

Developing Educational and User Applications of Network-oriented Electronic Design within the COPERNICUS Telematics Program*

A. I. PETRENKO

National Technical University of Ukraine, 'Kiev Polytechnical Institute', Peremogy Rd. 37, Kiev-56, Ukraine. E-mail: petrenko@cad.ntu-kpi.kiev.ua

ALLTED (All-Technologies System Designer) is a PC-oriented CAD system for nonlinear dynamic systems design providing a powerful procedure of optimization with parametrical and functional constraints for single- or multi-criteria tasks for DC, AC, and TR analyses. The comparative demonstration of ALLTED's possibilities to simulate and optimize electronic circuits is demonstrated together with a description of the networked ALLTED version being developed in partnerships with the support of a European Union Telematics development program.

INTRODUCTION

ALLTED is a CAD design system developed at the National Technical University of the Ukraine. It covers all design steps from an initial schematic diagram to a final design version [4, 8]. In order to determine all the parameter values necessary to meet the end specification requirements the mathematical model of an object is automatically constructed and steady-state (DC), transient (TR), frequency (AC), statistical (Monte Carlo), spectral (Fourier) analyses are carried out [1, 6]. This is followed by high-level operations such as Worst Case, Sensitivity Analysis, Optimization, Optimal Tolerance Assignment, etc.

The system is based on original algorithms and possesses some important adaptation features to ill-conditioned tasks and DC, TR stiffness [5, 7].

ALLTED has a SPICE-like appearance and functionality with the following list of circuit simulation features:

- schematic capture (Fig. 1) and Graphics Editor (Fig. 2);
- output graphics (Fig. 3 and Fig. 4), post-processor;
- device parameter identification subsystem;
- user-defined models and functions;
- mixed-mode (analog/digital) simulation;
- basic analysis (DC, TR, AC, Fourier);
- component model libraries;
- on-line helps, prompt/diagnostic message subsystem;
- advanced analysis (Monte-Carlo, sensitivity

analysis SA, worst case WC) for DC, TR and AC.

Note that SPICE provides SA and WC only for DC. In comparison to the SPICE family of programs ALLTED has the following additional features:

- Powerful procedure of automatic determination of secondary response parameters (delay, rise and fall times, bandwidth, resonance frequency, etc.) and a calculation facility of the functions of these parameters;
- general and very powerful circuit optimization capabilities for single- or multi-criteria tasks with parametrical and functional constraints. Secondary parameters may be used as optimized variables together with primary response quantities (voltages, currents, powers) [3];
- applications in different areas (electronic, mechanical, hydraulic, pneumatic, electro-magnetic) singly or in combination with existing libraries of user-defined options [2].
- a common approach to simulate hybrid objects consisting of different physical phenomena elements: electronic, hydraulic, pneumatic, mechanical, etc. and automatic procedures of common mathematical equations formation;
- user-defined models for object elements, procedures of model parameter identification, models library management.

The ALLTED software is already being used for education at the Kiev Polytechnic Institute, Michigan State University (USA), and Hong-Kong University. The algorithmic fundamentals of ALLTED are described in [6, 9].

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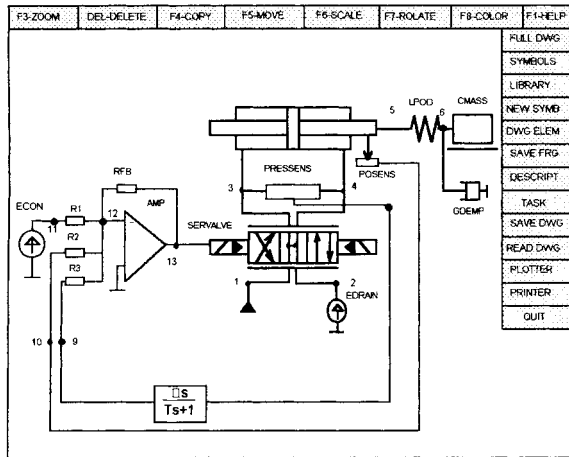


Fig. 1. Schematic diagram.

