

Space: a Toolbox for the Simulation of Analog Electronic Circuits

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Abstract : In this paper, we present a Matlab Toolbox called Space dedicated to the simulation of analog, linear or nonlinear electronic circuits under Matlab/Simulink. The advantages of this toolbox, beside its freeness, are: its modularity (new components can be easily added); its easyness of use (the signals in the circuit can be easily visualized and transformed without any programmation). Thus, this toolbox represents a complementary approach that transforms Simulink into a versatile simulation engine, since it now can handle systems as well as circuits.

Keywords : Analog Electronic Circuits, Numerical Simulations

1. Introduction

Until now, the graphical interface of Matlab, Simulink, could handle the simulation of systems and numerical circuits, but not of analog circuits. In this paper, we present a Matlab toolbox called Space that allows, under a user-friendly environment, the simulation of linear and nonlinear analog electronic circuits. The circuit is graphically specified by the user under the Simulink interface, as in the case of a system. Then, the program computes all voltages and currents in the circuit ; these signals can then be displayed interactively on the screen and can be processed, exploiting the Matlab environment, under their time domain or frequency domain version. This approach makes thus of Simulink a versatile interface able of handling any type of circuit and system.

2. Description of Space

the main features

The main features of Space are the following :

- a free simulator for linear and nonlinear electronic analog circuits
- a tool that requires no programmation from the user
- a user-friendly interface
- extended capabilities of circuit analysis : time domain and frequency domain study of all voltages and currents, computation of transfer functions and of both transient and steady-state behaviour

In order to fulfill these requirements, we have chosen the Matlab/Simulink numerical environment : the idea underlying Space consists in adding a software layer to Simulink that makes it able to handle not only systems, but also circuits. In this aim, we have adopted a method of description of circuits, called the modal method : the circuit is transformed into an equivalent differential system describing the behaviour of all currents and voltages. Once this conversion is performed, the differential system is solved using any of the numerical

methods of integration available under Matlab. Remark that Simulink is used, in Space, only as a graphical interface for the description of the circuit schematics.

the modal method

Let us first give a short description of the method of circuit description we have adopted in this approach : the nodal method is based on classical notions of graph theory. [1, 2].

Other methods could have be chosen, as the quadripole method. The first step of this method consists in numbering separately and arbitrarily all the components and the nodes of the circuits. Then, a matrix A , called the incidence matrix, that describes how the components are linked together in the circuit, is built according to the

$$A = \begin{cases} +1 & \text{if component } j \text{ has its output on node } i \\ -1 & \text{if component } j \text{ has its input on node } i \\ 0 & \text{else} \end{cases}$$

following convention :

In a second step, the circuit is divided into two complementary subcircuits called the tree and the cotree. The incidence matrix is itself divided according to this subdivision, and a simple calculus yields a cut matrix called Q , that allows to compute the currents in the tree in terms of the currents in the cotree, and the voltages in the cotree in terms of the voltages in the tree. A last step consists in building matrices A , B_1 and B_2 that allow to describe the behaviour of the circuit as follows :

$$\frac{d}{dt} X = AX + B_1 U + B_2 \frac{d}{dt} U$$

where

- U is the input vector that contains all voltage and current sources in the circuit
- X is the state vector that contains all voltages in the tree and all currents in the cotree

Matrices A , B_1 and B_2 are computed in terms of the incidence matrix Q and of the characteristics of all components of the circuit (resistances, inductances...). The corresponding formulas can be given upon request.

3. Use of Space

The Space interface appears on Fig.1 : it is exactly analogous to the Simulink interface.

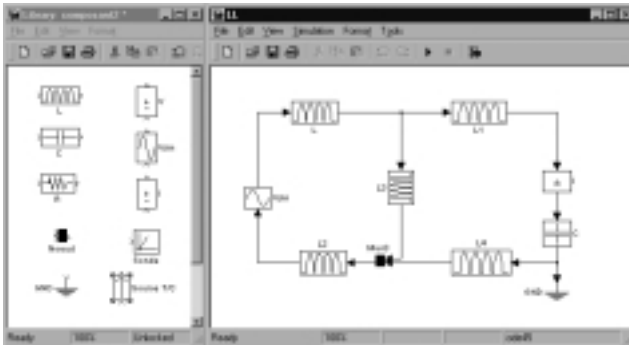


Fig.1: Space interface

The user may either study an existing circuit or create a new one, by drawing the circuit on a new window. The basic components (résistor, self, capacitor, voltage and current sources, ground) are selected in a library (left on Fig.1) and dragged and dropped in the circuit window. A simple mouse selection of a component allows to chose or modify its parameters, as shown in the case of a resistor on Fig.2.

