Radioelectronics and Communications Systems
Vol. 47, No. 6, pp. 45–49, 2004

Izvestiya VUZ. Radioelektronika
Vol. 47, No. 6, pp. 65–71, 2004
UDC 621.372.061

DESIGN OF ANALOG NETWORKS BY CONTROL THEORY METHODS. PART 2: NUMERICAL RESULTS

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The paper presents numerical results of design of nonlinear electronic networks based on the problem formulation in terms of the control theory. Several examples illustrate the prospects of the approach suggested.

This part of the work contains examples of comparative design of nonlinear passive and active electronic networks to illustrate the ideas formulated within the framework of the new approach reported in Part 1 [1]. The primary emphasis is placed on demonstration of new opportunities appearing due to application of the new methodology. The number of nodes in the networks taken for illustrations varies from 3 to 5 ($M \in [3, 5]$). We consider the problem of dc analysis, where the objective function $C(X)$ is defined as the sum of squared differences between the preset and current values of nodal voltages for some nodes, supplemented by additional inequalities for some elements of the network. The calculations presented below correspond to two different optimization methods: the gradient method and the Davidon-Fletcher-Powell method (DFP).

The basic system of equations ((15) and (16) presented in [1]) was integrated by the fourth-order Runge-Kutta method. The integration step was chosen optimal and independent for every new strategy to minimize the processor running time. The processor operation time indicated in the calculations corresponds to a computer with a Pentium-4, 2.2 GHz processor.

Figure 1 shows the equivalent circuit of the network to be designed. The circuit has four independent variables ($K = 4$), conductances y_1, y_2, y_3, and y_4, three dependent variables ($M = 3$), nodal voltages V_1, V_2, V_3, and two nonlinear elements.

The nonlinear elements are defined as follows: $y_{n1} = a_{n1} + b_{n1}V_1^2$, $y_{n2} = a_{n2} + b_{n2}V_2^2$. The nonlinearity parameters are $b_{n1} = b_{n2} = 1$. The components of the vector X are defined by formulas $x_1^2 = y_1$, $x_2^2 = y_2$, $x_3^2 = y_3$, $x_4^2 = y_4$, $x_5 = V_1$, $x_6 = V_2$, $x_7 = V_3$. Defining the components x_1, x_2, x_3, and x_4 by the above formulas automatically results in positive magnitudes of the conductance, which eliminates the issue of positive definiteness of the resistances and conductances and makes it possible to carry out the optimization in the whole space of magnitudes of these variables without any limitations.

In this case we have a system of seven equations playing the role of the optimization algorithm, while the network model can be expressed by three nonlinear equations:

$$\mathrm{d}x_i / \mathrm{d}t = -\delta F(X,U) / \delta x_i, \quad i = 1, 2, 3, 4; \tag{1}$$

$$\frac{\mathrm{d}x_i}{\mathrm{d}t} = -u_{i-4} \cdot \frac{\delta}{\delta x_i} F(X,U) + \frac{(1-u_{i-4})}{\mathrm{d}t}\left\{-x_i(t-\mathrm{d}t) + \eta_i(X)\right\}, \quad i = 5, 6, 7,$$

where

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3 December 2003