Lecture - 06
Why is reciprocity useful in practice?

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

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So, let us say I take some example toy network. So, why is reciprocity useful in practice, ok? So, let me take some arbitrary network R_1, R_2, R_3, R_4. And say there is V_1 here there was a current source here called I_1 another current source here called I_2, a third current source here called I_3, a fourth current source called I_4 and we have V_{out} alright.

How will we find V_{out}? What is the most straight forward thing to do? What is the first thing that strikes you when I ask you to find V_{out}? So, the first thing you know 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 right.

So, how many times are you solving the network? In this particular case you are solving the network equations how many times now? 1, 2, 3, 4, 5 times. Ok and is therefore, an inefficient of doing things. Now, why do I say it is an inefficient way of doing things? Because here I mean think about it when you solve a network, I mean you know when you say solve the network what would you do? How do you plan among go on solving this?

Yeah, I mean you know what is the mechanics of the process? You write KCL KVL I mean you choose your you know favorite set of you know, 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 correct ok.

The smart way of doing things is to use is to use reciprocity and the idea is the following. Well, we know that the transfer function from V_1 to V_{out} is the same if I instead injected let us say, let us say I injected a current source I here. What comment can you make about and measured the current I_1 here? Measured the voltage V_1 here the voltage sorry V_1 must be in this orientation V_2 here, V_3, V_4 ok.

So, if you use reciprocity what you know what do you think you can do? What conclusion can you draw regarding the transfer function from V out by V 1 in this network must be the same as? V 1 by V out or V out by V 1 in the network above is the same as I 1 by I in the network below ok. likewise, V out by I 1 in the network above is the same as V out by I 1 is the same as? V 1 by I and so on.

$$\frac{V_{out}}{V_1} = \frac{I_1}{I}$$

$$\frac{V_{out}}{I_1} = \frac{V_1}{I}$$

So, why is this a much smarter way of doing things? You solve the network only once correct and in one shot you are able to get all the transfer functions that you are after.

So, this reciprocity therefore, enables computation of multiple transfer functions in one shot without having to do the solution of nodal equations you know one by one by one by one ok and you might say well you know this is such a simple network you know is it really such a big deal to solve the network five times why is the there such a big fuss.

It turns out that in practice you know it is not uncommon for circuit designers to be dealing with transistors with I mean networks with you know 100 nodes 200 nodes where you have one output and why do you have multiple inputs? It turns out you know as we discussed in the very first class every electronic device turns out also adds noise. For instance, each of these resistors will add noise which is which can be modeled it turns out by you know 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 at the output of a network you need to find the transfer function from each of these sources to the out ok. So, this practical scenario where you need to compute several hundreds of transfer functions right in other words transfer functions from several hundreds of sources to a single output, which would need you know 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 1 evaluation you are now in a position to tell me what the transfer functions are from any source in the network to the out. Is this clear right? So, that is you know the one of the nice things about reciprocity. Now, you might argue and; however, there is one limitation and what is that limitation? what is the only I mean what is the limitation of I mean this; obviously, sounds like a great idea right except. Well, except that you know it does not hold any networks that we are most interested in namely.

Well, I mean you know passive networks are great, but you know most of the time we are dealing with active networks and active networks have control sources correct. So, it is all great, but you know it does not work for the real network that I am interested right, you understand.

So, it is like finding you know someone gave you like you know a terabyte SSD drive, ok to fix on your phone except you know you find out that you know the slot is of a different size ok and does not fit. So, all your plans of downloading like you know four hundred movies is you know is now underwater.