Course 1: How to solve circuits the right way – once and for all!

Lecture 1

The Joys of Circuit Analysis

Course 1: How to solve circuits the right way – once and for all!

Based on my book:

"Fast Analytical Techniques in Electrical and Electronic Circuits"
Published by Cambridge University Press, 2002.

Course 1: How to solve circuits the right way – once and for all!

Lecture 1

1. Meaningful and meaningless solutions to circuits.
2. Painful circuit analysis.
3. Painless and joyful circuit analysis.
4. Excruciating circuit analysis.
5. More joyful circuit analysis.
6. Dr. R.D. Middlebrooks's Legacy.

Lecture 1

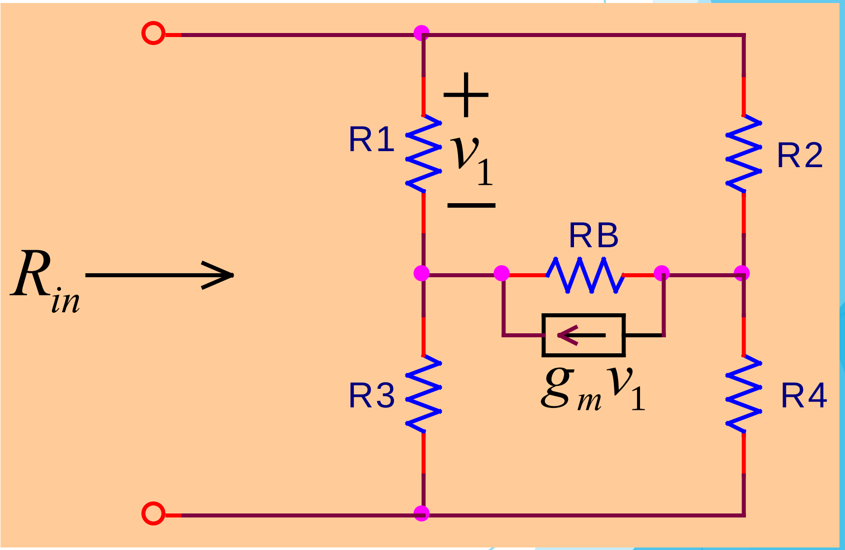
Excruciating circuit analysis

***Example 1*:** Extract g_m as a parameter in the input resistance of the bridge circuit with a dependent trans-conductance source, $g_m v_1$, shown in the figure.

This means that the input resistance should be in the form:

$$R_{in} = \frac{A + Bg_m}{C + Dg_m}$$

In which A, B, C and D are not functions of g_m.



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Excruciating circuit analysis

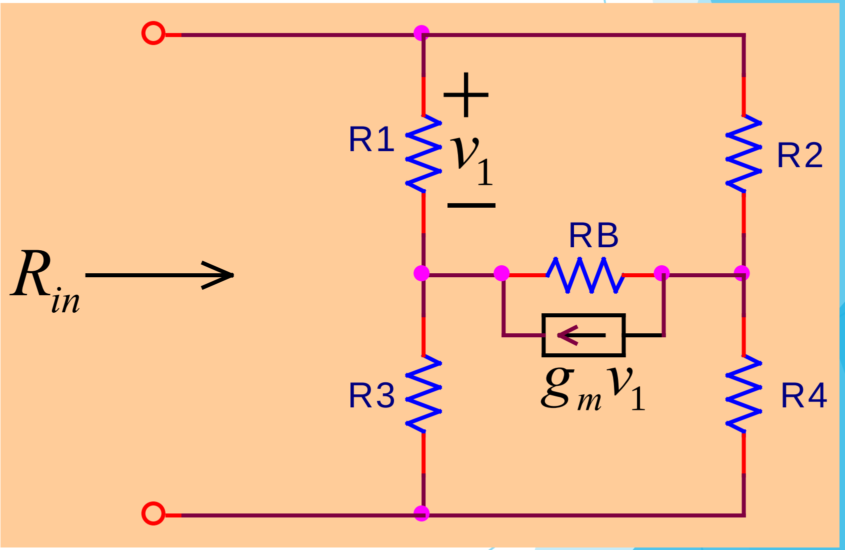
Example 1: (*cont.*)

I do not expect you to follow the next sixteen steps of algebraic misery to perform the method of parameter extraction using the nodal equations of this circuit.

This excruciating method is described in the following well-known reference:

L.O.Chua and Pen-Min Lin, *Computer Aided Analysis of Electronic Circuits: Algorithms and Computational Techniques*, Prentice Hall, New York, 1975.

I am including it in my lectures *only to drive home harder the concept of painless circuit analysis* that I am teaching.



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Excruciating circuit analysis

Example 1: (*cont.*)

STEP 1: Determine the Indefinite Admittance Matrix by *adding* a new element $R_s = 1/g_s$ at the input port!

