REPORT OF THE ACTIVITIES OF THE GROUP ON NETWORK THEORY OF THE DEPARTMENT OF ELECTROMAGNETIC THEORY, TECHNICAL UNIVERSITY BUDAPEST*

GY. FODOR

Department of Electromagnetic Theory,
Technical University, H-1521 Budapest

Received December 7, 1985

The Department, founded in 1949 by Professor Károly Simonyi and led by him till 1970, is active in groups following the specialization of the students. This report is on the research activities of the past five years in the field of network theory, carried out by the group (leader: Professor Gy. Fodor) teaching students specialized in instruments and control. The members of the group are active in other fields too, and members of other groups have also attained results in network theory; these activities, however, are not considered in this report. The members of the group have started their work under Professor Simonyi, all are directly or indirectly his disciples.

The objective of the group's activities is clarification of conceptual problems regarding algorithms for generating and solving the equations of networks of different types and for preparing computer programs based on them. The work was carried out partly by the members of the teaching staff, partly by post-graduate students working on their doctoral dissertation, and partly by students preparing their graduation thesis or performing compulsory and non-compulsory independent activities. The concept of the work was given by Gy. Fodor's books; in guiding the students' work and in developing the concepts in certain topics, Klára Cséfalvay's role is outstanding. Other members of the teaching staff of the department and members of the teaching staff of the Department of Instruments and Measuring also participated.

The report is grouped according to the types of the networks studied.

Continuous-time Kirchhoff-type networks

Theoretical results: concept of regularity of the network, classification of non-regular networks, description of linear networks by state variables, generation of normal and quasi-normal forms using nodal analysis, symbolic

* Dedicated to Professor Károly Simonyi on the occasion of his Seventieth Birthday

and semi-symbolic generation of the transfer function, calculation of sensitivity functions and their application for tolerance distribution, canonical form of the equations of non-linear networks and their solution.

Computer programs; name of preparer; computer type
ALIZ; Zs. Abonyi; PDP 11/45, HP 41 CV
KVAZI; Gy. Czéh, Gy. Kray, T. Szvitacs, A. Seres; PDP 11/45
LINA, KLINA; I. Varga; PDP 11/45
SYMBOL; L. Kunsági; PDP 11/45
SGSM; L. Szakony; C 64

The programs are suitable for the analysis of linear invariant networks. The permitted element set consists of resistances, capacitors, coils, coupled coils, independent and controlled sources or generators, ideal operational amplifiers (in all programs), resistive multi-ports with hybride-type characteristics (KVAZI, LINA), ideal transformers, negative impedance converters, gyrators (KVAZI, LINA, SYMBOL), operational amplifiers (ALIZ, SYMBOL), negative impedance inverters, frequency-dependent negative resistances (SYMBOL), linearized transistors (ALIZ), coupled capacitors (LINA). The programs KVAZI and KLINA are also suited for the analysis of quasi-regular networks.

Performances of the programs

— DC and AC analysis (all programs)
— $W(s)$ transfer function, its poles and zeros (ALIZ, KVAZI, LINA, SYMBOL)
— $W(j\omega)$ table (ALIZ, KVAZI, LINA, SGSM), Nyquist plot (KVAZI, SGSM), Bode plot (KVAZI, LINA, SGSM)
— state variable description (ALIZ, KVAZI, LINA)
— calculation and plotting of the time function of the solution (ALIZ, KVAZI, LINA)
— $W(s)$ fully or partially in the symbolic form (ALIZ, SYMBOL)
— expression of sensitivity functions, calculation and plotting of real and imaginary part (LINA, SYMBOL)
— from tolerance scheme: transfer function of Butterworth, Chebishev, inverse Chebishev and Cauer filters, parameters of second-order fundamental sections (ALIZ).

Discrete-time linear signal flow networks

Theoretical results: generation and solution of frequency-domain equations, generation and solution of the full and reduced normal form of the state variable description, symbolic and semi-symbolic network analysis, calculation of sensitivity functions.

Computer programs; name of preparer; computer type

DNA; L. Zsoldos, Z. Sik; PDP 11/45

DSYM; L. Kunsági; PDP 11/45

DLNA; A. Sipos Győri; C 64

All programs are interactive. DNA is only suited for handling two-pole transfer components, while DSYM and DLNA are suited for multi-pole components.

