Network Analysis
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Lecture – 82
General Impedance Transfer Circuit and Concluding Remarks

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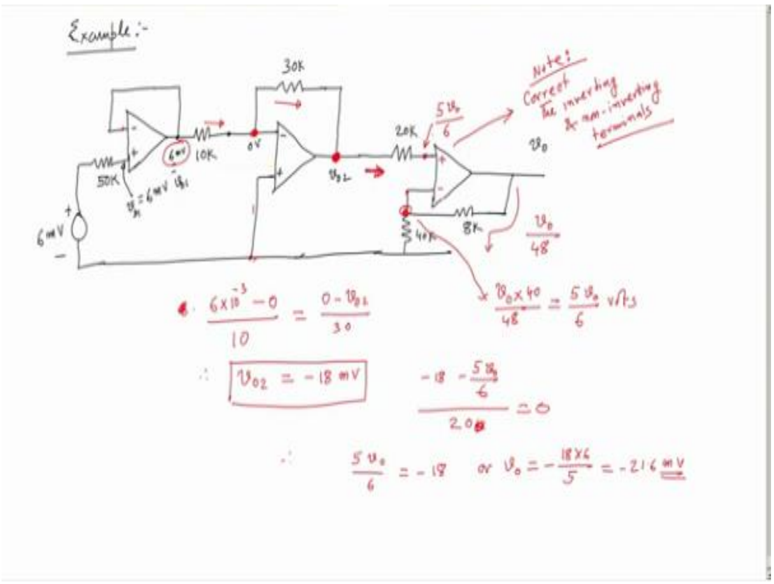

Welcome to the so called last lecture or concluding lectures of this course network analysis, lecture number 82nd and last time what we were doing; we were telling you about several problems where Op Amps are used as inverter; inverting amplifier and inverting amplifier means there must be a negative feedback, while writing down the problems perhaps in the first place I wrote it opposite.

There must be a negative feedback, so this sign corrections please note that, calculation part remains same okay, so this rules that is the voltage of this point and this point are same is true, if there is a negative feedback with a passive element like some resistors, inductors, capacitors whatever it is and there must be negative feedback and today I will first tell you about one interesting circuits based on Op Amp which will transform some general impedance transformation it will be able to do.

For example, in a transformer we have seen, if you connect an impedance z2, it will in the; from the input side, it will appear to be a square into z2, where is the number of turns. Similarly, we have seen if in a 2 port network when it was a gyrator, the input impedance is proportional to 1 over z2 okay. Now, here is a circuit which with which you will be, a general impedance transfer circuits.

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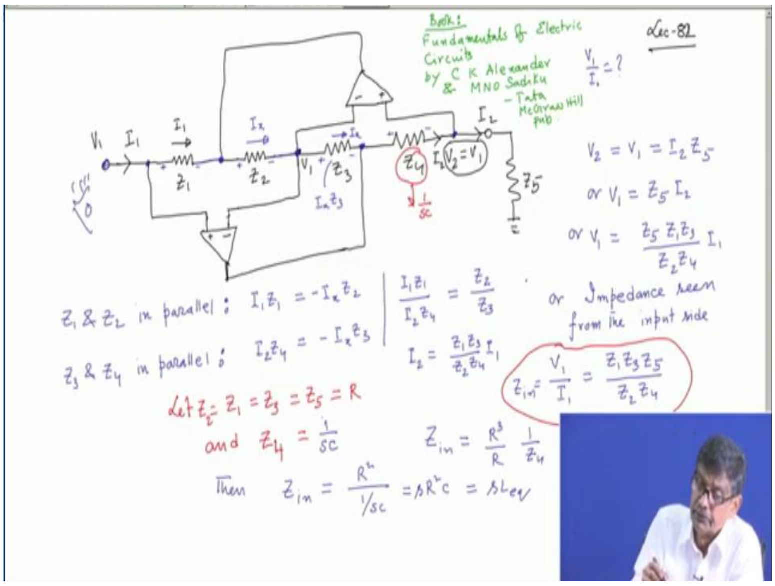

Let us first draw the circuit without much words, so that you will be able to understand what I am doing. For example you take 4 impedances, although I am drawing resistances it is true for any impedance say, z1 here, this is another impedance I could also draw a box but anyway, z2. Suppose, there are 4 impedances you connect, z3 and you have z4, very interesting circuit z4.

