

TOPICS OF SEMICONDUCTOR CIRCUITS AND DEVICES TUTORIAL MICROCOMPUTER SIMULATIONS

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INTRODUCTION

Very complex phenomena in the electronic circuits and in the semiconductor devices can be relatively easily demonstrated using microcomputer simulation. The graphical capabilities of the microcomputer systems are used to illustrate physical mechanism there. It helps for better understanding, and also it can be used for analysis and design purposes. The main difficulties is to find very rapid algorithms to simulate the transient responses in microelectronic circuits and devices. The development of very fast computer algorithms with small memory requirements was crucial to use a microcomputer as the demonstration tool. Of course different approach has to be used to simulate circuits and devices. This work is further development of the approach presented on 1983 ECTAS Conference in Phoenix, USA.

CIRCUIT ANALYSIS

The algorithm for the transient analysis of electronic circuit was developed based on the charge conservation principle [2]. The algorithm is different than other algorithms used in the most of the circuit analysis programs, where usually after circuit linearization, a sparse matrix techniques is used. Instead, a relatively simple explicit algorithm has been developed. The algorithm uses the unbalance of the conductive currents at each node to compute the charge stored on capacitances connected to that node. Let us assume, that a circuit contains capacitances which values can be modified for each time step.

A circuit contains the static elements, which currents can be

conduction function of node voltages.

In every circuit the sum of currents for each node is equal zero:

$$/3/ I_i(v_1, v_2, \dots, v_N) + \sum_{j=1}^N C_{ij} \frac{dv_j}{dt} = 0$$

First term in equation /3/ is the sum of conduction currents and second term is the sum of displacement currents (through capacitances). In traditional approach these equations are solved through linearization using Newton-Raphson algorithm and sparse matrix techniques [3]. In the presented algorithm it was assumed that for each time step the conduction currents are constant and they are computed in explicit way. Therefore the net the linear differential equation has to be solved:

$$/3/ \sum_{j=1}^N C_{ij} \frac{dv_j}{dt} = A_{ii}$$

A_{ii} is unbalanced conduction current for node i . Introducing discrete time step Δt problem is reduced to the solution of matrix equation:

$$/3/ [C_{NN}] [\Delta V] = [A_{ii}] \Delta t = [A_{ii}]$$

Above equation describes capacitance network forced by charged ΔV at each node. It should be notified that in matrix equation /3/ main diagonal is dominant therefore it can be solved by simple iterative procedure.

Comparison of presented algorithm with the most popular one used in the SPICE program [3] was carried out on VSM 700 computer. As result it was concluded that for the medium size circuit (about 20 transistors) the computing time of developed program was about 100 times shorter. Also in this case the computing time increases linearly with the circuit complexity in contrast to other known algorithms where the computer time depends on much factor than the number of circuit nodes. Other advantage of this approach is the small memory requirements.

Therefore it was possible to implement this algorithm for 3 various microcomputer systems: 6502 processor with 64k memory, Z-80 processor with 64k memory under CPM operation system and 8088 processor with 256k memory under MS DOS operation system. If it is assumed that for the purpose of demonstration the waiting time for one time increment should be less then 5 second, then in case of the 8-bit microcomputer the practical limit of the circuit size was about 10 transistor. However the transient analysis for the circuits up to 100 transistors can be carried too. In case of 16-bit microcomputer response time was only slightly better but much larger circuits could be analyzed. The program, on 6502 system with very good graphical capability, was used in the postgraduate courses in microelectronics for high school teachers at the Technical University of Gdansk. Various kind of digital integrated circuits were simulated. Also this tool was used to demonstrate the electro-thermal interaction in microelectronic circuits and devices. On the other special course for the industry the nonlinear LCR television circuits were simulated in order to demonstrate extreme conditions during switching-on transients.

SEMICONDUCTOR DEVICE ANALYSIS

The program for the semiconductor device simulation need more computing time despite the fact that simulation is done for one dimension only. This general program requires only as an input data the impurity profile and the applied voltage. The program solves set of five differential equations describing behavior of semiconductors. The solution algorithm follow directly the physical phenomena in semiconductors and can be described as follow. In nonequilibrium case the unbalanced electron, hole and recombination currents cause variation in electron and hole concentration.

$$/4/ \frac{dp}{dt} = -\frac{1}{q} \frac{dJ_p}{dx} - R$$

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