The components library can be enriched with new components : Space was designed so that any component can be itself a circuit consisting of several components. For example, the component « capacitor » used in the serial RC circuit shown on Fig.3 consists in a capacitor in parallel with a leak resistor, what is a classical model for a nonideal capacitor.

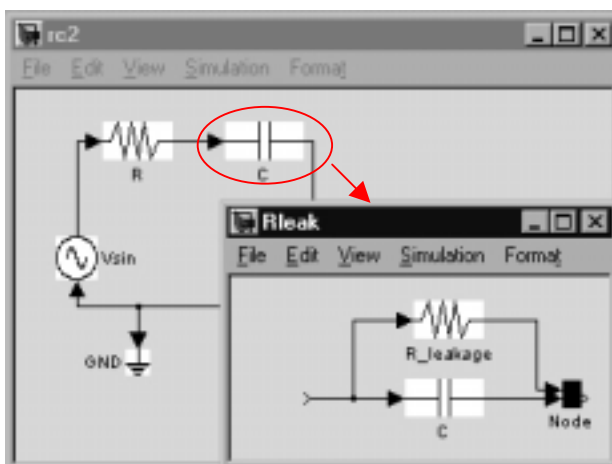


Figure 2: a nonideal capacitor

The simulation interval is, in the linear case, automatically proposed to the user as the maximum time constant of the circuit : the time constants of the circuit are computed as the eigenvalues of matrix A . This choice allows the best trade-off between the computation time

and the significance of the results, because all transient and the beginning of all steady-state behaviors are computed. However, the user may change this simulation interval to any value. In the nonlinear case, the notion of time constant is irrelevant, and the simulation interval should be chosen by the user.

4. Examples of use

The following figures are given to highlight the main features of Space.

This first example shows the transient response in a RC circuit. The figure represents the circuit and the computed voltage of the capacitor.

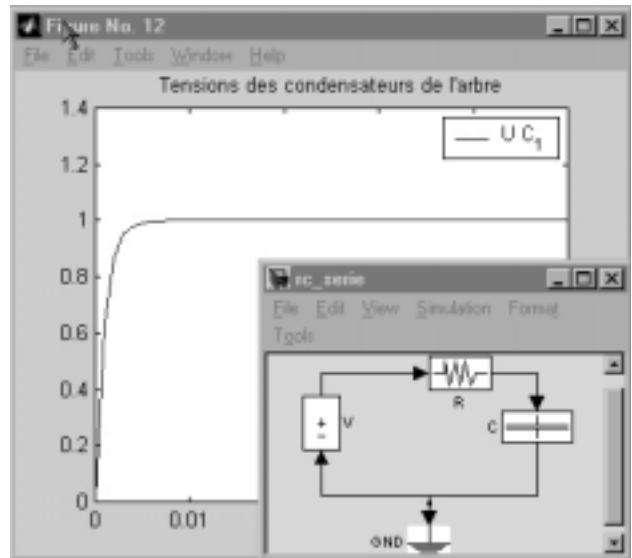


Figure 3 : charge d'un condensateur

Another example is given by the frequency response of a RLC circuit; figure 4 represents the frequency response that is visualized without any extra programming.

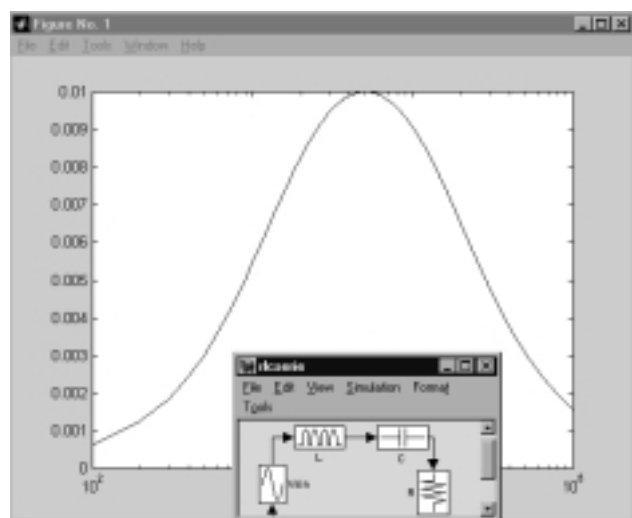


Figure 4 : réponse fréquentielle d'un circuit RLC

Future developments

We are currently working on some developments of Space, in the following directions :

- simulation of nonlinear circuits
- simulation of power electronics circuits

The simulation of power electronics circuits requires only to take into account some special components with specific behaviour, and to compute different kinds of powers in the circuit.

The simulation of nonlinear circuits is a more difficult task,

Références

- [1] Robert C. Balabanian, James A. McPeck, *Electrical Network Theory*, Krieger Publishing Company, June 1969
- [2] Egon Brenner and Mansour Javid, *Analysis of electric circuits*, New York, McGraw-Hill, 1959.