And this I will use as my input over here, this is my output now, what we do is that we take we require 2 Op Amps and these Op Amps are connected in this way, 3 terminals input, output and this one, this is plus, this is minus and these 2 points are connected here, this I will connect little later identically, you have another Op Amp which is connected here like this and whose input signals are connected here and the other one is here, this is how it is connected.

Now, what is done this third terminal that is the output terminal, it is connected there and this one is connected here that is all and of course, I must mention the polarity of this one. See, look at this Op Amp, here is some output voltage of the Op Amp with some negative feedback ultimately attached to it similarly, for this. Now, this is the thing okay, suppose this voltage is V1, first thing is; is this connection is complete yeah, so this is the V1.

See, looking at the networks we know these Op Amp you treat them to be ideal, therefore there cannot be any current here in the input side of the Op Amp, so what will be the voltage difference between these 2 potentials must be same, therefore it is V1, therefore the other one has to be V1, so that the voltage difference between them is 0, got the point, so the voltage; so if it is V1, I can immediately say this point cannot but be V1 that is all.

Similarly, if it is V1 voltage difference between them is 0, applying KVL simply, this potential I know with respect to common ground potential all the potential, these potential I know therefore, they add the potential difference is 0, so there it will be V2 which is equal to also V1 has to be, so this is the first thing just looking at the circuit I find this has to be true. Now, what we would like to do is this; we would like to find out the impedance seen by this circuit.

And what we will be doing here is that we will connect another impedance here say, z5 which is grounded okay, so all the potentials are with respect to this as V1 I1. Now, let us see the currents, this is current I1, this ideal Op Amp it will not draw any current, therefore this I1 has to flow through this z1 as well, it has to, this I1 comes over here but this current I cannot comment, it will not be same as I1 here that will be different.

Suppose, I say that this current is I2, then there is no current in this branch, therefore applying KCL here, it will also give me this current to be I2, it has to be ideal Op Amp, therefore this is I2, this is I2, this is I1, this is I1 that is good. Now, we would like to find out this voltage, mind you this V2 is equal to V1, I concluded and also this point potential is V1 that is what I concluded.

Now, what I will assume is this; this current let us say this current is Ix, if this is Ix, this Ix comes at this point but this Op Amp does not take any current similarly, this Op Amp, therefore same Ix will flow here as well, is it not, I mean 4 lines derivations simply, so given this network using 2 Op Amp, we come to this conclusions and we would like to find out what is V1 by I1 is how much that is impedance seen from the input side is voltage applied divided by the current.

Accha, now look at z1 and z2; z1 and z2 if you look carefully they are in parallel, why; because there is a common point this end, this end are connected here, what about the other ends of z2, their there is no voltage difference, so the potential of this point is same as this point therefore, z1, z2 are in parallel, it has to be. If that be the case, then I1 into z1 voltage drop across z1 with this is plus, this is minus is I1x.

And about this one what is the; this voltage must be equal to Ix into z2 but you see, if you write like this, this is plus, this is minus, this voltage is Ix into z2 but potential of this point I have to find out, potential of this point with respect to this, this is equal to - x into z2, so this is one equation or alternatively you can say this is minus Ix is flowing, so this is plus; plus, plus are joined.

So, in any case I1, z1 equal to Ix into z2, this is one equation similarly, we conclude that z3 and z4 also in parallel, why they are parallel; because this is the common point of z3 and z4, this is the common point, one point and the other point of z3 and this point of z4, voltage difference between them is 0 because no voltage between these 2, therefore they may be considered to be in parallel.

And we will then have potential difference between these 2 points is I2 into z4, I told you that is this side plus, this side minus will be this one and potential difference between these 2, if this is plus, this is minus Ix into z3 voltage difference, is it not that so, therefore this I2 into z4, this voltage plus and here it is minus, so it will be once again that negative minus Ix into z3, this will be the thing, accha.

If this is the case, then I can divide these 2 equations and get this relationship; I1 z1 divided by I2 into z4, Ix goes away and you are left with z2 by z3 like this, therefore this is the thing, so this is one equation. Now, you see look at this loop; V2 which happens to be equal to V1 will be equal to I2 into z5 or V1 is equal to z5 into I2 and this I2 I will express in terms of I1 which will be z1, z3 divided by z2 z4 into I1.

Therefore, I can write that V1 is equal to z5 into I2 was there and for I2 I substitute this thing that is z1, z3 divided by z2, z4 into I1 or impedance seen from the input side is V1 by I1 z in let me call it and that value is equal to z1, z3, z5 divided by z2 into z4 into that is all, this is the thing. Now, what you do is this that you suppose, we say that let z1 equal to z3 you said these values; z1, z3 is equal to z5.

