Basic Electrical Circuits
Dr Nagendra Krishnapura
Department of Electrical Engineering
Indian Institute of Technology Madras

Lecture – 26

Just to show you another functionality that can be implemented using control sources. We consider how to scale the value of an element and in this case, I will take a capacitor an example, but you could equally well use some other element.

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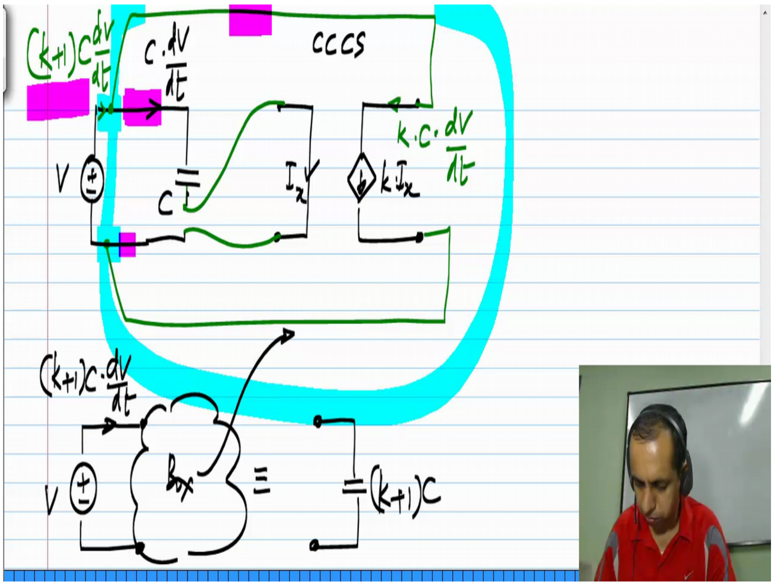

So, let say I connect a voltage source V across a capacitor C and this draws a current C times the time derivative of V. Now, I have variety of control sources, but for now let me consider a current controlled current source. Let say this is I x and this is some k times I x. Now, let say that I want to alter the characteristics between these two terminals in some way I want to scale it, what I can do is the following. I will sense the current flowing through the capacitor using the input branch of the current controlled current source.

Now, you observe that absolutely nothing has change as for as the capacitor is concerned, the voltage across the capacitor still V, because this part is a short circuited, it is just a wire. So, the voltage across the capacitor still V, so the current through the capacitor still C times d v by d t. Now, if you look at the current through the current controlled current source it is k times C times d v d t. Now, let me do one thing, let me take the control current and also connected across the voltage source, which is driving the capacitor.

Clearly you will see that the current that is drawn from the voltage source will be k plus 1 times C times the time derivative of V. We have C times d v by d t in this wire and k times C times d v by d t in that wire. So, the total current drawn is k plus 1 C times the time derivative of V. Now, again let me enclose the entire circuit in a box and look at only these two terminals. What do I have? It says that if I connect a voltage V to this whole box containing this, it draws a current k plus 1 times C times time derivative of V.

So, it means that this entire box here looks like a capacitance of value k plus 1 times C. So, what do I mean by it looks like that? If I gave you two boxes, one consisting of the capacitance C and a current controlled current source of value k connected of like this and another box which has actually a capacitance of value k plus 1 times C. There is no way you can distinguish between the two, we cannot tell which is which by measuring voltages and currents at the two terminals and that is what is in general meant by equivalent circuits.

So, you could have a box with very complicated circuitry here, but let say across the terminals you measure the voltage and current and come up with the relationship V equals I times something. And you know that, that relationship belongs to a resistor. So, this whole entire complicated circuit within the box cannot be distinguished from another box, which consists of a single resistor of that value. So, without opening the box you cannot tell what is inside, as far as the terminal characteristic are concerned, it is just a resistor.

Similarly, in this particular case as far as the terminal characteristics are concerned, it is just a capacitor. So, now, this kind of scaling of element can also be achieved using a voltage controlled voltage source.