NETWORK-ORIENTED ELECTRONIC DESIGN

In addition to the standalone educational applications, we are now employing network capabilities to deliver a wider range of CAD software and study cases, faster and better tailored to the needs of users. This expanded use is being developed with the support of the European COPERNICUS program. The development is carried out in the project 'Multimedia Education: an experiment in delivery of Computer Based Learning materials' (Task PL 96 1046). This program supports Telematics projects which are taken up jointly between Eastern European and Western European institutions, i.e. between members and non-members of the European Union. Its aim is to support dissemination of Telematics technology in member countries as well as in the politically reformed countries of Eastern Europe.

The partners in this project are:

- The CAD Department of the National Technical University of Ukraine 'Kiev Polytechnic Institute'.

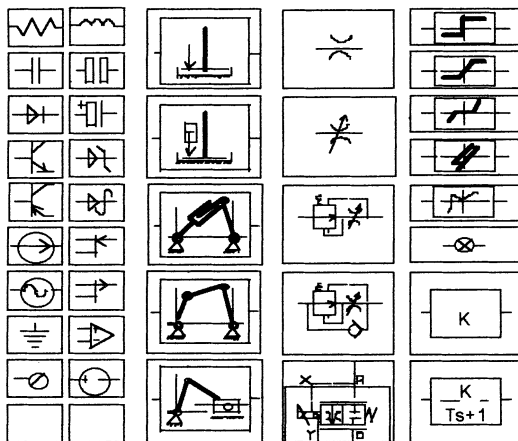


Fig. 2. ALLTED Graphics Editor icons.

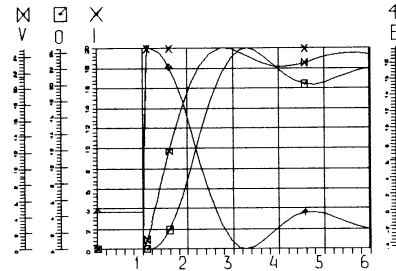


Fig. 3. Transient response.

- Bristol University (UK).
- FIM-Psychology, University of Nuerenberg-Erlangen (Germany).
- Wroclaw Technical University (Poland).

Within this project the following general aims are being pursued:

1. To respond to the needs of users in Electronic Design (e.g. ASICs) focusing both on the delivery of multimedia simulation packages developed by partners and their improvement by making them more open for use with other CAD tools, more understandable and more widely available through the network.
2. To adapt the CAD software to specific needs by allowing local individuals to reconfigure the modules and to provide design examples relevant to the problems concerned. The ability to update on site is therefore very important, and it is particularly important for the user to consult via the network on the tool and packages available for solving particular problems.
3. To make use of network capabilities to interactively access a range of remote CAD tools as part of the design capabilities and to allow individuals to interact with a remote mentor via the network.

The main emphasis is to build and validate different network delivery methods for multimedia education materials targeted at universities and private companies. The project is being implemented in two phase:

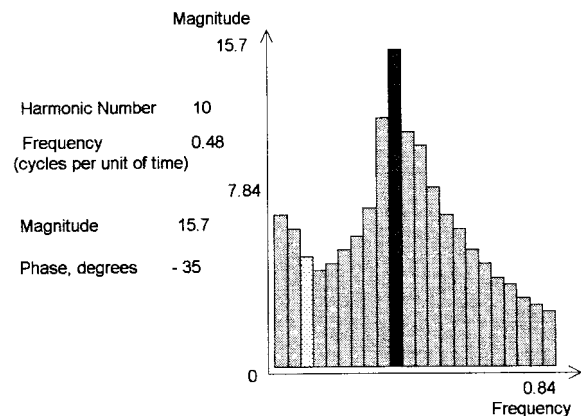


Fig. 4. Spectrogram example.

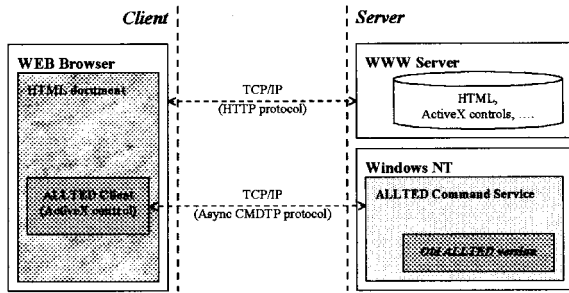


Fig. 5. Networked ALLTED version.