Suppose, some R, some resistance I will connect and also equal to z2, suppose all are met resistance, they may be different values also but resistance I make and then and suppose, z4 is this one although, resistance symbol I have drawn; it can be drawn by a box but it could be any impedance z4, so z4 what I do, I make it capacitive that is 1 by SC.

Or before that let me see therefore, we say z in is equal to under this condition, it will be R cube, z1, z3, z5 divided by R and 1 over z4 and I can say that this is R square by z4, therefore the input impedance seen is the reciprocal of z4, now if z4 is capacitive suppose, 1 by SC or say inductive or say capacitive, z4 equal to 1 by SC, then I will say z in equal to R square by z4 which will be equal to R square C into S.

Now, so the impedance seen from the supply is S into something, is not it is equal to some S into L equivalent because for inductance only, the impedance seen is SL, for capacitance 1 over omega C, similarly if you think z4 is an inductor, so the this reciprocal business will make it either if it is inductor, it will be capacitance and so on. In general, if z4 is any form, say z4 is equal to R bar + jx bar, then 1 over z4 will be ultimately some R equivalent minus jx equivalent.

Therefore, this sort of circuit can be used, what happens is this in very large scale integrating circuit if you want to simulate an inductor between these 2 terminals, you would like to connect an inductor, inductor you know requires a magnetic circuit with lot of turns, size becomes more bulky, therefore instead of that you can connect; if you connect an inductor here, it will appear to be a capacitance between these 2 points.

Therefore, you can replace this inductor by a capacitor, is it not or if you connect a capacitor instead of inductors at z4 connect a capacitance, then this points, input points V1 I1 it will treat this to be an inductor, nothing is better than that that is you are using a capacitor can be made tiny compared to an inductor and it can be accommodated in your circuits.

Mind you these are not power circuit, 220 volts circuit, 230 volt circuit not like that, control level voltage circuit, where if you want to have different impedance seen by this side, you can make it. There are various versions of this, it may be floating inductor this, that I will not go into those things but only as an application of an ideal Op Amp circuit, I think it is very interesting and initial circuit is proposed by some name by somebody whose name I have forgotten, you go through the textbooks you will find that.

There was a paper on that therefore, this circuit therefore can be treated, where z4 is the thing, here I will connect the things and this impedance will appear different looking from the same. Anyway, this you do and not but the least last time I told you I will tell the name of the books from which I solve this problem, please see for problem solving this book, there are many in general for all circuit topics that I have covered.

There are many worked out examples, also examples to be done by the students are given in this book whose name is this book is; you go through the worked out example as well as your own examples including the Op Amp circuits here, it is like fundamentals of electric circuits by CK Alexander and MNO Sadiku, very good book a Sadiku, for problem solving and this one also ideas you can get newer ideas, it is by Tata Mcgraw Hill publications, you can refer to this book, accha.

Now, today what I will be doing this being the last lecture I will try to summarize the whole course, okay.

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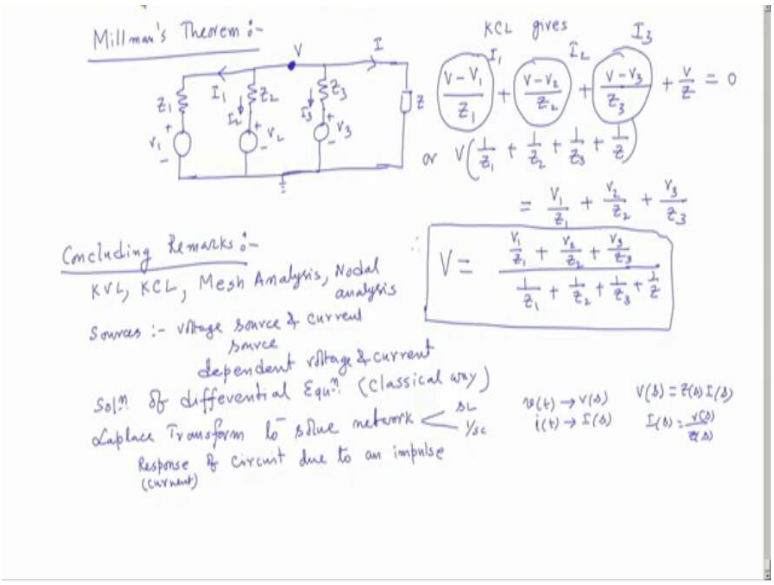

And before that while going through going back myself, I found only one theory I forgot to mention that briefly I will tell, very simple theory and that is called Millman's theorem, very simple theorem but useful. what it states that suppose, if you have a network having z1, there is some voltage source v1, there may be phasors, impedances, DC, AC whatever it is, there are other source z2 and here is v2, there are several sources like this z3 v3 like this, there are several voltage sources with impedances.