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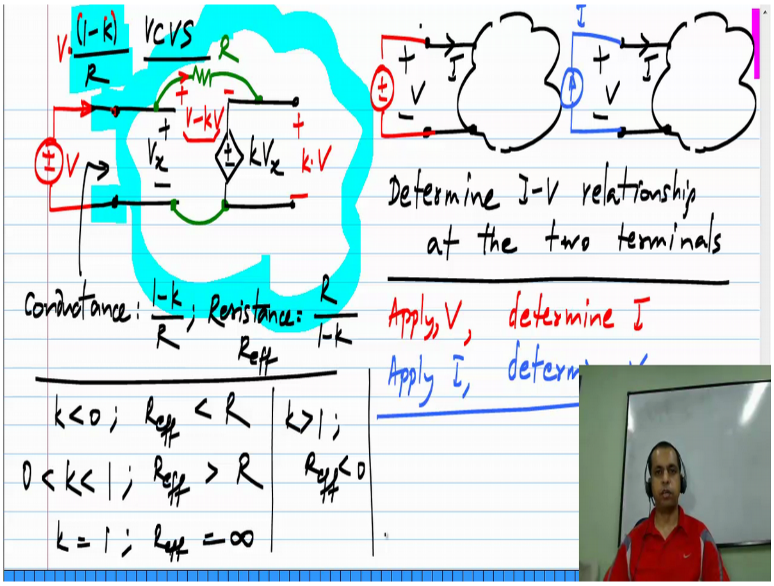

One example of that which is quite popularly seen in circuits, I will show that here without discussing it too much. So, let say we have a voltage controlled voltage source with a scaling factor k. Now, let me do a few things, let me connect these two parts together and let me connect a resistance R between these two. Now, I enclose this whole thing within a box and what I am interested in is, finding out the equivalent characteristic between these two terminals.

Now, what do I mean by finding the characteristic between these two terminals as I mentioned before? You have a box with these two terminals and what you have to do is to determine the current voltage relationship, where the current and voltage are measured at the two terminals. So, that is what is meant by finding the equivalent behavior or finding the equivalent circuit and so on and the way to do that is, you either apply a voltage source V and determine the current I alternatively.

You can also apply a current source I and determine V, both these are possible, some of them are more convenient in some context, but the two are perfectly equivalent. Once you do this, you know the relationship between V and I and you will be able to tell what the equivalent circuit is. Now, for this particular case, let me apply a voltage V, because this V x equals V by Kirchhoff's voltage law very simple application of it, the voltage across this is k times V, but again by Kirchhoff's voltage law the voltage across the resistor in this polarity is v minus k times V.

So, the current drawn from the source will be equal to the current flowing in the resistor, which is this voltage divided by the resistance value. So, it is V times 1 minus k divided by R and you know from ohms law that whatever is multiplying V is the conductance between these two terminals. So, this between these determines it is looks like a conductance of value 1 minus k by R or a resistance of value R by 1 minus k.

So, you can if you have physical resister R by connecting end of with the voltage control voltage source like this, you can change it is volume. You can also see what happens with this, if k is smaller than 0 let me call this the effective resistance R effective, R effective will be smaller than R and if case between 0 and 1, R effective will be more than R and if k is exactly equal to 1 R effective will be infinity; that means, that it looks like in open circuit.

What does it mean if k equals 1? This voltage is exactly this same as that voltage, there is no voltage across R at all, all though there is a resistance it does not draw any current, because the voltage across it is 0. And finally, if k is more than one then R effective will become negative. So, you can take a resistor make it look like it is smaller, make it look like it a larger, make it look like even an open circuit or you can even make it look like a negative resistance.

So, these are all not for any specific purpose at this point, but illustrate the possibilities. But, later when you go to active circuits you see that some of these concepts are actually used in practical circuits, sometimes you will need to it is needs the value of resistor for various reasons and these things are used. So, that is in summary utility of control sources they are used for modeling and abstraction of complicated circuits into simple models as well as for synthesis of exotic functions.