

Circuit Analysis for Analog Designers
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Lecture - 11
MNA stamps of controlled sources - the VCCS & VCVS

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MNA "stamp"

$$\begin{bmatrix} \text{---} & \text{---} \\ G & 1 \\ \text{---} & -1 \\ 1 & -1 \end{bmatrix} \begin{bmatrix} \text{---} \\ \text{---} \\ \text{---} \\ I \end{bmatrix} = \begin{bmatrix} \text{---} \\ \text{---} \\ \text{---} \\ V_s \end{bmatrix}$$

Modified Nodal Analysis

⇒ Augmented G matrix : $(n+p) \times (n+p)$
 Unknowns : $(n+p) \times 1$
 Source vector : $(n+p) \times 1$

Alright. So, you know. So, once you know the number of nodes in the network, the number of independent current sources and the number of independent voltage sources I mean the job is very straight forward you first set up a matrix of size $(n + p) \times (n + p)$. And then you go element by element and to the initialized matrix full of 0's you just add the stamp of that particular element.

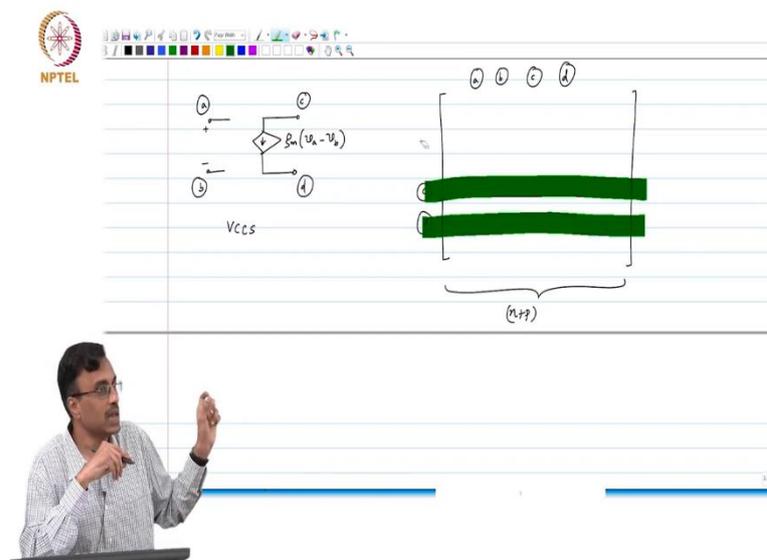
If you see a conductance you add to this matrix this you know you first initialize the 0 cross, I mean $(n + p) \times (n + p)$ matrix full of 0's then you go element by element you know the stamp of each element you just add that stamp to the existing matrix right. So, and you know, I mean this is of course, a simple-minded way of doing this.

You know, if you have a huge network, you know you do not want to create so, much location. So, you want do not want to allocate so much memory at one time right. Then you can be probably you can do smarter things like you know that is whole that whole that is a different ball game it is all about memory management and so on right.

But at least in principle, you go element by element and then add to the existing all 0 augmented conductance matrix the stamp of that particular element. And this is what is done in all circuit simulators because SPICE will generate a net list from the schematic that you draw and then you know the matrix generation is simply go line by line.

And then you know figure out what element you are trying to plop into the matrix you who know it is stamp already. So, you just add that stamp to the network. Of course, we are not happy with just networks with conductance, current sources and voltage sources we are also going to have controlled sources. So, let us see what we can do with controlled sources.

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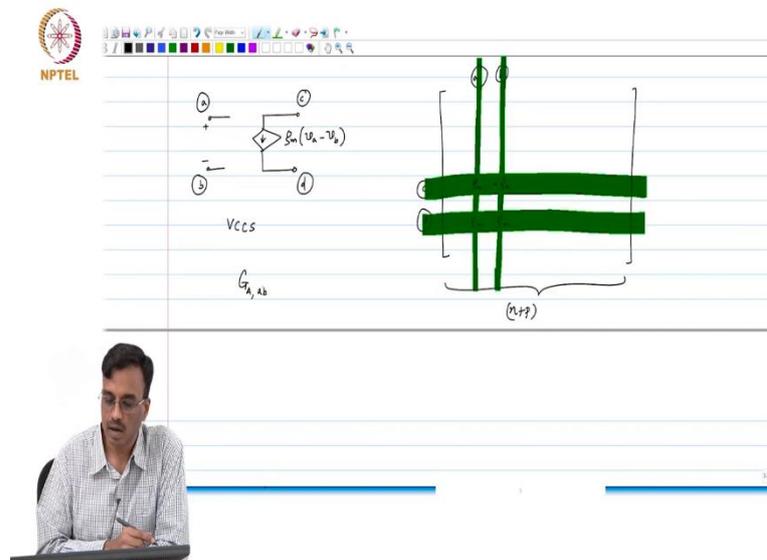


