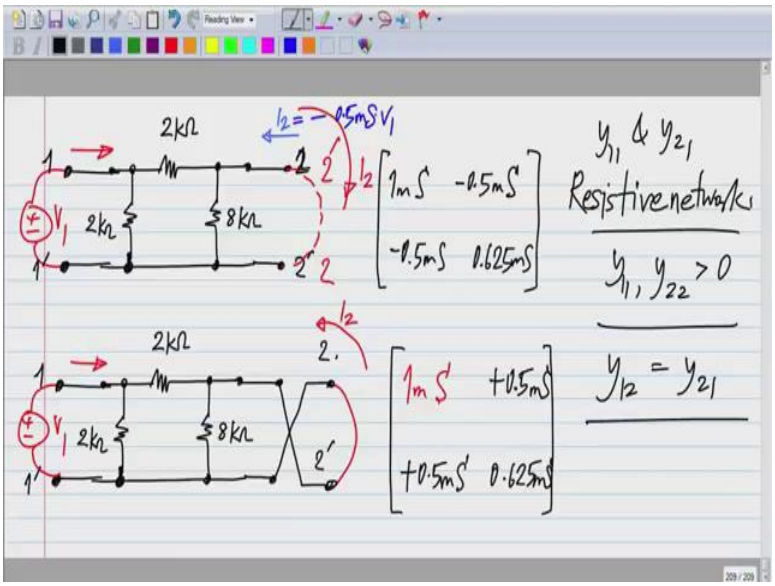

So, these are something that you can use as sanity checks y 1 1 and y 2 2 have to be more than 0 and y 1 2 equals y 2 1 any questions about what we have done so far.

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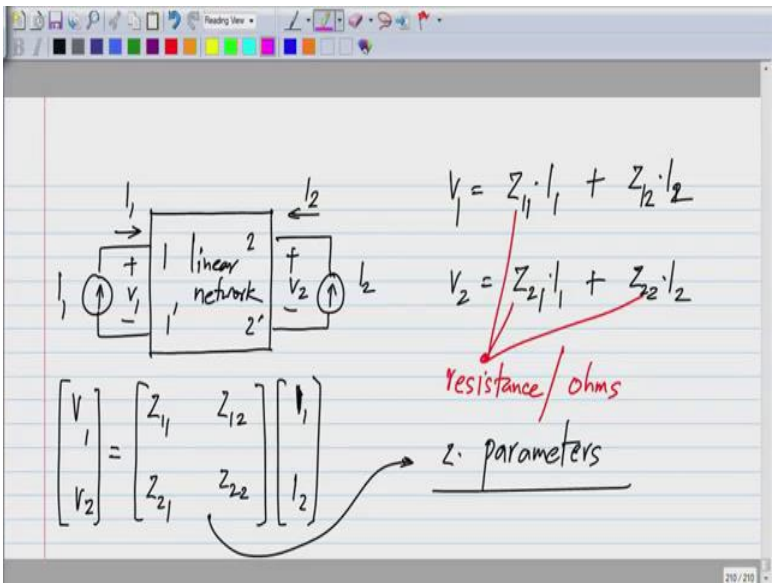

Now, instead of applying voltages and finding currents we can apply I 1 and I 2 and determine V 1 and V 2 as a result of I 1 and I 2 as before if you make I 2 zero then both V 1 and V 2 will be proportional to I 1, because this is linear network. So, with V 2 equal to 0 and I 1 will be sorry V 1 will be some number let us call it z 1 1 I 1 and V 2 will be

some number z 2 1 times I 1. So, this is with I 2 equal to zero, similarly, with I 1 equal to zero both V 1 and V 2 will be proportional to I 2.

So, we will end up with V 1 and z 1 2 times I 1 and V 2 being z 2 2 times sorry z 1 2 times I 2 and V 2 being z 2 2 times I 2. Now, if both I 1 and I 2 are non zero by super position, you will get the sum of these things. So, here voltages are expressed as some function of currents and these numbers what will be the dimensions and units of these numbers z 1 1 z 1 2 z 2 1 and z 2 2. So, clearly you multiply I 1 by some number to get a voltage, so these have dimensions of resistance and even its of ohms and again for this matrix form sorry I have to write V 1 V 2 as a function ofi one I 2 and these are known as z parameters.

