Networks, Signals and Systems
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Lecture - 01
Module - 06
Introduction to Network Elements and Sources

Good morning friends, We will see series on networks signals and systems.

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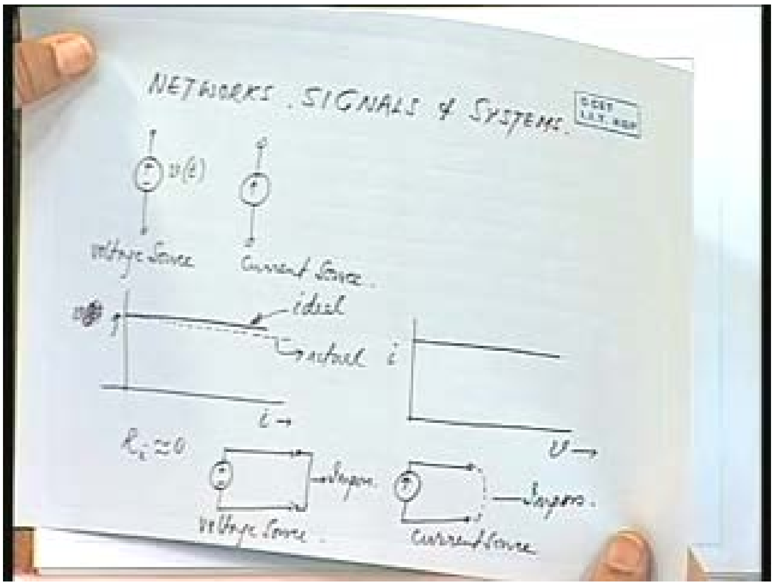

We expect all of you have already gone through the basic electrical engineering course where you have covered basic ohms law, cuts of current law, voltage law, network theorems and basics of single phase AC circuit, 3 phase circuits, impedances, complex impedances, phases etcetera. We also expect that we have been expose to basics of integral and differential calculus and linear differential equations.

We will study here in this subject the behavior of interconnected network elements primarily the passive elements like resistance inductance capacitance mutual inductance and so on and their behavior that is the variables, voltages, currents, charges etcetera in different branches of a network, how they behave with the a under the influence of different types of signals. So we shall be considering on the 1 hand network behavior as it is and different types of signals their influences of the network.

We will also at the later stage go to general systems general physical systems and try to find out how these equations the network equations are applicable to general physical systems as well. We will also go through the graph theory that is extensively used in networks some elementary concepts of graph theory will also be introduced in this particular course and after

2 or 3 lectures we will go through kind of a tutorial exercise. We will discuss some typical problems and we will work out in this class.

So let us start with a elementary concepts which you have probably gained in earlier classes this would be only to augment your earlier information is with certain information is, see there are 2 types of sources in the electrical engineering electrical energy 2 types of sources they can be a voltage source or a current source, again a voltage source can be an independent voltage source or a dependent voltage source. Similarly, a current source can be independent current source or a dependent current source a voltage source is normally shown like this, a symbol for a voltage source is like this, symbol for a current source is like this. So this is a voltage source, this is a current source.

Now in reality no source is ideal, an ideal voltage source, an ideal voltage source will have voltage current characteristics like this that is ideal 1 the voltage remains constant for all values of current as you keep on drawing more and more of current in reality there will be more and more of internal draw. So there is an internal resistance which we approximate to 0 provided this drop is very very negligible. So the actual slope the actual characteristics will be drooping, the voltage will be dropping with the with the current. So this is the actual characteristics.

Similarly, a current source will have a constant current, constant current and the voltage as well as the terminal will be varying so for the voltage source, for an ideal voltage source, for an ideal voltage source a short circuit is an impossible event. You cannot have a voltage source which can be ideally short it, if you have an ideal voltage source it can never be short it because if you short circuit this the terminal voltage become 0, a constant voltage source means terminal voltage should be constant. So this is an impossible event similarly, a current source an ideal current source which is supposed to supply a constant current cannot be open circuited because the current has to flow, it has to have a path.

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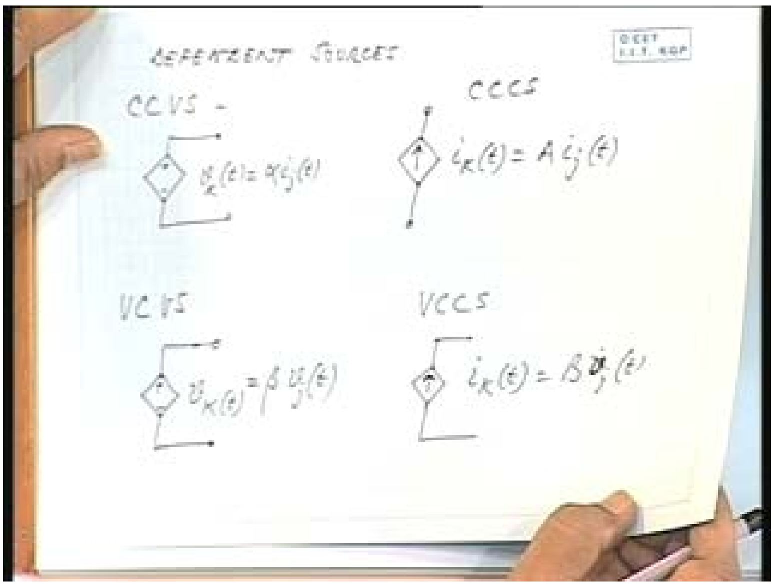

So an ideal current source cannot be open circuited, open circuit condition is an impossibility similarly, short circuit condition for an ideal voltage source is also an impossibility. So this is current source this is impossible, this is also impossible for an for a voltage source. Then we have dependent source dependent sources can be 4 types we can have current controlled voltage source, we call it CCVS, current controlled voltage source so we will have a symbol like this. This voltage for this kth source is proportional to some current through some other branch that is i_j is the current through some jth element in the network multiplied by some alpha. So this is the terminal voltage so this is CCVS. Similarly, you have CCCS current controlled current source shown like this and i_k (t) will be some A times i_j (t). So this is current controlled current source.