- *Preparation phase*: user needs analysis, preparation and adaptation of electronic CAD and simulation software for remote access: client-server CAD software, remote CAD tools.
- *Main phase*: set-up of local delivery servers, exploiting a range of delivery methods—downloading, WWW, remote tools; developing a range of methods of interactive human tutor based services—e-mail, discussion list, audio and video-conferencing with experts, development and validation of education management system.

The CAD department in Kiev is preparing multimedia learning software based on ALLTED with the facilities of distance on-line education and network distribution. A further major educational and training tool being developed for the Web in this project is the EDEC electronic education software developed by a consortium of UK universities and which is represented in our project by the University of Bristol, Electronics Department. This software was described by Hicks *et al.* [10].

Pilot software based on client-server technology has been developed (Fig. 5). It can serve multiple clients, in different classrooms or company locations (Fig. 6).

For the remote working with ALLTED a Web browser (Microsoft Internet Explorer 3.01, Netscape Navigator), which supports ActiveX controls, is required. For Windows 95 installation of DCOM is required.

The screens of the ALLTED Client and Main Menu are shown in Fig. 7 and Fig. 8.

The following are the active commands:

- File*—for tasks and simulation results presentation and restoration on a local computer;
- Execute Task*—for task-fulfilling control on ALLTED server;

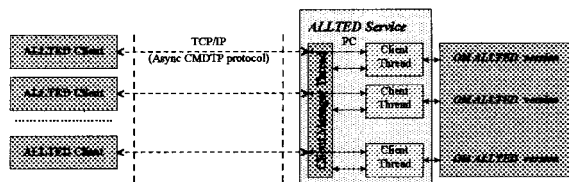


Fig. 6. Multi-user ALLTED service.

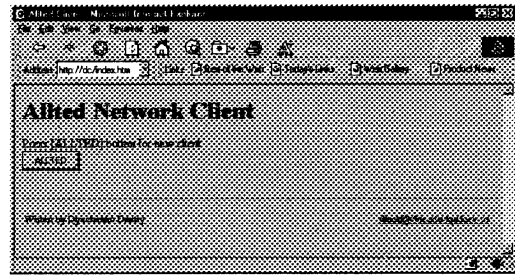


Fig. 7. ALLTED client screen.

- On-Line*—for on-line working through direct connection with the server;
- Break*—for task stopping on-line;
- E-Mail*—for off-line working;
- Check E-Mail*—for checking a mail with simulation results;
- Server Change*—for changing a server name when a particular task is being run.

After pushing the button 'ALLTED' (Fig. 7) you can print your task description or open a file with the task at the upper part of the Client screen



Fig. 8. Main menu of operation.

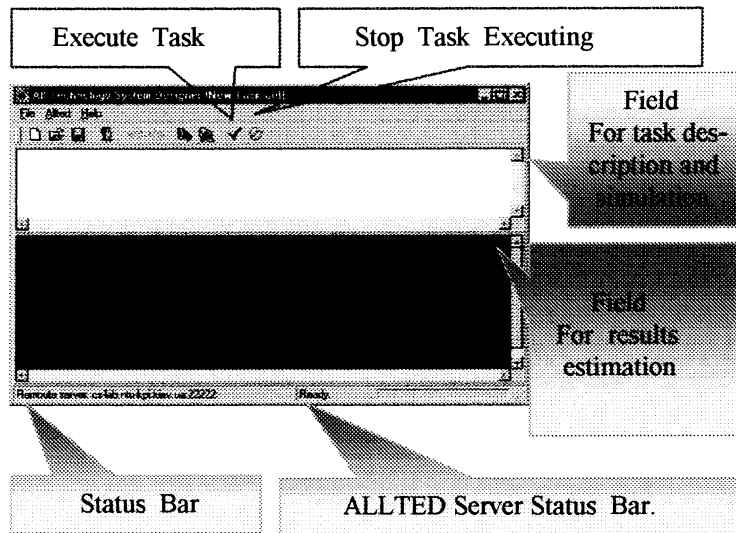


Fig. 9. Screen fields for task description and simulation results estimation.

(Fig. 5). Then select the options Allted > Execute task > On-Line or push the button 'Execute task' of the Speed Bar. The Status Bar will change showing the current task situation (Connecting . . . , Connected, Sending task . . . , Executing task . . . , Receiving results . . . , Ready). The simulation results (or possible description mistakes) will be shown in the lower part of the screen (Fig. 9).