Now, there is a question if current direction is opposite what will be V 1 and V 2 it will be negative of whatever we have here. Now, like I said this V 1 and I 1 for the two port so this V 1 and I 1 V 2 and I 2 are chosen with passive sign convention, so V 1 is positive of I 1 one will be flowing into terminal. When V 2 is positive on top I 2 will be flowing into that terminal, now in this case I applied I 1 and I 2 in the same direction. So, just like previously when I applied this voltage sources I took I 1 to be positive and lower one to be sorry upper one to be positive in both places.

Now, that is how these parameters are defend if you apply external current which is flowing downwards cases it will become. So, these are known as z parameters, now in the next lecture we can discuss this in more detail I will quickly introduce more parameters sets and we can close today’s lecture.

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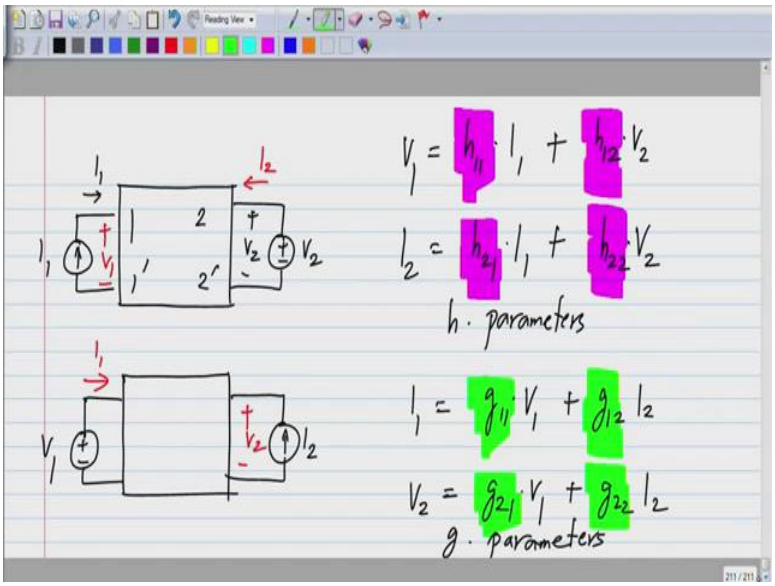

We have applied voltage sources on both sides or current sources on both sides it is also possible to do a hybrid that is I apply current I 1 on the left side and I apply voltage V 2 on the right side. Then, I measure two unknowns which are V 1 and I 2, so the reason to have all these choices is to have there are some practical situations where one or the other is convenient. So, in this case if V 2 is 0, then both V 2 and I 2 will be proportional to I 1 V 1 will be something times I 1 and this is denoted by the letter h h one one times I 1 and I 2 will be h two times I 1 and if I 1 is zero.

Both I 1 and I 2 will be proportional to V 2, so we will have h one two times V 2 and h two times V 2 V 1 and y two and if both I 1 and V 2 are non zero you will end up having the super position of the two. So, these are known as h parameters, so please think about the dimensions of a these numbers dimensions of these numbers and similarly, the fourth alternative is to have V 1 apply V 1 apply I 2 and measure V 2 and I 1.

In this case, again when I 2 is zero both I 1 and V 2 will be proportional to V 1, so I 1 will be some number z 1 1 times V 1 and V 2 will be some number z 2 1 times V 1. When I 1 is zero sorry V 1 is zero I 1 and V 2 will be proportional to I 2, so we will have g 1 2 I 2 and g 2 2 I 2 and these are known as g parameters. So, in this case also please think about the dimensions and units of these four numbers because now we have in some cases current and some other cases voltage. So please think about these things and we will continue from here in the next lecture.