Similarly, you have voltage controlled voltage source which is v_k (t) equal to beta times v_j (t) and voltage controlled current source VCCS which will be shown like this i_k (t) equal to some B times v_j (t) which is v_j (t) okay. So these are the 4 different types of dependent sources, let us have a small numerical problem.

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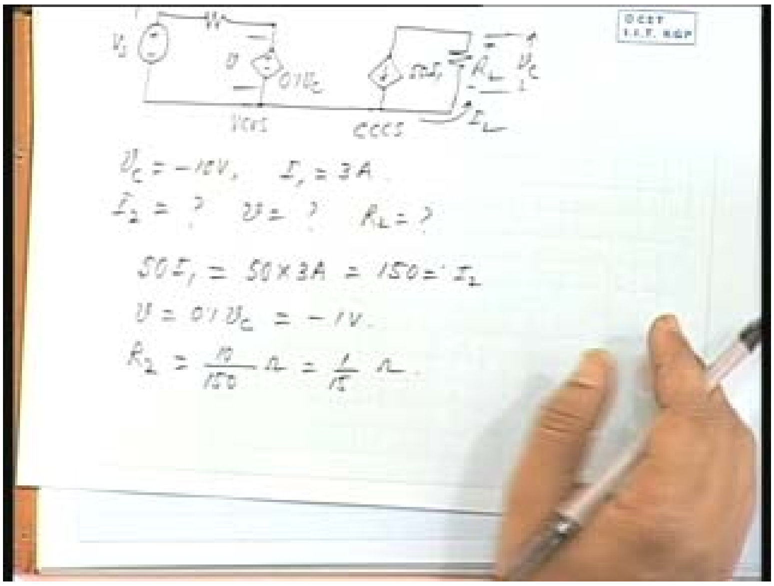

Suppose you have given voltage source V_s connected through a resistance R_1 and you are having a controlled source VCVS whose voltage is 0.1 times V_c and you are having another source a current source dependent current source CCCS sending a current through resistance R_2, the voltage across R_2 is V_c note the signs of the voltage is at the currents this is I_2, this is I_1.

Now you are asked if V_c is equal to minus 10 volts and I_1 is equal to 3 amperes what would be the values of I_2 that is flowing through R_2 and the voltage of the VCVS that is what is this voltage V. Now you can see this resistance value 50 times I_1, R_1 is given as well 50 times I_1 is equal to I_2, this is given as 50 I_1, so 50 times I_1 sorry 50 times I_1 is equal to 50 into 3 amperes that is 150 this will be equal to I_2 is it alright because these are current source that is sending a current through this and the current source is a it is a dependent current source 50 times I_1.

So whatever be that value of I_1, I_1 is given as 3 ampere, so that l multiplied by 50 is the current I_2 so that comes to 150 amperes okay. Therefore voltage v of this VCVS will be 0.1 into V_c that is minus 1 volt R_2 as given as see V_c is equal to minus 10 volts already given. So.1 times, .1Vc. So that gives you minus 1 volt okay. If you are also ask to calculate R_2 how much will be R_2? Now you know V_c that is given and you are given I_2, so you can calculate R_2 will be 10 volts divided by and 150 so many ohms that is 1 by 15 ohms. So you could be given any number of parameters to be determined and for a controlled source like this we can calculate like this.

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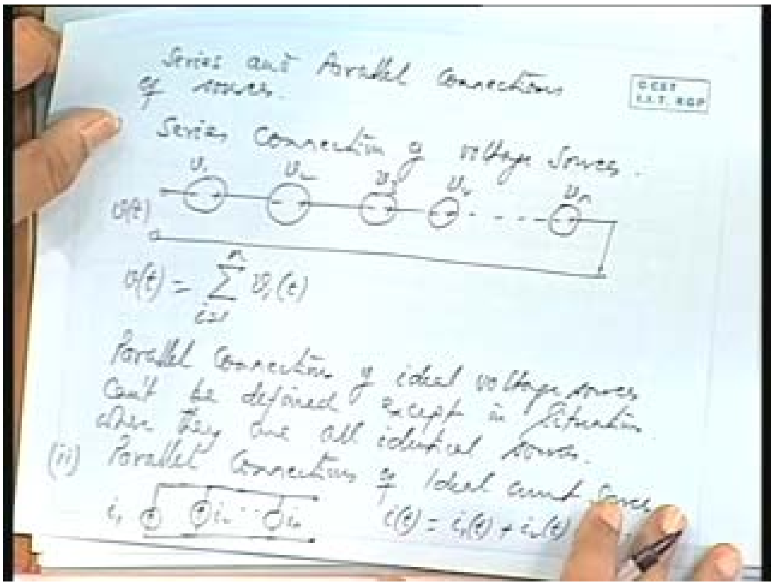

Now we come to series and parallel connections, series and parallel connections of sources series and parallel connections. Now let us see when can you have series connection of sources like this voltage sources you can put them in series, series connection of voltage sources what will you get? you can have v_1, v_2, v_3, v_4 up to v_n connected in the same sense. So this is v_t, therefore v_t will be summation of all these voltages v_i (t), i varying from 1 to n parallel connections of ideal voltage sources is not defined, parallel connections of ideal voltage sources it is does not possible, it is does not possible to have parallel connection of deal voltage sources. For example, if you have v_1 and v_{22} different voltage sources if you put them together what will be the terminal voltage it is undefined okay. You can connect ideal voltage sources in parallel only when they are having identical voltages all right.

So cannot be defined except in situations where they are all identical they are all identical. Similarly, parallel connections of current sources, parallel connections of ideal current sources. You can have i_1, i_2 and so on i_n, the net current i_t will be i_1 (t) plus i_2 (t) and so on. So current sources if they are put in parallel will give rise to an equivalent source which will be equal to i_1 plus i_2 plus i_3 and so on, like the voltage sources, the current sources cannot be put in series unless they are all identical that is current sources if you want to put them in series all of them must have the same current reading.

