

# Re: generalized Thevenin?

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- *From:* Jens Tingleff <[jensting@xxxxxxxxxxxxx](mailto:jensting@xxxxxxxxxxxxx)>
  - *Date:* 19 Jul 2007 02:30:51 -0700
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In article <[fZCni.39974\\$Um6.1086@xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx](mailto:fZCni.39974$Um6.1086@xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx)>, Jon Slaughter says...

"Jon Slaughter" <[Jon\\_Slaughter@xxxxxxxxxxxxx](mailto:Jon_Slaughter@xxxxxxxxxxxxx)> wrote in message [news:IHCni.39972\\$Um6.28321@xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx](mailto:news:IHCni.39972$Um6.28321@xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx)

"Robert" <[Robert@xxxxxxxxxx](mailto:Robert@xxxxxxxxxx)> wrote in message [news:CfCni.9752\\$zA4.6770@xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx](mailto:news:CfCni.9752$zA4.6770@xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx)

"Jon Slaughter" <[Jon\\_Slaughter@xxxxxxxxxxxxx](mailto:Jon_Slaughter@xxxxxxxxxxxxx)> wrote in message [news:SHzni.2490\\$Dx2.1132@xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx](mailto:news:SHzni.2490$Dx2.1132@xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx)

Is there a generalized Thevenin's theorem for arbitrary "black boxes"?

i.e., Suppose I have something like

$$\begin{matrix} \text{---} > I \\ V + \text{---} [ ] \text{---} 0 \end{matrix}$$

where [ ] is a black box.

I should be able to write something like

$$V = Z(t, V, I) * I$$

which sorta resembles ohms law. V and I generally depend on t.

if [ ] is a resistor then  $Z(t,V,I) = R$  and in

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general Z also depends on  
a set of parameters.

But what about more complex black boxes?

If its a resistor and a capacitor then what?

V ----||----^v^v^v^v----- 0

Then  $Z(t,V,I) = ?$

For passive components is Z a linear  
differential equation?

Any other ways to simplify such  
expressions?

The reason I ask is I have a circuit that has a  
lot of these "paths"  
that are connected in some way but each  
path is the same configuration  
with only the "constants" of the components  
that are different.

Thanks,  
Jon

There's Middlebrook's Theorems but I don't think that's what  
you're  
asking about.

[http://en.wikipedia.org/wiki/Extra\\_element\\_theorem](http://en.wikipedia.org/wiki/Extra_element_theorem)

Robert

Actually it looks very similar and it seems close to my problem.  
Essentially I have a circuit where each "branch" looks identical(Actually  
its not but uses identical topology... its almost fractal like) and I am  
trying to use that symmetry to make it easier to solve. I'll have to read  
up on it to see what exactly it doing though.

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hmm... actually it doesn't seem to be what I want. My problem is similar to his but each branch in the graph has the same "structure".

For example, take any graph and treat an edge as a black box that contains passive elements. Then each edge is described by a linear differential equation  $L_E \dot{E}$  where  $E$  is the edge indicator which really only depends on the passive elements characteristics. Then is there a way to simplify the graph/solve the system for the voltages and currents?

In a passive circuit, the complexity of finding the solution grows with the number of nodes – sorry :-( Think of finding the voltages along a string of resistors. For two resistors, the voltage at the middle point depends on the value of two resistors. For three resistors (same structure in each branch...) both of the two internal voltages depend on the value of three resistors, etc etc. (However, if you know in advance that all the resistors have the same value, you can easily calculate the solutions for all the internal nodes.)

Solving the network to find all node voltages / branch currents can certainly be done the "hard way." This uses admittance matrices, as in  $i = Y v$  (with "v" the vector of internal voltages and "i" the vector of external currents and "Y" the admittance matrix).

[http://users.ecs.soton.ac.uk/mz/CctSim/chap1\\_2.htm](http://users.ecs.soton.ac.uk/mz/CctSim/chap1_2.htm) (for instance)

I think there's actually hope for solving your problem if you have a very simple and regular structure. In that case, you might be able to find the inverse of the Y matrix (this is what you need in order to solve the circuit equations) in a way simpler than the general way. An advantage of this approach is that you don't need to use the actual elements in each branch, you can use a symbol for each distinct branch admittance and enter the actual branch admittances in the solution.

Symbolic simplification of matrix inversions is pretty difficult to do, though.

So, the short answer is that going from simple circuits like a resistive divider to more general circuits is not simple.

[..]

So essentially between any two nodes we have  $V_b - V_a = Z \cdot I$  which is just ohms law in some sense but  $Z$  is somewhat arbitrary. The problem is that in general  $Z$  depends on the nodes, current, and time along with all the other components that exist on that branch.

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Worse – the voltages at the ends of this branch depend on all other voltages.

You can think of it very similar to solving the graphs of resistors that most people do in basic electronics or physics courses except I want to replace them with more general components. In the case of a resistor its very simple. In the case of a capacitor it is not.

Actually, for a circuit with only capacitors, it's not different from a purely resistive circuit (just a lot more unknown voltages at DC...).

Since I want to take into account the transients I get system of integral equations(because of the non-constant/non-sinusoidal input voltages and unknown node voltages). Of course these integral equations are equivalent to a system of differential equations.

Essentially you can think of each branch representing a linear differential equation. But each linear DE "looks" the same as every other one except for the constant coefficients and it might depend on different currents and voltages.

It seems though I should be able to recursively simplify the circuit until I find all the unknowns. well, this should be obvious but the issue is, is the size. Just hoping for a way to reduce the complexity because of the "symmetry" that exists.

For some very special circuits, yes (e.g. resistor strings, delta or star shaped circuits, etc). In general, I think not.

Anyways, probably no way to do what I want but I can wish...

It's worth thinking about this. I studied in a group where the professor made a Big Discovery as a young student when hearing about a deceptively simple result at a conference (for all passive circuits, the sum of voltages in the solution is always constant – or something[1]) and asking himself if that could really be true and then wondering what the consequences were. The answer was the companion circuit and its use for sensitivity analysis :-). He thought it was so trivial that he didn't publish it right away. Tut tut. Two lessons in that anecdote :-)

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Good luck

Best Regards

Jens

[1] You look it up. Annoyingly, I cannot remember right now.

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"Never drive a car when you're dead!" Tom Waits

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