DESIGN EXAMPLE

The system is demonstrated in an example of the operational amplifier for a unity-gain buffer (Fig. 10). It facilitates the following implementation:

- The design of a MOSFET-transistor VLSI with the same BSIM model of MOSFET as SPICE-3F does.
- Unique ALLTED's features (which are absent in SPICE-3F) such as optimization, automatic determination of secondary response parameters, building a dependence curve of response parameters for selected transistors' parameters.
- ALLTED's suitability for designing op-amps, generators, switches, logical blocks and other VLSI fragments.

For the op-amp circuit (Fig. 10) a transfer characteristic $V_{out} = f(E_{plus})$ was determined, when voltage E_{plus} was applied between nodes PLUS and MINUS and was linearly varied from

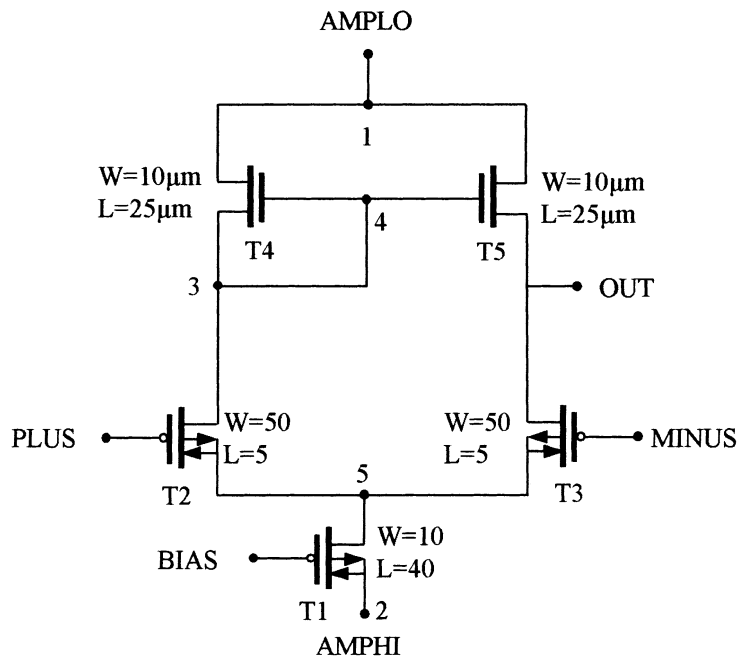


Fig. 10. Op-amp circuit.

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Object
1 Search MOSMOD;
2 Circuit Opamp_for_Unity_Gain_Buffer_N_2;
3 Jdrain(Din,Sin) = F701(TYPE, L, W, Wmult, TOX, VFB,
  PHI, K1, K2, ETA,
4 Eamplo(1,0)=-3;
5 Eamphi(2,0)=2;
6 T2(3,plus,5,5) = Pcab.BSIMlng( L=5.u, W=50.u );
7 T3(out,minus,5,5) = Pcab.BSIMlng( L=5.u, W=50.u );
8 T4(3,3,1,1) = Ncab.BSIMlng( L=25.u, W=10.u );
9 T5(out,3,1,1) = Ncab.BSIMlng( L=25.u, W=10.u );
10 T1(5,bias,2,2) = Pcab.BSIMlng( L=40.u, W=10.u );
11 Ebias(bias,0) = 0.72823;
12 Eplus(plus,minus)=ftab(0,-2.0e-4,1000.m,2.0e-4);
13 Eminus(minus,0)=0;
14 #output
15 #Rout(out,0)=1000.0k;
16
17
18 &

Library section BSIMLNG
1 Model BSIMLNG( D, G, S, B );
2 Rd(D,Din)=RSH; Rs(S,Sin)=RSH;
3 Jdrain(Din,Sin) = F701( TYPE, L, W, Wmult, TOX, VFB,
  PHI, K1, K2, ETA,
4 X2E, X3E, MUZ, X2MZ, UO, X2UO, U1, X2U1, X3U1,
5 MUS, X2MS, X3MS,
6 NO, NB, ND, VDD, XPART, DL, DW,
7 CJ, MJ, PB, CJSW, MJSW, PBSW,
8 CGDO, CGSO, CGBO, FC / UJdrain, UJCgs,UJCbs);
9 JCbs(B,Sin) = F702(/UJCbs);
10 JCbd(B,Din) = F703(/UJCbd);
11 JCgs(G,Sin) = F704(/UJCgs);
12 JCgd(G,Din) = F705(/UJCgd);
13 JCgb(G,B) = F706(/UJCgb); &