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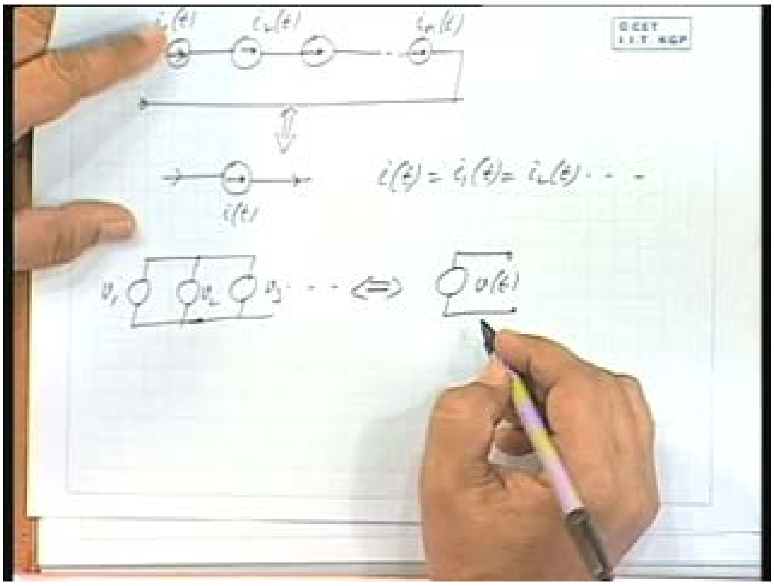

So i_1 (t) i_2 (t) and so on i_n (t) this is equivalent to let us put the symbols i_t where, i_t is equal to i_1 t equal to i_2 (t) and so on. So in the previous case also for voltage sources parallel connections if you put all of them will be on the same voltage level. So if v_1, v_2, v_3 and so on have to be put in parallel then v_t equal to v_1 (t) equal to v_2 (t) and so on and you, I am not always writing v_1 (t), v_2 (t) the augment is dropped it is understood this is means v_1 (t), v_2 (t) v_3 (t) and so on it may be constant it may be vary with time but they must be identical. So this is all about series and parallel connections of current sources and voltage sources there is another situation when suppose you are having a voltage source in parallel we have current source what will be the equivalent yes, I am expecting question.

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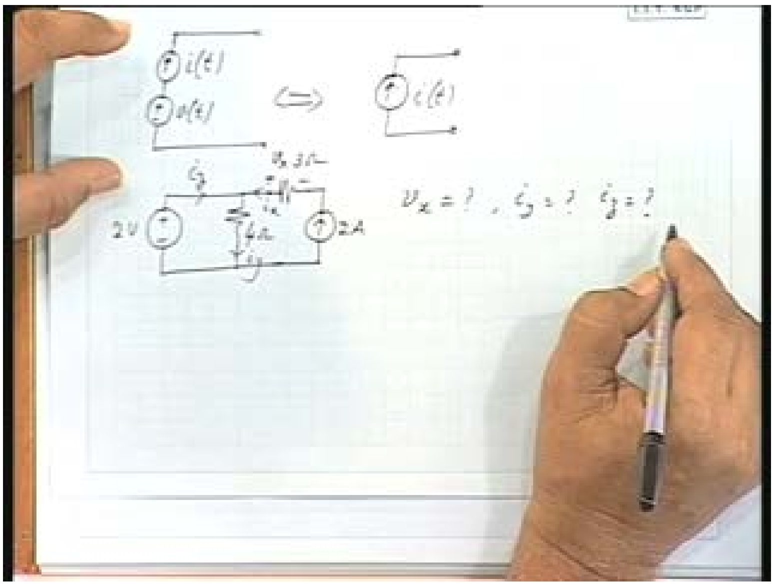

Can you tell me what could be the equivalent of this, this is v_t this is it both are ideal sources. Now the terminal voltage must be constant so this is equivalent to just the voltage source v_t so current source is redundant here current source does not have any rule to play it does not give any additional voltage alright because the terminal voltage must be same okay. So for a parallel connection of voltage source and current source we can replace this by an equivalent single voltage sources of the same magnitude v_t.

Similarly, if you are having a current source in series with a voltage source, voltage source and current source in series what be the equivalent, it will be a current source because the same current has to flow through this so voltage source becomes redundant alright there is no influence of the voltage source here as such. Let us work out simple example of a network connection with the sources as indicated here suppose you have a_2 ampere current source and 2 volts voltage source connected in this fashion this is given as 4 ohms, this is 3 ohms and the polarity is shown with this what will be this current i_y, i_z and if I denote this as i_x, i_x is 2 ampere given and v_x as the voltage across this if I denote v_x as the voltage across this. So question asked is how much will be v_x i_y and i_z also what will be the power supplied by the 2 sources.

Now you can see 2 ampere current is flowing from this side this side, so this is at a higher potential this at a lower potential current is going like this so 3 ohms into 2 amperes 6 volts will be the drop across this from this side to this side. So the polarity shown here if that represents v_x, so v_x will be minus 6 volts is it alright minus 6 volts. Now how much will be i_y could you please tell me what will be i_y i_y you can see 2 volts will be appearing across this. So it will be 2 volts divided by resistances 4 ohms alright I will not put volts and ohms we can straight away write 2 by 4 ampere that is 0.5 ampere is it alright.

Now what will be i_z what will be this current this is 2 ampere this is .5 ampere, so 1.5 ampere current will be flowing through this in this direction size it will be minus 1.5 ampere, is it alright? How much is the power supplied by the current source? How much is the power supplied by the current source? Now you have seen that this is getting charged this voltage source is not supplying power it is receiving power because the current is flowing in this direction. So voltage source is receiving current of minus 1.5 ampere that is 1.5 ampere in this direction against a voltage of 2 volts. So voltage multiplied by current 2 in to 1.53 watts of power will be received by the voltage source so power received by the voltage source alright received is 2 in to 1.5 watts that is equal to 3 watts okay.