From the first step, you can already see that this is NOT going in the right direction!

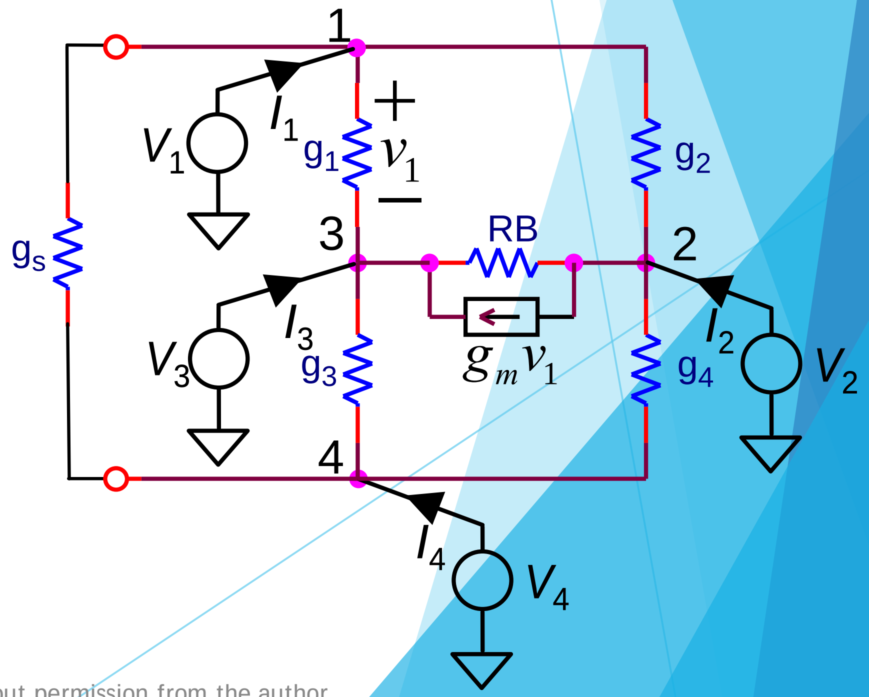
Instead of simplifying the circuit, you are making it more complex!

Nevertheless let us proceed!

Label the nodes and the sources V_1 through V_4.

Write the nodal equations and the IAM as follows:.

$$I = Y_{ind} V$$



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Excruciating circuit analysis

Example 1: (*cont.*)

STEP 2: At each node n, determine the current I_n using superposition for V_1 through V_4 and obtain:

$$Y_{ind} = \begin{bmatrix} g_1 + g_2 + g_s & -g_2 & -g_1 & -g_s \\ g_m - g_2 & g_2 + g_B + g_4 & -g_m - g_B & -g_4 \\ -g_m - g_1 & -g_B & g_m + g_B + g_1 + g_3 & -g_3 \\ -g_s & -g_4 & -g_3 & g_s + g_3 + g_4 \end{bmatrix}$$

This was not bad because all we had to do was write simple equations and use superposition.

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Excruciating circuit analysis

Example 1: (*cont.*)

STEP 3: Extract g_s according to the following cofactor theorem.

Theorem. *If a parameter, α, appears as (+α) in positions (i,k) and (j,m) and as (– α) in positions (i,m) and (j,k) in the indefinite admittance matrix* Y_{ind} *, then:*

$$\text{Cofactor of } Y_{ind} = \text{Cofactor of } Y_{ind}\Big|_{\alpha=0} + (-1)^{j+m}\alpha \text{ Cofactor of } (Y_\alpha)$$

where Y_α *is another indefinite admittance matrix not containing α and obtained from* Y_{ind} *as follows:*

1. *Add row j to row i in* Y_{ind} *.*
2. *Add column m to column k in* Y_{ind} *.*
3. *Delete row j and column m in* Y_{ind} *.*

Note: *ALL cofactors of an IAM are equal.*

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Excruciating circuit analysis

Example 1: (*cont.*)

In our case $\alpha = g_s$ so that we have:

$$\text{Cofactor of } Y_{ind} = \text{Cofactor of } Y_{ind}\Big|_{g_s=0} + (-1)^{j+m} g_s \text{ Cofactor of } (Y_{g_s})$$

STEP 4: Determine $Y_{ind}\Big|_{g_s=0}$

$$Y_{ind}\Big|_{g_s=0} = \begin{bmatrix} g_1 + g_2 & -g_2 & -g_1 & 0 \\ g_m - g_2 & g_2 + g_B + g_4 & -g_m - g_B & -g_4 \\ -g_m - g_1 & -g_B & g_m + g_B + g_1 + g_3 & -g_3 \\ 0 & -g_4 & -g_3 & g_3 + g_4 \end{bmatrix}$$