Library section PCAB.BSIMLNG
1 List Pcab.BSIMlng;
2 TYPE=-1;
3 L=2.u; W=18.u; TOX=250.0e-04; VFB=-1;
4 PHI=1; K1=1; K2=0;
5 ETA=0; X2E=0; X3E=0;
6 MUZ=350; X2MZ=0;
7 UO=0.0; X2UO=0.0;
8 U1=0.7; X2U1=0.0; X3U1=0.0;
9 MUS=350; X2MS=0.0; X3MS=0.0;

10 NO=2.5; NB=0.0; ND=0.0; VDD=5.0; XPART=0.0;
11 DL=0.0; DW=0.0;
12 CJ=0.0; MJ=0.0; PB=0.0;
13 CJSW=0.0; MJSW=0.0; PBSW=0.0;
14 CGDO=1.5e-9; CGSO=1.5e-9; CGBO=2.0e-10;
15 FC=0.0; WMULT=1;
16 RSH=0; &

Library section NCAB.BSIMLNG
1 List Ncab.BSIMlng;
2 TYPE=1;
3 L=2.u; W=18.u; TOX=250.0e-04; VFB=-1;
4 PHI=1; K1=1; K2=0;
5 ETA=0; X2E=0; X3E=0;
6 MUZ=1100; X2MZ=0;
7 UO=0.0; X2UO=0.0;
8 U1=2.0; X2U1=0.0; X3U1=0.0;
9 MUS=1100; X2MS=0.0; X3MS=0.0;
10 NO=2.5; NB=0.0; ND=0.0; VDD=5.0; XPART=0.0;
11 DL=0.0; DW=0.0;
12 CJ=0.0; MJ=0.0; PB=0.0;
13 CJSW=0.0; MJSW=0.0; PBSW=0.0;
14 CGDO=1.5e-9; CGSO=1.5e-9; CGBO=2.0e-10;
15 FC=0.0; WMULT=1;
16 RSH=0;