How much is the power consumed by this, how much is the current i_y .5 so .54 into .5 square is the power consumed here then 2 amperes into 2 squared into 3 that much power 3 into 2 square that much power is consume by this and the power received by the voltage source is 3 watts so the total power will be supplied by the current source so that watts out to be this is half square 1 watt this is 4 into 3 is it not 12 plus 3 plus 1. So that gives me 16 watts, so 16 watts of power will be supplied by the current source okay. Let us now consider a simple network where we can make use this principle of parallel connections of voltage sources and current sources alright.

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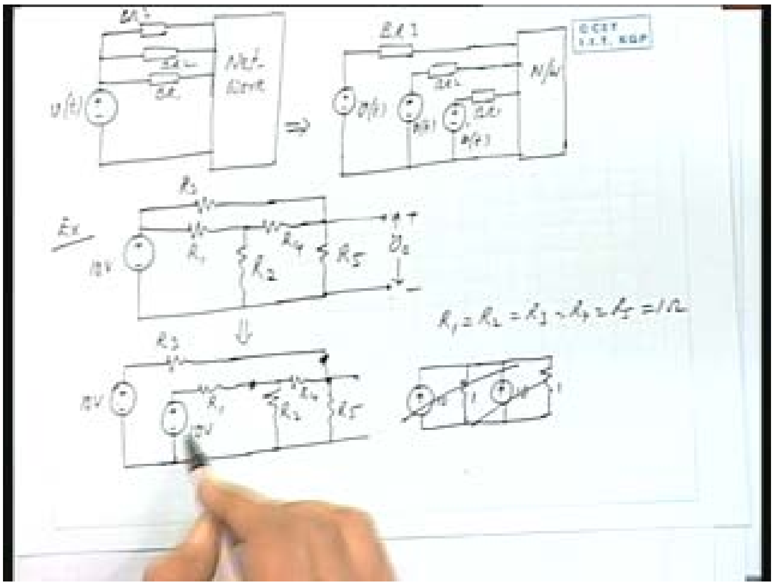

So we have a network, I will just draw this this is branch 1, this is branch 2, this is branch 3 and so on okay. They are all connected to a network like this I am showing only the part of the network that is of relevance at this moment from this side rest of the network is shown like this part. Now this can be equivalently represented as as if I am connecting all these branches separately by different voltage sources of the same magnitude it is possible this is branch 3, this is branch 2, this is branch 1. All these are connected to the same network segment. So what we have done is replacing a single voltage source we have replaced the single voltage source by multiple sources of the same magnitude v_t, this is also v_t this is also v_t at times it simplifies our competition let us see 1 simple example mind you it is not necessary that all this network problems can we solve by a unique method.

You can always adapt any method for solutions but at times certain methods will be having more advantages over other methods and for that we have to reduce the network conveniently at different times using these principles. So let us have network like this, we are required to calculate the output voltage v_0 for this network. This is a 10 volt source and we have got all these values okay will be giving the value soon this can be reduced first of all let me draw this R_1, R_2, R_4, R_5 okay. Suppose we were given all these resistance value as 1 R, R_1 equal to R_2 equal to R_3 equal to R_4 equal to R_5 equal to 1 it is only a simple example that we have to show you, you can have any values the reduction is very clear. Now this is a 10 volt source, this is a 10 volt source.

Now a voltage source with a series resistance as you know can be replaced by a current source with a parallel resistance this is what you have done in Theremins equivalent conversion from thermin 2 not an equivalent so 10 volts by 1 ohm that gives me 10 ampere current source in parallel with 1 ohm resistance. Again 10 volts by 1 ohm this source will also be ten ampere with 1 ohm okay and then you are having well let me redraw it. Let me redraw this because here there is a connecting resistance in between so this terminal and this terminal cannot be directly connected. So let me draw the equivalent from here 10 ampere 1 ohm, you can put it this way then 1 ohm 1 ohm this is R_5, this is R_2, R_4, R_5 and you are having another source 10 ampere with 1 ohm and this is, see this is connected at the output terminal with R_5 so this is connected here okay. This is the voltage that you are interest in okay v_0 (t) okay.

So 1 ohm and 1 ohm in parallel can be replaced by this is 10, this is 1 and 1 in parallel will be .5 that is good, 0.5 ohm then you have 1 ohm then this and this you can see okay. If we you can you put them together should we put them together okay, we will retain it as it is because this output terminal we are interested in so we will keep this as it is. Let us reduce this network so 1 and 1 has been reduced to .5, 1 ohm then 1 ohm and this side is retained as it is. Now 10 and .5, 10 ampere and .5 can again replaced by an equivalent voltage source of 5 volts in series with .5 ohm .5 ohm and then you have 1 ohm and then this side you have 1 and 10 ampere.

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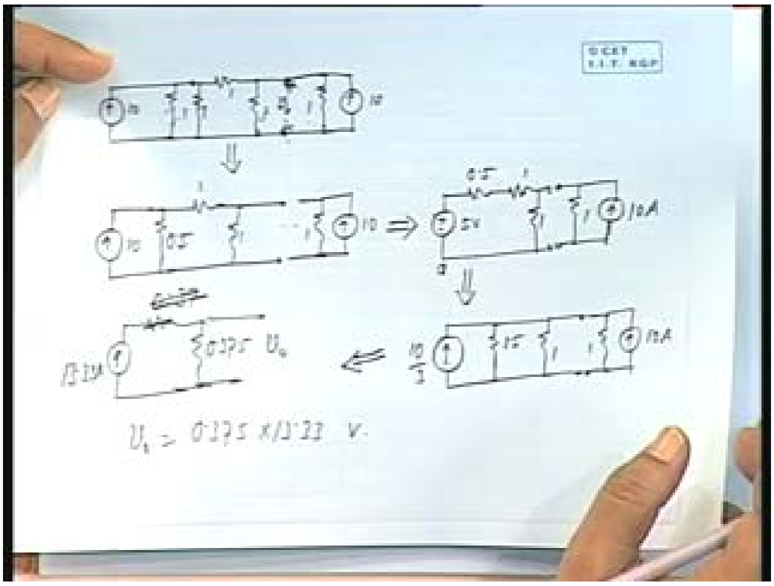

Okay so we have used the principle of separating the voltage source into 2 equivalent voltage sources then voltage source is replaced by an equivalent current source and then we are making reductions in the network elements, parallel elements replaced by a single 1 then again from current source switching back to voltage source then you are having 2 series resistances put them together 1.5. So I can put this as a single current source, what will be the value?