For example, the simplest one to deal with is the voltage controlled current source; now I am not going to sit and draw the entire network I am just going to focus on the nodes this $g_m(v_a - v_b)$, this is the network. This is the controlled source and we have to figure out remember that we are trying to figure out what the stamp of this controlled source is correct. So, in general therefore, this the augmented conductance matrix will be you know of this form you know it will have you know $(n + p)$ rows in the $(n + p)$ columns and. So, all the action will be basically between in which rows and which columns in the rows corresponding to a, b I mean if at all there is any action it will be in only in these rows and these columns correct. So, can you tell me what will happen to in which row we will have the stamp of the voltage controlled current source?

Well, the current is flowing between node c and d. So, all the action will be in the rowth rows which correspond to the cth and dth nodes. So, all the action will be here in this row, correct. So, we do not have to worry about these two guys correct and the current depends on which voltages?

Node voltages a and b right. So, we do not need to worry about the cth and dth columns right. So, the entries will happen here does it make sense, and what is the entry?

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In the cth row you have g_m into v_a ok, and minus g_m into v_b , correct; it make sense people and likewise in the dth in the dth row what do you see?

Minus g_m . Alright, does it make sense? So, in other words the augmented conductance matrix right. Let us call that $G_{sub\ capital\ A}$ so, not to get confused between small a the a bth sorry let us forget about that for time being right. So, you can see therefore, that the MNA stamp of the voltage controlled current source looks largely similar to that of a conductance with the key difference that being. Well, you know if you had a conductance what would happen. The stamp would look kind of similar the only difference would be that the c dth row simply become the same as the a b d.

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Slide 107 shows a circuit diagram with nodes a, b, c, and d. A dependent current source $g_m(v_a - v_b)$ is connected between nodes c and d. A voltage source V_{CCS} is connected between nodes a and b. The nodal analysis shows a 4x4 matrix G with green highlights on the diagonal elements and the off-diagonal elements in the first two rows and columns.

a b d, right. I mean and intuitively that make sense right if I short these two how does it look like? If I short a with c and b with d, what does it look like? It looks like the conductance value g_m and then you know that basically will appear in the a bth row and a bth column ok.

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Slide 108 shows the same circuit diagram as slide 107. The nodal analysis shows a 4x4 matrix G with green highlights on the diagonal elements and the off-diagonal elements in the first two rows and columns. The text "G matrix no longer symmetric" is written below the matrix. The matrix is shown as a 4x4 matrix with nodes a, b, c, and d. The matrix is: $G = \begin{bmatrix} g_m & 0 & 0 & 0 \\ 0 & g_m & 0 & 0 \\ 0 & 0 & 0 & -g_m \\ 0 & 0 & g_m & 0 \end{bmatrix}$. The text "MNA step is transposed:" is written to the right of the matrix.

