A Modeling Technique for Simulating Power Supply Noise Coupling in a Complex System

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A methodology based on Verilog-A modeling is studied to efficiently simulate the power supply noise coupling in a complex system. The modeling tools have been implemented.

The purpose of this study is to find a generic and efficient way of verifying the supply noise coupling between different blocks in a complex system. The interest of this work is coming from the fact that running transistor-level simulation for complex functional blocks, having very different frequency of operation (e.g. transceiver with 2.45 GHz carrier frequency, audio analog processing, DC-DC converter, etc.), can be too resource-hungry.

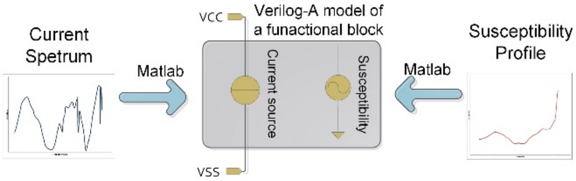

Figure 1: Modeling.

Rebuilding the performances of blocks by Verilog-A behavioral models is considered as a good approach, which is compatible with different design environments. A simple Verilog-A model for supply noise coupling simulation is shown in Figure 1. It consists of two key elements:

- A current source based on the given spectrum of the current flowing through the supply pin of the functional block: with these current sources and the intended regulators, the supply noise can be simulated
- An internal AC voltage source based on the given susceptibility profile: it gives the maximum accepted supply noise level (frequency dependent) of the functional block as a victim, and is used as the reference to judge the acceptance of the supply noise

The chart flow of the modelling is presented in (1) of Figure 2. The two major steps are:

- Approximating current spectrum and susceptibility in Matlab
- Rebuilding the approximation results with Verilog-A

Approximating the current spectrum and the susceptibility over a wide frequency range is the major challenge of this work, considering the accuracy and stability limitations of conventional approximation approaches [1]. In this project, the approximation approach based on the frequency range segmentation is used: applying the approximation over a small frequency subrange, and summing approximation results.

(1) $$\left(\sum_{n=1}^{N}\frac{c_n}{s-a_n}+d+s\cdot h\right)\approx\left(\sum_{n=1}^{N}\frac{\overline{c_n}}{s-a_n}+1\right)f(s)$$

By solving Equation (1) with complex conjugate zero and pole pairs, the frequency range segmentation is automatically achieved; and boundary issue of segmentation is solved.

Equation (1) is a nonlinear problem, as the unknowns, "a_n", appear in the denominator. The "vector fitting" methodology [1] solves the Equation (1) as a linear problem in two stages (as shown in (2) of Figure 2): 1) pole identification and 2) residue identification.

To rebuild the approximation results obtained by Equation (1) with Verilog-A, 2nd order Laplace transform is used for each zero/pole pairs:

(2) $$H(s)=\sum H(s)_i+d, \qquad H(s)_i=\frac{n_2s^2+n_1s+n_0}{d_2s^2+d_1s+d_0}$$

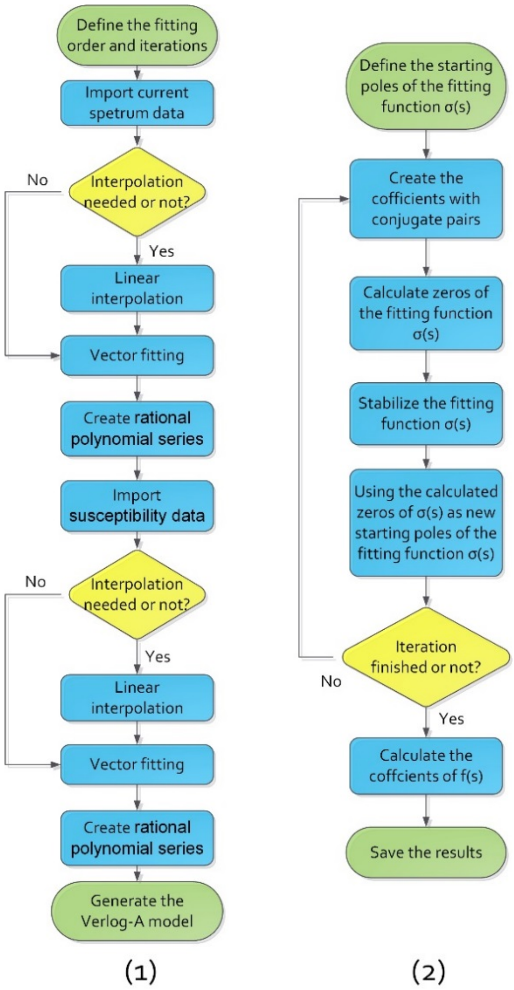

Figure 2: (1) Flow chart of the modeling procedure; (2) Flow chart of the vector fitting procedure.

One modeling example has been carried out based on the supply noise measurement results of the transceiver of icyTRx65 chip: with 90th-order approximation, a Verilog-A model with an approximation error of less than ±5% over the frequency range from 100 Hz to 2.5 GHz is achieved.

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[1] B. Gustavsen, A. Semlyen, "Rational approximation of frequency domain responses by Vector Fitting", IEEE Trans. Power Delivery, 14 no. 3 (1999) 1052