So from here okay I will draw in this side from 5 volts and 1.5 ohm I can draw a resistance of 1.55 by 1.5 yes, 1 ohm resistance in the parallel branch there is a 1 ohm resistance I forget to show that. So 1 and 1.5, 1 and .5 that makes it 1.5 and this current source will be 5 by 1.5, so 10 by 3 amperes and then there is a parallel resistance of 1 ohm and then you have 1 ohm 10 ampere okay.

So from here you can see 1.51 ohm and again 1 ohm, so what will be the net value 1 ohm 1 ohm is .5 with that to 1.5 in parallel, so that gives me .375. Now you see I have put all of them together so this node so far I did not disturb this node which was representative of that earlier node here that is this represents the voltage v_0 okay those so that has not been disturbed that has not been disturbed here okay I have just replaced this voltage source but I have not replaced R_5 so far. So the voltage across R_5 this is same as the voltage in the entire combination now so how much is this so ten by 3 and 10, 2 sources together will be 13.33 this is 3.33 plus 10 so 13.33 amperes in series with 11 and 1.5. So that gives me 0.375 sorry, this will be parallel 0.375 and what is this voltage, voltage across this. So it is the current multiplied by this resistance so the voltage v not will be 0.375 into 13.33 volts is it alright. We could have solved it by any other method Nodal analysis and many other methods. This is only to demonstrate the use of the principle of dividing the voltage source in to 2 equivalent identical voltage sources and then addition of current sources and so on.

We will take up some problems using this principle to determine the voltages in the under different situations when R_1, R_2, R_3, R_4, R_5 having different values. So I will take that of in a tutorial class later on. Yes, please please, sir you can solve this by any other network analysis techniques, we do not demonstrate at this moment specific advantage advantages will be clear see no particular problem is having a unique solution as such but there are certain short cuts which we will find in course of time when you at a particular typical network problem okay. So you should be always conversion with the conversion of 1 type of source to another type source or dividing the voltage source sometimes current sources if there is a single current source I can always break up in to many current sources in series identical current sources in series similarly, for voltage sources 1 single voltage source I can always fill it up into equivalent identical voltage sources as we have demonstrated here so I will just mention the principle for a current source.

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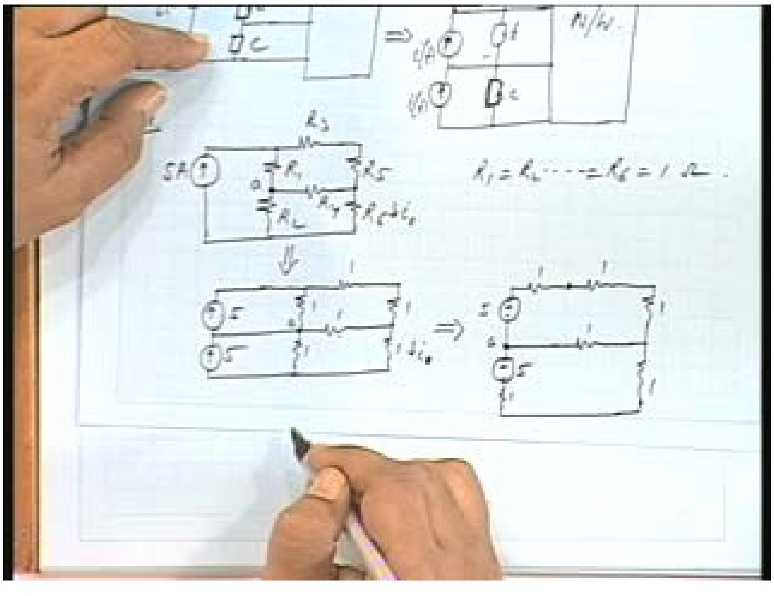

Similarly, if you are having a single current source feeding a network like this and there are elements like this see this is the rest of the network this can be equivalently shown like a current source here. A current source here that is I am having multiple current sources this is element a, b, c it can be a general impedance. So a, b, c and this is the rest of the network I can show it like this you can see this same i_t, i_t, i_t, i_t and so on the same current source has been split up in to 3 identical current sources in series it is possible alright. This is an interconnection that have put it was not there earlier how much is a current through this I can assume a current i_t coming like this and another current i_t going like this so i_t this way an i_t this that will be cancelling. So there is no current so it is a virtual connection it is a virtual connection that I can make with 3 current sources okay.

So we can demonstrate this principle of splitting up a single current source into a number of series current sources through a simple example. Let us have a current source once again I will take a very simple network with simple values only to demonstrate the principle R_1, R_2, R_4, R_3, R_5 and R_6, you are required to calculate the current i_0 through R_6 okay. Let us mark these point this particular point as a okay this is a_5 ampere current source alright 5 ampere current source. We are having all the register values as unity 1 ohm, so this source you are asked to calculate i_0 this source can be replaced by 2 equivalent current sources as in this diagram, this is 5 ampere again this is 5 ampere okay.

Now I am putting 1 ohm, 1 ohm, 1 ohm, 1 ohm, 1, 1 okay and you are asked to calculate the current through this. So this can be again see this particular network this particular network now I am going to this is .8 mind it I am going to replace by a voltage source this element 5 ampere with 1 ohm will be 5 volts with 1 ohm in series, very good and then you are having 1 ohm this and this I will show them separately okay and then this 1 ohm. Similarly, this side you have 5 volts in series with 1 ohm okay 1 ohm alright this is the polarity. So let us further reduce this this point a comes here alright this is the point a because this is replaced by this okay. So this is the point a similarly, this is replaced by this so this is a junction okay.