And here maybe you have connected a load impedance z, then how to find out the currents flowing through all the branches as well as this impedance in the output circuit, so this current may be I1, so you see this is the current I, now what I will do is this, what is the best method of solving this? There are only 2 nodes okay, so consider this to be a reference node and consider this potential is V. If you know this potential V, then you can find out any branch currents you like that is the idea.

So, write KCL at this point, KCL gives what; the current in this branch I1 will be V1; V - V1 this way I have directed, so V - V1 by z1 + V - V2 by z2 + V – V2 by z3, all current going out this current I2, is this one this is I3 and this is plus I which is equal to + V by z and that must be equal to 0, therefore you can see that V; V is the unknown 1 over z1 + 1 over z2 + 1 over z3, I could write it in one stroke also.

We know the rules, all impedances connected some of the reciprocal of the impedances of this node only, this node voltage is necessary and so this is the thing and this will be equal to V1 by z1, take these terms on the right hand side and V2 by z2 + V3 by z3, therefore this voltage V is equal to V1 by z1 + V2 by z2 + V3 by z3 divided by sum of all the impedances reciprocal.

So, in Millman's theory theorem, it says that if this kind of circuits are there, several voltage sources along with their internal impedances connected in parallel and it is supplying a load, then this voltage can be easily found out, so what it will be; V1 by z1 + V2 by z2 + V3 by z3 will be this and this will be equal to 1 by z1 + 1 by z2, so this is the formula used here, so this is Millman's theorem and can be applied in circuits wherever you place this.

So, after you get V, then I1 you have to calculate this is I1, calculate I1, calculate I2 and calculate I3 in the usual way okay, so this theorem was somehow I forgot to mention, so today I mentioned, it is 2 lines derivations after you have gone through this course this is nothing, I mean you can just assimilate this now, coming to the concluding part of this whole course.

See, in this course we have started from the very basics about; so concluding remarks about the course; concluding remarks. First thing is we started from the basic KVL, KCL equations, then Mesh analysis, the usual stuff analysis, then nodal analysis is it not, these things we did and then first I introduce these with DC sources but later it was modified to AC sources as well if you are interested in steady state analysis.

Or even if you are interested to find out the solution along with transient part, then Laplace domain is the best one but before that to solve network problems in time domain, we require to solve differential equations, okay and before that I introduce to its sources that is voltage source and current source and in the latter half of this course we also talked about dependent; these are called independent sources, dependent voltage and current sources may also be present; dependent voltage and current sources.

This we discussed somewhat at the later end of this course but anyway this was sources, then we know how to write down KVL, KCL in time domain, so solution of differential equation, I spent quite some time solution of differential equation that will be necessary if you want to find out the total solution for currents in a circuit which is excited by time varying sources, so solution of differential equation.

And that is the classical way of solving a circuit equation; classical way okay, after you have done this so, it also gives you both time domain as well as steady state response. See, the usual order of any circuit, time constant of the order of some milliseconds or in terms of supply, 20 millisecond period 50 or supply, there may be 2, 3 cycles of supply, so after that only steady state prevails.

Then, we introduce the phasor notations how to get the steady state solution straight away that is also an important thing to know okay. So, solution of differential equation, later we found that okay, the solution of differential equations can be replaced by Laplace transform technique; Laplace transform to solve network problem, so some basics of Laplace transform I told, then several circuits can be solved.

Only thing wherever there is inductor you replace it by yourself, wherever there is capacitance you replaced by SC and R do not do anything, R keep it there and supply voltage vt change it to vs, any currents in the circuit it change it to Is, then what happens is this vs becomes equal to zs into Is, therefore I can invoke all the rules that we have learned in DC circuit because it is also linear, so far as zi is concerned, z is a constant thing.

Therefore, for any input voltage I could find out the value of Is as vs by zs, it is a very popular technique and take the inverse to get the current domain solution, replaces by j omega you will get the solution when the supply frequency is AC, otherwise it covers all the types of signals. Remember I also discussed somewhat at length that what happens if the source is somewhat awkward source like impulse source, response of a circuit.