Task
1 dc;
2 tr;
3 const tmax=1000.m,dcmxat=50,lerr=1.0e-3,err=0.01;
4 plot Ueplus,vout;
5 plot vout(Ueplus);
6 fix ain0=fixa(Ueplus,1.m),ain1=fixa(Ueplus,999.m);
7 fix bin0=fixa(vout,1.m),bin1=fixa(vout,999.m);
8 int delta1=ain1-ain0;
9 int delta2=bin1-bin0;
10 func gain=f5(1/delta2,delta1);
11 varpar W.t3=W.t2(10.u,100.u);
12 varpar L.t3=L.t2(2.u,20.u);
13 varpar W.t4=W.t5(5.u,50.u);
14 varpar L.t4=L.t5(10.u,100.u);
15 mva;
16 control gain;
17 const numb=10;
18 &

```

Fig. 11. Op-amp simulation task file.

–200 mV to +200 mV for 1 s. Bias voltage $E_{\text{bias}} = 0.72$ V was applied to transistor T1.

It is possible not only to find out the relationship $V_{\text{out}} = f(E_{\text{plus}})$, but also to calculate the gain coefficient as:

$$\text{Gain} = \frac{\Delta V_{\text{out}} / \Delta E_{\text{plus}}}{\div (E_{\text{plus}} t_2 - E_{\text{plus}} t_1)} = \frac{(V_{\text{out}} t_2 - V_{\text{out}} t_1)}{\div (E_{\text{plus}} t_2 - E_{\text{plus}} t_1)}.$$

The op-amp simulation task file is given in Fig. 11 and includes circuit description (object part) and analysis requirement (task part). A plot of the relationship $V_{\text{out}} = f(E_{\text{plus}})$ is shown in Fig. 12. For the purpose of gain calculation the directive FIX was used which allows determination of input and output signal values at $t = 1$ ms and $t_2 = 999$ ms (ain0, ain1, bin0, bin1 on Fig. 11). With the help of another directive INT, differences $\text{delta1} = \text{ain1} - \text{ain0}$, $\text{delta2} = \text{bin1} - \text{bin0}$ were defined and a directive FUNC allowed to determine:

$$\text{Gain} = \text{delta2} / \text{delta1}$$

The multivariable analysis of an op-amp circuit was carried out to determine the dependence of gain on channel widths and lengths of transistor T2, T3, T4, T5. The circuit was simulated N times by selecting one of the variable parameters from the range A_{min} to A_{max} with steps equal $(A_{\text{max}} - A_{\text{min}}) / (N - 1)$ as given by a directive VARPAR (Fig. 11). All other parameters were considered constant. After N simulation another parameter was selected as variable and the simulations continued until the VARPAR list ran through.

In our case the list included eight parameters: VARPAR = {W.T2, L.T2, W.T3, L.T3, W.T4, L.T4, W.T5, L.T5}. A directive CONTROL was used to investigate gain. ALLTED is able to show simultaneous parameter changes by the following construction:

$$\text{VARPAR W.T2} = \text{W.T3}(10 \mu\text{m}, 100 \mu\text{m})$$

Figures in brackets set the min and max values which the parameters W.T2 and W.T3 can have. In

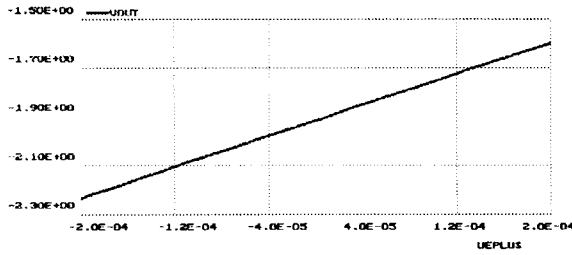


Fig. 12. Dependence curve $V_{out} = f(E_{plus})$.

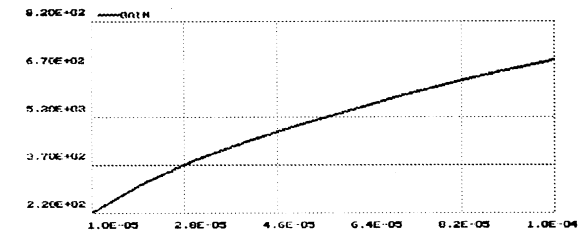
Fig. 13 the effect of changing W.T3 and L.T3 on the gain are shown.

OPTIMIZATION

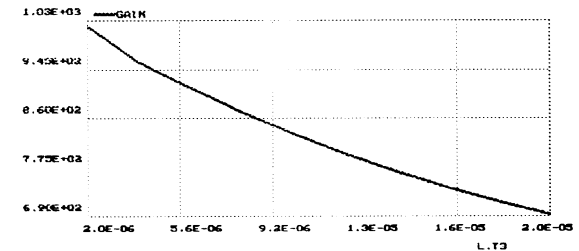
The results of the multivariable analysis of the op-amp show the possibility of increasing the gain coefficient by selecting proper values of W.T2, W.T3, L.T2, L.T3, W.T4, W.T5, L.T4, L.T5. This task is completely solved by ALLTED as an optimization task:

$$\{W, L\} = \text{ARGMIN}(1/\text{Gain})$$

For optimization a directive OPTIM was used (Fig. 14). The goal function to be minimized can be selected by the directive OF from the system library (in our case it was function F5) or defined by a user. An optimization method is selected from ten possible ones by the constant METHOD. In our case this is a shrinking random method together with a generalized variable order method which uses four terms of Taylor's expansion for an objective function [2,7]. Variable parameters as before at MVA were determined by the directive



(a)



(b)

Fig. 13. (a) Dependence characteristic curve for $\text{Gain} = f(W.T3)$; (b) Dependence characteristic curve for $\text{Gain} = f(L.T3)$.

Task

```

1 dc;
2 tr;
3 const tmax=1000.m,dcmaxit=50,lerr=1.0e-3,err=0.01;
4 #plot Ueplus,vout;
5 plot vout(Ueplus);
6 fix ain0=fixa(Ueplus,1.m),ain1=fixa(Ueplus,999.m);
7 fix bin0=fixa(vout,1.m),bin1=fixa(vout,999.m);
8 int delta1=ain1-ain0;
9 int delta2=bin1-bin0;
10 func gain=f5(1/delta1,delta2);
11 of maxgain=f5(1/gain);
12 varpar W.t3=W.t2(5.u,100.u);
13 varpar L.t3=L.t2(2.u,20.u);
14 varpar L.t4=L.t5(10.u,250.u);
15 optim;
16 const numb=40,operr=1.0e-6,method=40,oprint=1;
17 &
    