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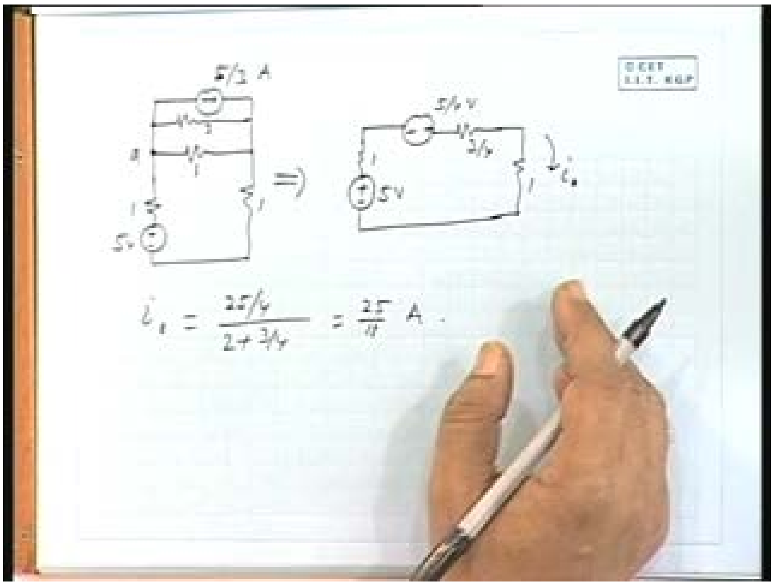

Now this point a this is 1 ohm from this point this is 1 ohm, this is 5 volts with 3 ohms resistances. So I can replace it again by a current source, so I replace it by a current source and a resistance how much is that resistance this is 5 by 3 ampere and 3 ohms okay and then this is the point a we are having 1 ohm, 5 volts and then 1 ohm. So 3 and 1 ohm in parallel with 3 by 4 ohms multiplied by 5 by 3. So this combination I can replace by now you see I am replacing once again the current source by voltage source. So it will be of a voltage source polarity will be because the current is going like this. So this is at a higher potential, so it will be like this. So 5 by 3 is a current source value multiplied by the equivalent resistance 3 by 4, so it will be 5 by 4 volts in series with 3 by 4 ohms okay and then you are having 1 ohm. So how much is the current now i_0.

So i_0 will be 5 volts plus 5 by 4, 25 by 4 correct 5 volts plus 5 by 4 divided by the total resistance 112 plus 3 by 4. So 25 by 11 ampere is that alright you could have obtain by any other method. We will take up similar problems in the tutorial class with different values of R_1, R_2, R_3 for this problem also.

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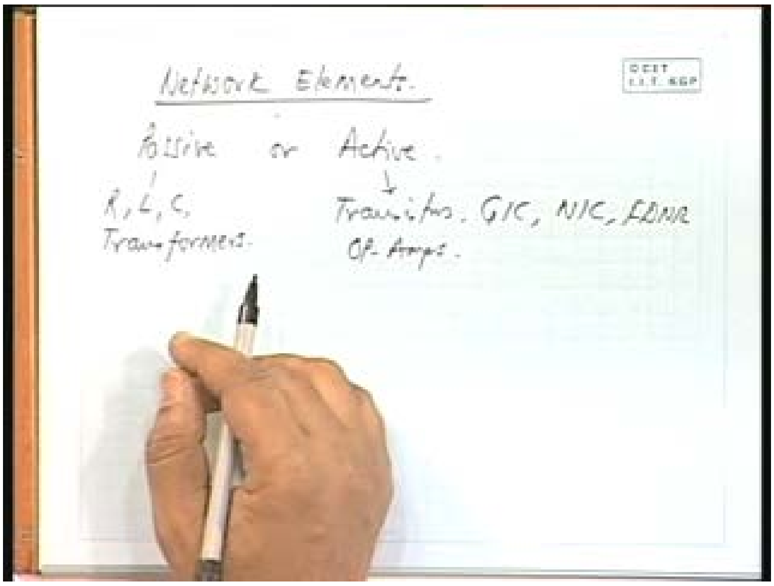

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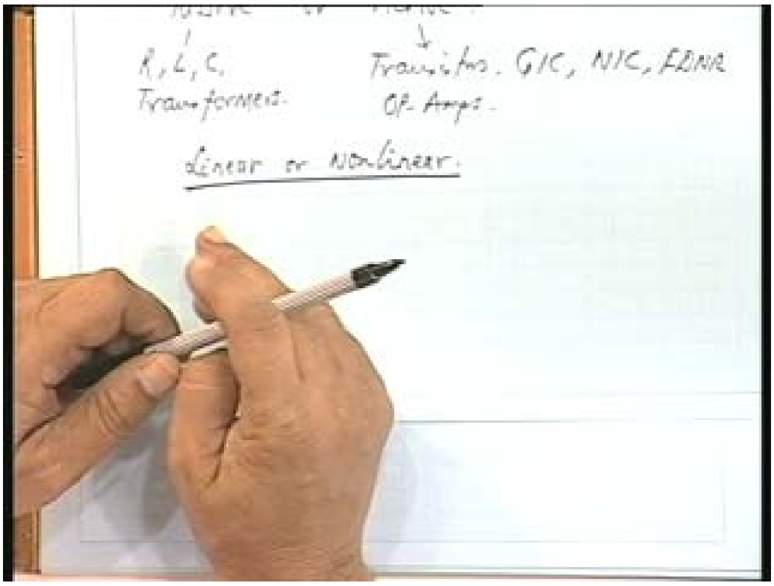

Now, we shall be discussing something about we shall be discussing something about network elements. The network elements are either passive or active what are passive element what you mean by passive elements elements which are not dependent on any energy source like your resistance capacitance inductance or transformers. These are passive elements okay and active elements are dependent on some other energy sources okay like transistors you require a DC supply transistors GIC's general impedance converter negative impedance converter FDNR, frequency dependent negative resistance.