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Excruciating circuit analysis

Example 1: (*cont.*)

STEP 5: Determine Y_{g_s}

$$Y_{g_s} = \begin{bmatrix} g_1 + g_2 + g_3 + g_4 & -g_2 - g_4 & -g_1 - g_3 \\ g_m - g_2 - g_4 & g_2 + g_B + g_4 & -g_m - g_B \\ -g_m - g_1 - g_3 & -g_B & g_m + g_B + g_1 + g_3 \end{bmatrix}$$

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Excruciating circuit analysis

Example 1: (*cont.*)

STEP 6: Extract g_m from $Y_{ind}\big|_{g_s=0}$ by a *second* application of the cofactor theorem

$$\text{Cofactor of } Y_{ind}\big|_{g_s=0} = \text{Cofactor of } Y_{ind}\big|_{\substack{g_s=0\\g_m=0}} + (-1)^{j+m} g_m \text{ Cofactor of } (Y_{ind}\big|_{\substack{g_s=0\\g_m}})$$

STEP 7: Determine $Y_{ind}\big|_{\substack{g_s=0\\g_m=0}}$

$$Y_{ind}\big|_{\substack{g_s=0\\g_m=0}} = \begin{bmatrix} g_1+g_2 & -g_2 & -g_1 & 0 \\ -g_2 & g_2+g_B+g_4 & -g_B & -g_4 \\ -g_1 & -g_B & g_B+g_1+g_3 & -g_3 \\ 0 & -g_4 & -g_3 & g_3+g_4 \end{bmatrix}$$

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Excruciating circuit analysis

Example 1: (*cont.*)

STEP 8: Determine $Y_{ind}\Big|_{\substack{g_s=0\\ g_m}}$

$+g_m$ occurs in in the positions (2,1) and (3,3) and $-g_m$ occurs in positions (3,1) and (2,3).

$$Y_{ind}\Big|_{\substack{g_s=0\\ g_m}} = \begin{bmatrix} g_2 & -g_2 & 0 \\ g_3-g_2 & g_2+g_4 & -g_3-g_4 \\ -g_3 & -g_4 & g_3+g_4 \end{bmatrix}$$

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Excruciating circuit analysis

Example 1: (*cont.*)

STEP 9: Extract g_m from Y_{g_s} by a second application of the cofactor theorem

$$\text{Cofactor of } Y_{g_s} = \text{Cofactor of } Y_{g_s}\Big|_{g_m=0} + (-1)^{j+m} g_m \text{ Cofactor of } (Y_{g_s,g_m})$$

STEP 10: Determine $Y_{g_s}\Big|_{g_m=0}$

$$Y_{g_s}\Big|_{g_m=0} = \begin{bmatrix} g_1+g_2 & -g_2-g_4 & -g_1-g_3 \\ -g_2-g_4 & g_2+g_B+g_4 & -g_B \\ -g_1-g_3 & -g_B & g_B+g_1+g_3 \end{bmatrix}$$

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Excruciating circuit analysis

Example 1: (*cont.*)

STEP 11: Determine Y_{g_s,g_m}

$+g_m$ occurs in in the positions (2,1) and (3,3) and $-g_m$ occurs in positions (3,1) and (2,3) in Y_α

$$Y_{g_s,g_m} = \begin{bmatrix} g_2 + g_4 & -g_2 - g_4 \\ -g_2 - g_4 & g_2 + g_4 \end{bmatrix}$$

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Excruciating circuit analysis

Example 1: (*cont.*)

STEP 12: Determine the cofactor $Y_{ind}\Big|_{\substack{g_s=0\\ g_m=0}}$

Since all cofactors are the same, we chose the simplest possible which is the following determinant:

$$\text{Cofactor of } Y_{ind}\Big|_{\substack{g_s=0\\ g_m=0}} = \begin{vmatrix} g_1+g_2 & -g_2 & 0 \\ -g_2 & g_2+g_B+g_4 & -g_4 \\ 0 & -g_4 & g_3+g_4 \end{vmatrix}$$

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Excruciating circuit analysis

Example 1: (*cont.*)

STEP13: Determine the cofactor $Y_{ind}\Big|_{\substack{g_s=0 \\ g_m}}$

$$\text{Cofactor of } Y_{ind}\Big|_{\substack{g_s=0 \\ g_m}} = \begin{vmatrix} g_2 & 0 \\ -g_3 & g_3+g_4 \end{vmatrix}$$

Step 14: Determine the cofactor $Y_{g_s}\Big|_{g_m=0}$

$$\text{Cofactor of } Y_{g_s}\Big|_{g_m=0} = \begin{vmatrix} g_2+g_B+g_4 & -g_B \\ -g_B & g_B+g_1+g_3 \end{vmatrix}$$

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Excruciating circuit analysis