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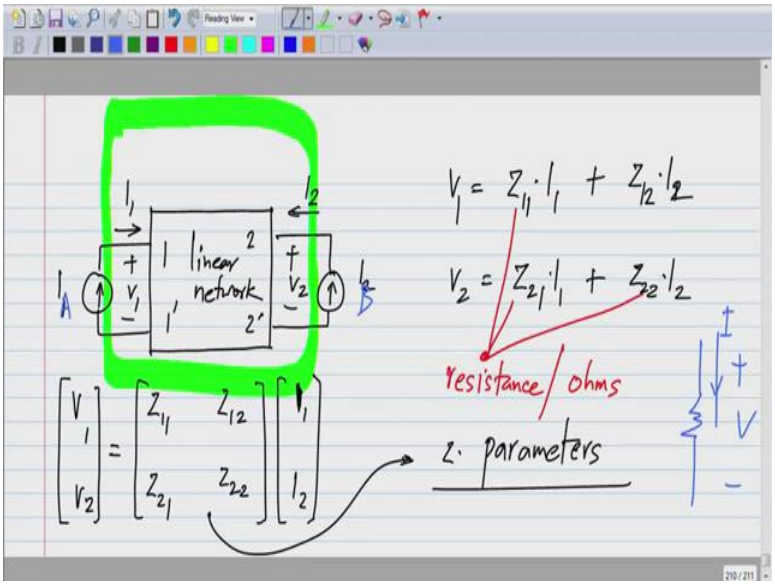

Now, there is a question I guess this refers to the previous one that I have I 1 upwards and I 2 downwards something the corresponding terms will be negative. So, this formulation is for the two port as V 1 and I 1 define this way for the two port, so if the external applied currents. So, let me change the notations so that it is not confusing I a and I b, so if you make I a downwards I will be minus I a. So, that is what will come here, but this definition is assuming the passive sign convention for the two port network with that this V 1 will be like this and I 1 will be flowing into the plus sign V 2 will be like that and I 2 will be flowing into the plus sign.

So, that is how the parameters are defined, this is similar to if you have this is similar to the convention for any component. If you have a resistor we apply V like this and current going into the positive terminal of this voltage and take the ratio V by I that is the resistance. So, we do not take I going that way similarly, this is by convention we use the passive sign convention for the two port network. So, if there are any questions I will answer them otherwise, well we will stop here and continue with other parameters in the next lecture.

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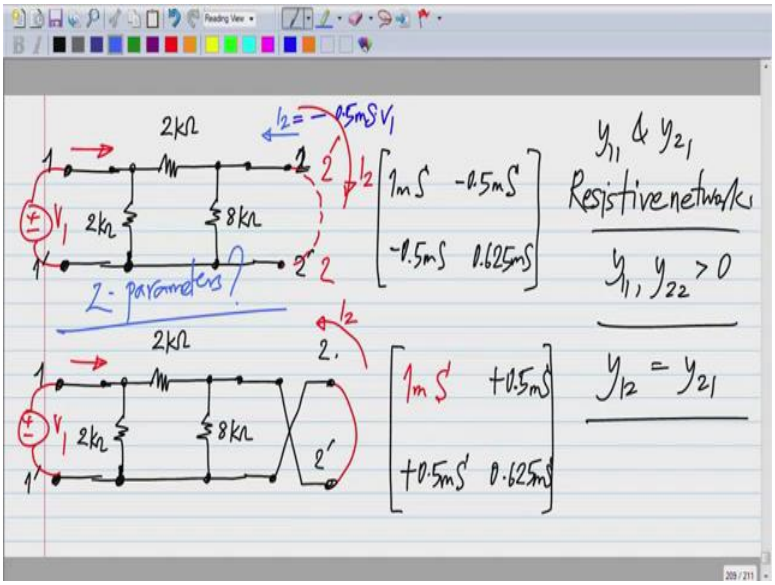

So, in the meanwhile I will encourage you to calculate the z parameters of this network, you calculate the z parameters of this and see how it is related to y parameters of the same network. So, it appears that there are no questions, I will see you next week, stopped.