So these are the examples of active elements transistors GIC negative impedance converter FDNR, frequency dependent negative resistance and so on, Op-amps and passive elements are simple resistance, inductance, capacitance and transformers were mutual coupling is also involved. So these are the different network elements we shall be concentrating mostly on networks consisting of passive elements and very occasionally we will be mentioning about active elements. Then network elements can be linear or non-linear, linear or non-linear, what you mean by linear elements? what you by linear elements? Linear elements obey the principle of super position that is good. So we will be in the next class we will be discussing in details about the linearity and non-linearity that exist in common items like R L C and so on and what are the different types of non linearities that you come across in systems. Thank you very much.

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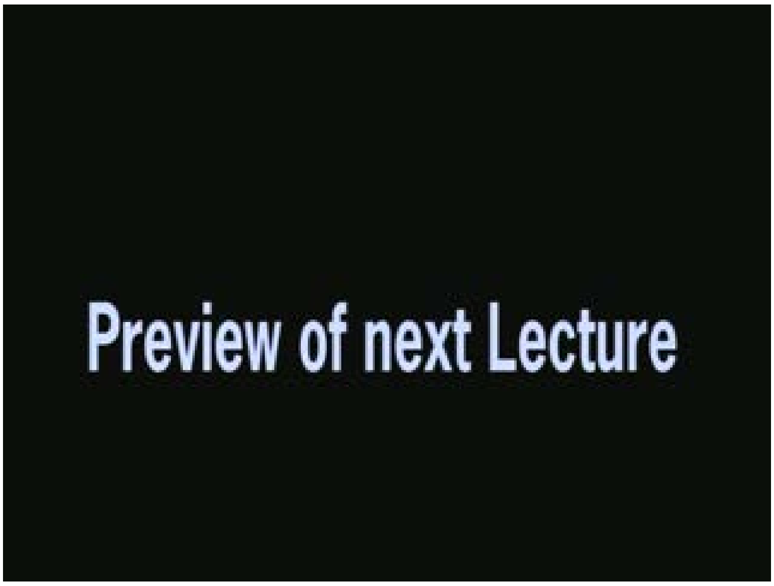

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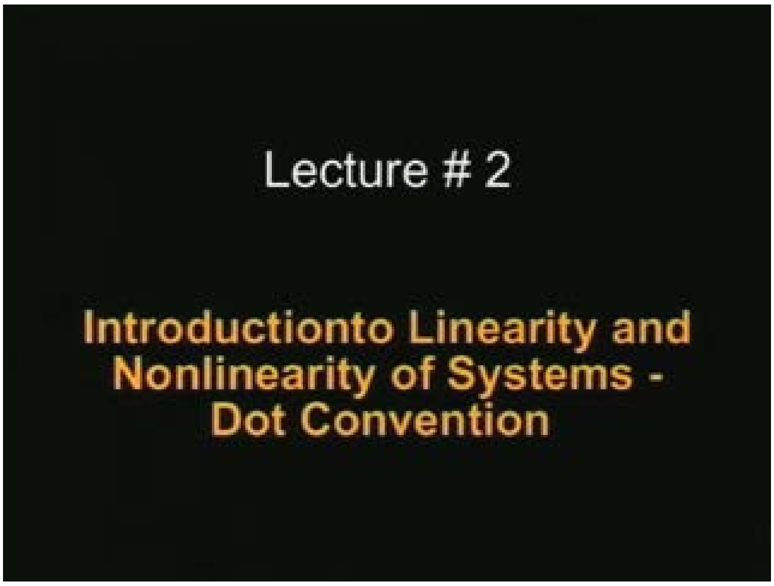

Okay, Good morning friends, we will continue with our earlier discussions on linearity of systems as we had mentioned, a linear system will have the property like this mathematically we can write the property like this if we excite a system by an input x_1 (t) it can be either a voltage or a current and the corresponding output is y_1 (t).

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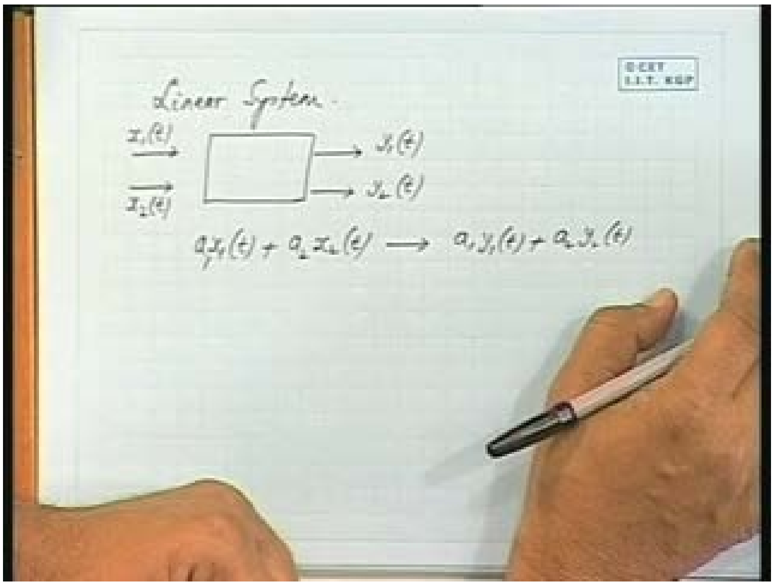

Similarly, if we excite it by an input x_2 (t) and the corresponding output is y_2 (t) then any combination of x_1 and x_2. So a_1 x_1 plus a_2 x_2 (t) will result into a_1 y_1 t plus a_2 y_2 (t) if the system is linear, this is the principle of, now sometimes you are given the system equation in the form of differential equations or do you determine whether a differential equation is a linear differential equation or not. Suppose you are given and I will give you a simple example here d square x by dt square plus 2 into dx by dt minus 3 into x is equal to some force in function f_1 (t) may be sin t, sin 4t, another equation d square x by dt square, whole square plus 2 in to dx by dt minus 3 x is equal to sin 4 t. The third equation is dx by dt sorry, d square x by dt into t plus 2 into dx by dt minus 3 x is equal to sin 4t, d square x by dt square plus 2 into x into dx by dt minus 3 x is equal to 4 t.