Example 1: (*cont.*)

STEP 15: Determine the cofactor Y_{g_s, g_m}

$$\text{Cofactor of } Y_{g_s, g_m} = g_2 + g_4$$

STEP 16: From the relationship between the Indefinite Admittance Matrix and Admittance Matrix one can show that:

$$Z_{in} = \frac{\text{Cof.}\, Y_{g_s}\Big|_{g_m=0} + g_m \text{Cof.}\, Y_{g_s, g_m}}{\text{Cof.}\, Y_{ind}\Big|_{\substack{g_s=0 \\ g_m=0}} + g_m \text{Cof.}\, Y_{ind}\Big|_{\substack{g_s=0 \\ g_m}}}$$

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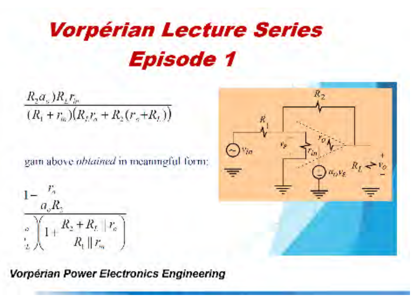
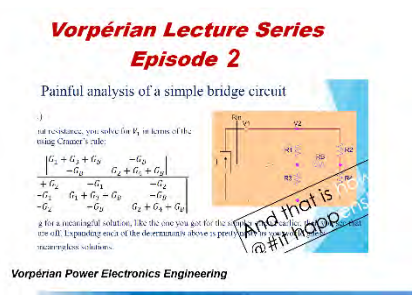
Excruciating circuit analysis

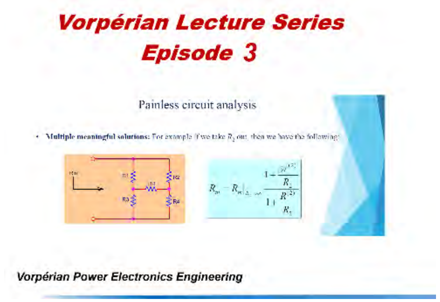
DISCUSSION:

1. The method of parameter extraction is about as painful as tooth extraction – without N_2O!
2. You arrive at the answer after you expand four determinants – assuming you have survived the algebra.
3. This is exactly how you get meaningless solutions to network problems.
4. This is exactly how you get turned off from electronic circuits.
5. This is how you put yourself at the mercy of circuit simulation programs trying to make sense out of a circuit.

Complete Vorperian Lecture Notes







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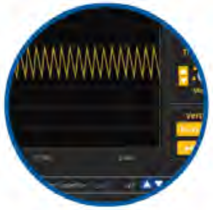

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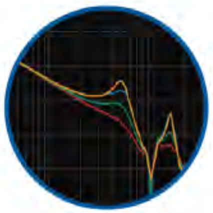

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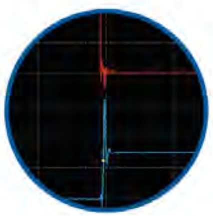

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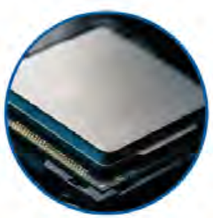

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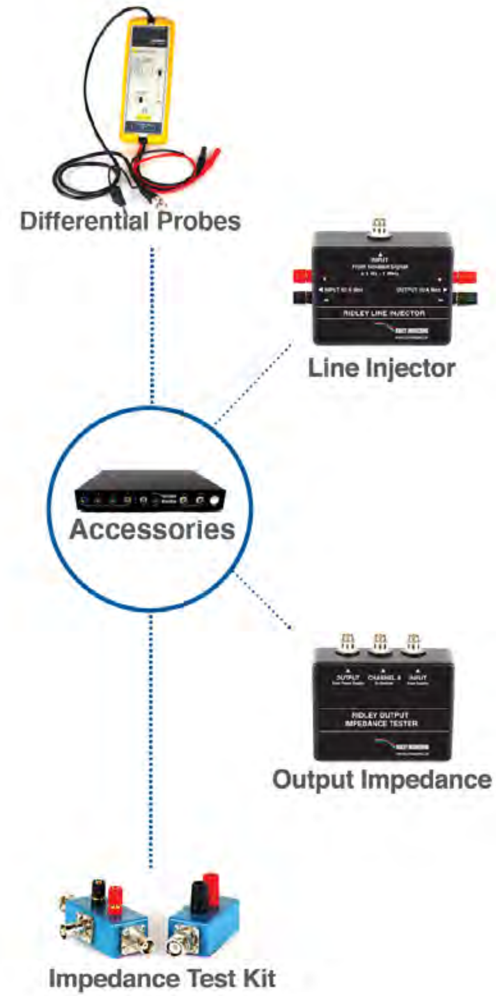

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