Introduction to Time - Varying Electrical Networks
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Lecture - 6
Why is Reciprocity Useful in Practice?

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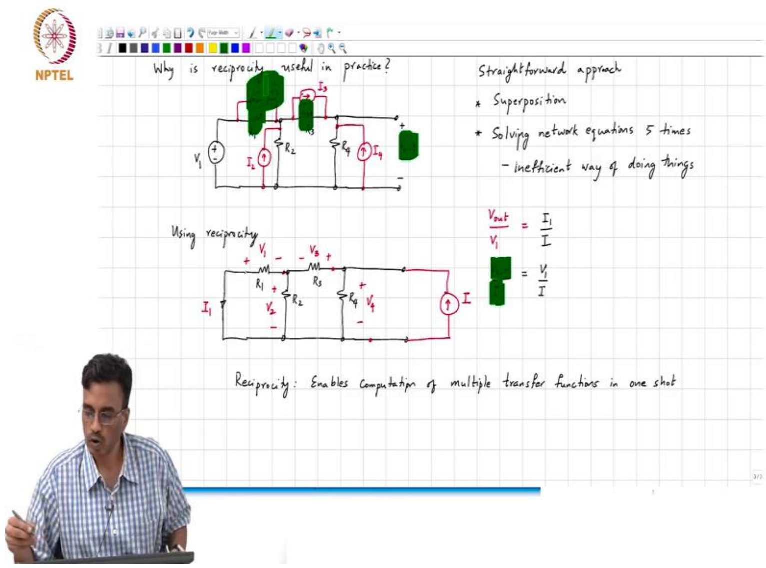

So you may and you might, I mean, I am sure all of you have seen this in your classes basic circuit theory classes, long, long while ago. And apart from giving you 2 marks in an exam, you might be wondering what is the earthly use of, I mean it sounds like a cool theorem but so what? Why is this, why is this useful in practice? I will show you why it is useful in practice with an example.

So let us say I take, I do not know, some example toy network. So why, why is reciprocity useful in practice? So let me take some arbitrary network R1, R2, R3, R4 and let us say, there is V1 here.

There was a current source here called I1, another current source here called I2, a third current source here called I3, a fourth current source called I4, and V out. How will we find V out, what is the most straightforward thing to do, what is the first thing that that strikes you when I asked you to find V out?

Student: (())(02:25)

Professor: Very good. So the first thing that comes to our mind is to say, superposition. The straightforward approach is to basically say, use superposition. So and what does this entail? You de energize all sources except one, and you find the transfer function from one source to the output, and you do this for all the sources that are there.

So how many times are you solving the network? In this particular case, you are solving network equations how many times now? 1 2 3 4 5 times, and is therefore, an inefficient way of doing things.

And why do I say it is an inefficient way of doing things? Because you are, I mean, think about it. When you solve a network, I mean, when you say solve the network, what would you do, how do you plan, go on solving this?

Student: (())(04:08)

Professor: Pardon.

Student: (())(04:11)

Professor: Yeah, I mean, what are the mechanics of the process? You write KCL, KVL; I mean, you choose your favorite set of, if you like mesh analysis, you do mesh analysis; if you do like node analysis, you do node analysis.

But finally, you will end up doing the same thing over and over again five times with only a small change. The smart way of doing things is to use reciprocity and the idea is the following. Well, we know that transfer function from V1 to V out is the same if I instead injected, let us say, let us say injected a current source I here.

What comment can you make about and measured the current I1 here, measured the voltage V1 here, the voltage, sorry, V1 must be in this orientation, V2 here, V3, V4? So if you use reciprocity what, what do you think you can do, what conclusion can you draw regarding the transfer function from V out by V1 in this network must be the same as, yes, people? V1 by V out, or V out by V1 in the network above is the same as? I1 by I in the network below.

Likewise, V out by I1 in the network above is the same as, V out by I1 is the same as V1 by I, and so on. So why is this a much smarter way of doing things? You solve the network only once, and in one shot, you are able to get all the transfer functions that you are after.

And, therefore, the, so this reciprocity, therefore, enables computation of multiple trans functions in one shot without having to do, this solution of nodal equations, one by one by one by one. And you might say, oh well, this is such a simple network, is it really such a big deal to solve the network 5 times, why is the there such a big fuss?

It turns out that in practice, it is not uncommon for circuit designers to be dealing with transistors with, I mean, networks with 100 nodes, 200 nodes, where you have one output. And why do you have multiple inputs? It turns out as we discussed in the very first class, every electronic device, it turns out, also adds noise.

For instance, each of these resistors will add noise, which is, which can be modeled it turns out by either a voltage source in series or by a current source in parallel with the resistor. And if you want to figure out how much noise there is the output of a network, you need to find the transfer function from each of these sources to the to the output.

So this practical scenario where you need to compute several hundreds of transfer functions, in other words, transfer functions from several hundreds of sources to a single output, which would, which would need, using a simple minded approach would need several hundred evaluations of the same network where you are doing the same thing over and over again, if you use reciprocity, it is simply just evaluating the network once.

And with this just one evaluation, you are now in a position to tell me what the transfer functions are from any source in the network to the output. Is this clear? So that is the, one of the nice things about reciprocity. Now, you might argue and however, there is one limitation, and was that limitation?

Student: (())(10:40)

Professor: Pardon. What are the only, I mean what is the limitation of I mean, this obviously sounds like a great idea except, well, except that it does not hold the networks that you are most interested in namely, well, I mean, passive networks are great but most of the time, we are dealing with the active networks, and the active networks have controlled sources.

So it is all great but it does not work for the real network that I am interested in, you understand? So it is like finding someone gave you like a terabyte SSD drive to fix on your phone, except you find out that the slot is of a different size and does not fit. So all your plans of downloading like you know 400 movies is now under water.