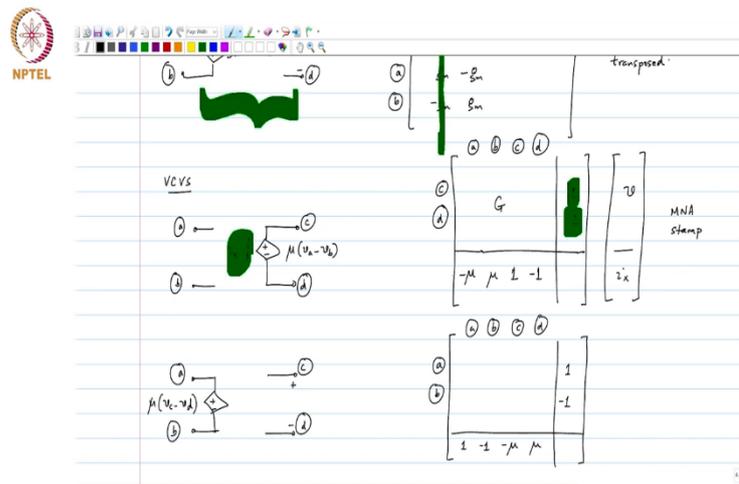
Now, what comment can you make about the structure of this matrix now? Earlier when we had only conductance's this was? Symmetric, correct now it is no longer symmetric ok. So, with the controlled source I mean it is possible ok and out of curiosity if I did this

I mean this is just simply this $g_m(v_c - v_d)$ ok. So, how will the MNA stamp of this look like? This will happen in the a th and b th rows and in the c th and d th columns and what will happen? This will be g_m minus g_m and this will be minus g_m and g_m ok. So, what comment can you make about the MNA stamp of this versus this?

$$\begin{bmatrix} g_m & -g_m \\ -g_m & g_m \end{bmatrix}$$

What was whatever was happening in the cth row of this guy is happening in the cth column of ah this chap, correct. So, if you flip the controlling and controlled ports you can see it is very clear that the MNA stamp is simply the What? Is simply the transpose, is that clear right? So, please bare this in mind we will come back to this later ok. So, we finish the simplest of the controlled sources. Now, let us see alright.

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The next controlled source we will talk about is the voltage controlled voltage source and again we are trying to find MNA stamp or the voltage controlled voltage source. So, let us call it is gain it occurs between these four. So, let us call the gain $\mu(v_a - v_b)$ right again. So, we have a voltage source and what is the problem with the voltage source.

Whether it is controlled or uncontrolled I mean you know what happens. The current is an unknown. So, you need to add an extra unknown to the set of equations correct. So, and this current I am going to call let us say i_x I mean i_x ok and therefore, what should we do you know how the MNA stamp of this look like.

We had the original G matrix. Now, we need to add we need to add an extra. So, we have the node voltage vector right and then we have to had an extra unknown i_x ok and in which rows will all the action be happening. In c and d and which column of these rows will all the action be happening. Which column do you think all the action is happening? In the last column right. So, that is basically the cth row should have a plus 1 and the dth row should have a minus 1.

No no no this model see this is the. This is the current right. So, that is i_x is flowing; I mean these entries you know basically model the fact that a current i_x is flowing from out of node c and then current i_x is flowing into node d right. So, we have an extra unknown. So, we need an extra equation, what is that extra equation? You know $v_c - v_d$ is nothing but $\mu(v_a - v_b)$ or in other words, $v_c - v_d - \mu(v_a - v_b) = 0$. So, what should where all does action happen now that happens in the last row, which all columns do you see action happening a b c and d correct. So, c must be 1, d must be minus 1, a must be minus μ . And b must be plus μ , alright.

$$v_c - v_d - \mu(v_a - v_b) = 0$$

$$\left(\begin{array}{cccc|c} & & & & 1 \\ & G & & & -1 \\ \hline -\mu & \mu & 1 & -1 & \end{array} \right) \begin{pmatrix} v \\ i_x \end{pmatrix}$$

So, this is the MNA stamp of or the voltage-controlled voltage source alright. And now out of curiosity what I am going to do is see what happens when I just flip the voltage source the controlling and controlled ports around. So, this is now $\mu(v_c - v_d)$ and this is v_c , this is v_d . So, what comment can you make about this matrix now?

So, in which rows must this the you know must will which of those rows will be affected. a and b, and what you see? People come on. So, in the last column we basically see 1 and minus 1 and what about all the columns which basically say I have a b c and d and what you see? 1 minus 1 minus μ plus μ . Alright, ok. So, stop here and continue in the next class.

$$\left(\begin{array}{cccc|c} & & & & 1 \\ & G & & & -1 \\ \hline 1 & -1 & -\mu & \mu & \end{array} \right)$$

So, tomorrow is 8'o clock class. Please, you know show up on time right, do not walk in and all.