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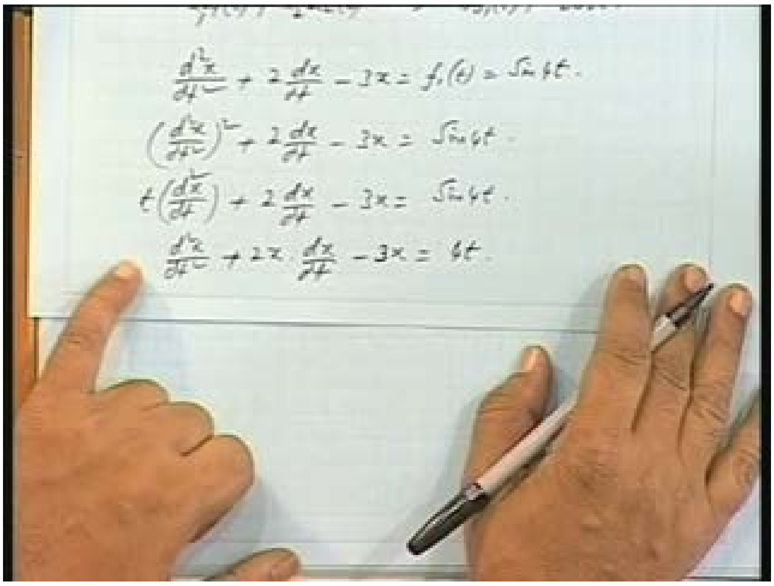

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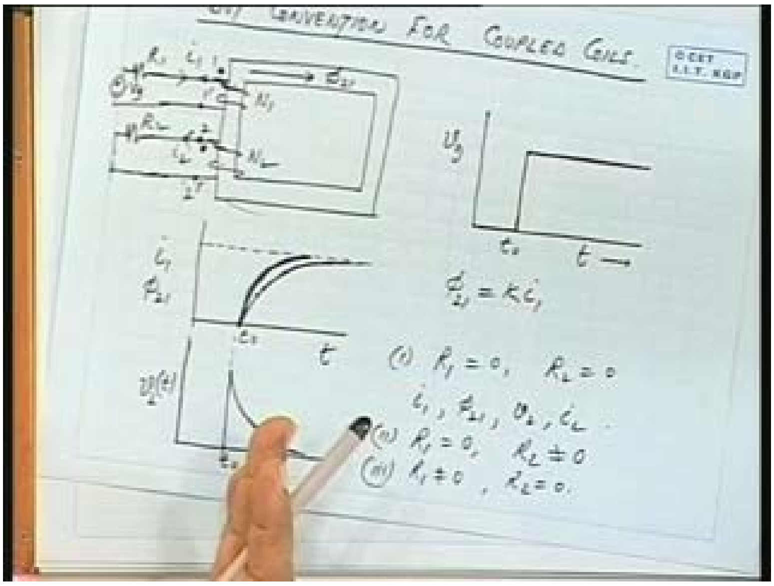

Now out of these which 1 will be linear which one will be non-linear which one will be representing a non-linear system yes, well of considerable value so so it will be somewhere in between if R_1 is 0 and R_2 is 0, if R_1 is 0 and R_2 is 0 what happens that is across an inductance, across an inductance if I switch on a supply as a DC voltage if I apply across an inductance pure inductance there is no resistance what happens to the current. It is L di by dt which is constant v, so if it is L di by dt L di by dt which is constant that means I will be constantly increasing it is a integral v dt okay it is proportional to integral v dt. So I will be constantly increasing that means we will get a current that will be continuously increasing and that will cause a secondary current also in the reverse direction that will also be constantly increasing. So both primary and secondary currents will be increasing continuously okay.

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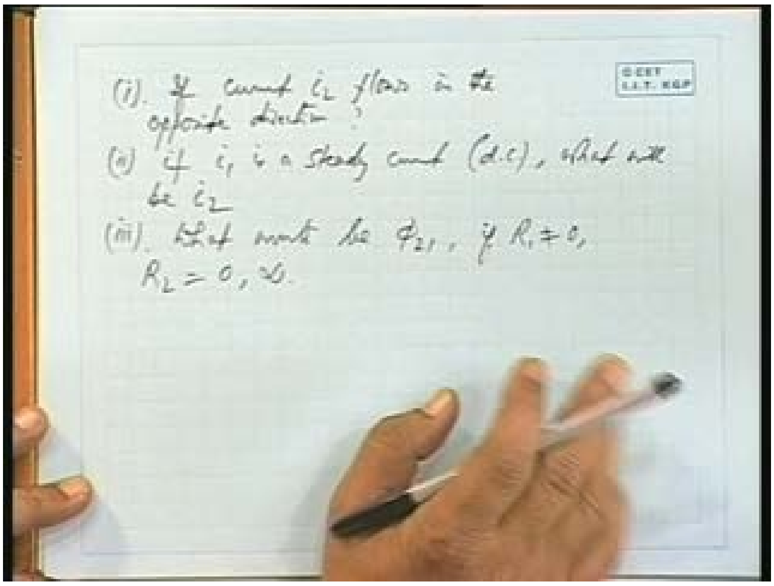

So this is a a this a very interesting situation for example sometimes when you apply a sudden change in the voltages just say in pulse a pulse voltage, in a pulse transformer you get sudden changes and then though the voltage is there, there is no change alright there is no change. So on the secondary side there is no output whenever there is a change there is an output of the secondary side. So this principle is used in a pulse transformer, okay thank you very much. We will continue with this in the next class.