Performances of the programs

— list of the network (DNA, DSYM)
— normal form of the state equation (DNA)
— the transfer function $W(z)$, its poles and zeros numerically (DNA) and semi-symbolically (DSYM)
— weighting function, unit step response analytically (DNA)
— inverse z-transformation (DNA)
— list and Bode plot of the transfer characteristic $W(e^{j\vartheta})$ (all programs)
— sensitivity functions (DNA, DSYM)
— response in numerical form (DNA)

Filter design

— approximation of FIR and IIR filters (L. Kunsági) interactive program; PDP 11/45
— wave-digital approximation of the *LC* ladder filter (Zs. Abonyi);
— INTEL 2920 microprocessor program, ASSEMBLER
— wave-digital lattice filter (L. Szakony); TMS 320 program

Mixed linear signal flow networks

Theoretical results: generation and solution of complex frequency domain equations of continuous and discrete-time (analogue and digital) networks containing multi-pole components, generation and solution of the state variable normal form.

Computer program; name of preparer; computer type

ADCIRC; S. Szegő; PDP 11/45

Permitted set of elements: continuous and discrete time sources, two-pole and multi-pole transfer components, A/D and D/A transverters.

Performance of the program:

— state variable normal form

— time function of the responses.

SC networks

Theoretical results: generation and solution of time domain, z-domain and frequency domain equations of multiphase ideal and dissipative coupled capacity networks, reduction of the system of equations by introducing blocks, generation of the transfer matrix, normal form of the state variable description for regular and quasi-regular networks.

Computer program; name of preparer; computer type

— SC-CIRC; Zs. Ákosfai, Z. Fekete; VC 64

Set of elements: ideal C and S, dissipative operational amplifier.

Performance of the program: generation of the state variable normal form per phases, which can also be solved for quasi-regular cases by the application of KVAZI. Further development is in progress.

Wave-digital simulation

Theoretical results: unified wave variable description and discrete time approach of linear and non-linear lumped and linear distributed networks, generation and solution of the canonical equations of the discrete-time network, resolution of algebraic loops.

Computer program; name of preparer; computer type

— TIME; L. Petróczky, EMG 777

Performances of the program after supplying the model of the linear or non-linear two-pole component of the wave variable model of the linear distributed-parameter two-port network:

— state-variable description in a canonical form,

— discrete-time approach of the responses, tabularly and graphically.

The graphical display gives a clear idea of the wave phenomena in the network.

Bibliography (from 1980 on)

a) Books

GY. FODOR: Nodal analysis of electrical networks (in Hungarian). Műszaki Könyvkiadó, Budapest 1982. An extended English publication is under way.

K. CSÉFALVAY et al.: Program systems for network analysis (in Hungarian). Tankönyvkiadó, Budapest 1985.

GY. FODOR: Electromagnetic theory I. Electrical networks (in Hungarian) Tankönyvkiadó, Budapest 1985.

b) Doctoral dissertations

I. VARGA: Calculation of sensitivities and its application for the optimization of networks (in Hungarian), 1984.

K. CSÉFALVAY: Wave variable simulation and discrete approximation of mixed component networks (in Hungarian) 1985.

c) Graduation theses

I. VARGA: Analysis of linear time-invariant regular and quasi-regular networks (in Hungarian), 1982.

ZS. ABONYI: Application of data-processing microprocessors (in Hungarian), 1984.

L. KUNSÁGI: Approach of transfer characteristics (in Hungarian) 1984.

L. PETRÓCZKY: Wave-digital simulation of continuous-time networks (in Hungarian), 1985.

d) Conference lectures

K. CSÉFALVAY—L. KUNSÁGI: Generation of symbolic transfer functions and sensitivities (in Russian). Popov Conference, Moscow 1985.

K. CSÉFALVAY—V. KRIZS—L. PETRÓCZKY: Use of wave digital networks for time domain simulation of mixed lumped and distributed circuits. 2nd International Symposium on System Analysis and Simulation, Berlin 1985.

K. CSÉFALVAY—I. VARGA: Sensitivity calculation in discrete-time networks. ECCTD '85, Prague 1985.

L. KUNSÁGI—K. CSÉFALVAY: Symbolic network analysis. ECCTD '85, Prague 1985.

K. CSÉFALVAY: Discrete modeling of networks with lumped and distributed parameters (in Russian). 3rd International Symposium of Departments of Electromagnetic Theory in Socialist Countries, Moscow, 1985.

e) Papers

I. VARGA: Sensitivity analysis of linear networks by a modified nodal method. Periodica Polytechnica Electrical Engineering, 29, 13 (1985). In Hungarian: Híradástechnika, *35*, 169. (1984).

K. CSÉFALVAY—I. VARGA: Sensitivity analysis of discrete-time networks (in Hungarian). Híradástechnika, *36*, 193 (1985).
L. KUNSÁGI—K. CSÉFALVAY: Symbolical analysis. I. Continuous-time networks, II. Discrete-time networks (in Hungarian) Híradástechnika (in press).

f) Papers for scientific students' circles

21 papers between 1980 and 1985; 2 won special prizes, 7 first prizes, 5 second prizes, 4 third prizes, 3 were rewarded with books.

Prof. György FODOR H-1521 Budapest