Response of a circuit means maybe current response due to an impulse, now of course all these rules were developed for linear time invariant circuits and therefore, several interesting rules were developed.

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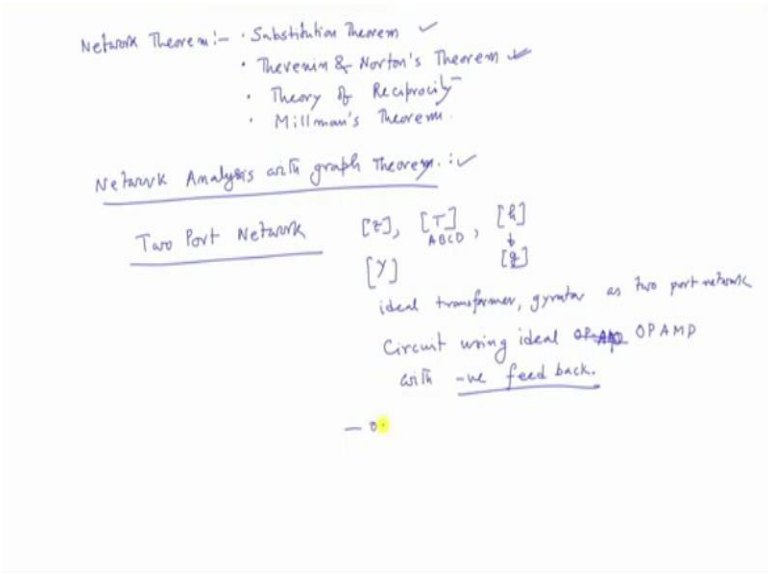

Then, the network theorems these are very important things; network theorems what I did was several network theorems, whatever I could collect; recollect I will tell that network theorems, various network theorems of which one of the popular theorem is substitution theorem that is in any circuit in any branch where there is an impedance but if it is carrying an current I, you can replace that branch by a current source I, things like that we know that.

Then we did the most important theorem; Thevenin and Norton's theorem, their applications, how to find out those equivalent circuits, when these sources are independent sources or also when there is a mix-up of sources; both independent and dependent sources are present, so those topics please go through them, they are very interesting and this one. Then, we did theory of reciprocity these things; theory of reciprocity, okay.

And then today, for example we have done Millman's theorem which I missed earlier, Millman's theorem things like that, then the major topic I covered in this course is what is called the network analysis with graph theory, considerable lectures I have taken and I have only because graph theory itself is a very big subject, I have only applied the graph theory which is absolutely essential.

And very easy way you can go and graph theory generally is applied to solve a circuit if the network is peak and then you write some quotes in a systematic way you can find out the currents or voltage, here also several theorems like cut set matrix, these that we have considered, so go through that part also. Then a network analysis after that we have done 2 port network and here also several lectures I have taken to find out several representation of 2 port network, what a 2 port network is.

And impedances; impedance representation z matrix, T matrix which is nothing but ABCD matrix, then h matrix representation and the inversion of z is Y matrix, ABCD inversion, no name is given I think something h parameters, its inversion matrix is g matrix conductance matrix and so on and when the networks are connected in cascade, it is better you represent in ABCD parameters.

So that the overall ABCD parameters of cascaded networks will be simply the product of T matrices, then we consider 2 important elements; one is called ideal transformer and gyrator as a 2 port network and finally, we did some circuit using ideal Op Amp with negative feedback that is important feedback and the analysis of this type of circuit is very easy and after you have gone through these courses, I hope you able to do that.

So that is all I do not know, there might have been mistakes when I have written so many things, which I might have overlooked, my sincere request to you will be if any such basic mistake comes to your; while you are going through this lecture if you find oh, there is a mistake here, please point it out, I will try to correct in the later stage. Wish you all the very best for this course, it is a nice course.

Last thing about this is I find that network analysis is a beautiful course, it will challenge your intellect, see it is solving a network problem is an art and I may not be the best artist, I do not claim that maybe one of you or one of the best artists because I have handled several students, students will come up with solutions I find amazingly beautiful okay, I was thinking this way this problem could be solved that way, very nice course.

So, I have tried to give you ideas how to really handle networks which may be complicated, which may be tricky whatever may be but you have your own approach, do not try to remember so many formulas, stick on the basics and always remember in any network problems, the concept of energy balance is another interesting thing where things can be done okay. So, with that with best wishes to you all, I closed this course on network analysis, thank you.