```

Fig. 14. Optimization task file for op-amp circuit.

VARPAR. Optimization results are given at Fig. 15.

The plots $V_{out} = f(E_{plus})$ before and after optimization (Fig. 16) show that the optimization parameter Gain was increased from 1500 to 5000 without changing the circuit schematic for the op-amp. Similarly it is possible to solve other optimization problems such as minimization of time delay or rise and fall times of Vout, minimization of consumed power, decreasing fragment square, etc. None of these tasks can be solved by the PSPICE program.

CONCLUSIONS

Trial tests show that ALLTED solves the optimization problems directly and effectively using an ordinary PC.

ALLTED is related to innovative design tools and methodology for the simulation, analysis, optimization and design of nonlinear dynamic systems, as used in robotics, mechatronics and other applications. It helps to improve electronic systems performance, reliability and maintainability because it can take into account any user-defined nonlinear performance function or component model, optimal parameter values and their tolerance assignment, faults and simulations, etc.

Optimization is one of the most powerful features of the software being developed. It uses a variety of effective methods to solve constrained

Object status at last point
 Objective function
 MAXGAIN = 0.2235452412D-03
 Variable parameters

Name	Low boundary	Optimal value	Upper boundary
W.T3	0.50000E-05	0.78986E-04	0.10000E-03
W.T2	0.50000E-05	0.78986E-04	0.10000E-03
L.T1	0.20000E-05	0.16287E-04	0.20000E-04
L.T2	0.20000E-05	0.16287E-04	0.20000E-04
L.T4	0.10000E-04	0.14772E-03	0.25000E-03
L.T5	0.10000E-04	0.14772E-03	0.25000E-03

Fig. 15. Optimization results

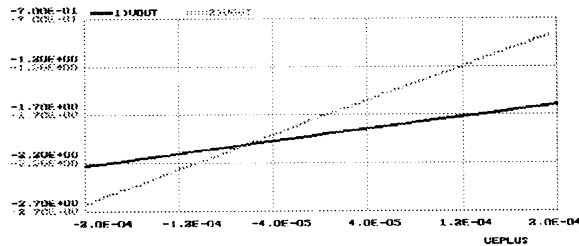


Fig. 16. Comparative plots $V_{\text{out}} = f(E_{\text{plus}})$ before (solid) and after (dotted) optimization.

or unconstrained optimization problems with single or multiple criteria. It also provides means for users to specify how output characteristics meet the required object quality by formulating object design requirement in the form of goal functions and constraints.

With the network development now under way in the COPERNICUS-INCO program it will soon be available to students and other users via the Internet. For further information: <http://www.cad.ntu-kpi.kiev.ua>.

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Anatoly Petrenko is an acknowledged scientist and originator in the concepts and development of design automation techniques in the former USSR, an organizer of advanced electronic engineering education and professional training in the Ukraine, and a technical leader in the initiation and development of international and European educational and research programs. Prof. Petrenko obtained his Engineering Degree in 1957 from the Kiev Polytechnic Institute, a Diploma of Imperial College in 1960 from London University, his Candidate of Science Degree (Ph.D.) in 1961 from Moscow Power Institute and Doctor of Science degree in 1969 from Moscow Power Institute. He was a visiting professor at California University (Berkeley) in 1976 and a visiting Professor at Michigan State University in 1991. Prof. Petrenko was invited for lecturing to Sofia and Gabrovo Technical Universities (1970, 1977), Wrocław and Warsaw Technical Universities (1975), Budapest Technical University (1979, 1984), Munich Technical University (1989), Surrey University (1989), Sydney Technical University (1989), Torino Politecnica (1988), Carnegie-Millon University (1991), Concordia University (1993) and New Jersey Institute of Technology (1995). The scope of Prof. Petrenko's scientific activities and interests include computer-aided techniques, circuit simulation and optimization, large-scale systems, numerical algorithms, and VLSI design and layout.