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USSR Report

ELECTRONICS AND ELECTRICAL ENGINEERING

(FOUO 10/81)

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CONTENTS

CERTAIN ASPECTS OF COMPUTER HARD AND SOFT WARE: CONTROL, AUTOMATION, TELEMECHANICS, TELEMETERING, MACHINE DESIGNING AND PLANNING

UDC 681.3.06

ELECTRONIC CIRCUIT ANALYSIS ALGORITHMS TAKING INTO ACCOUNT THE FINITE WORD LENGTH OF COMPUTERS

Kiev IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: RADIOELEKTRONIKA in Russian Vol 24, No 6, Jun 81 (manuscript received 12 Aug 79, after revision 19 Jun 80) pp 102-104

[Article by N.G. Levshin]

[Text] Below are presented methods of reducing errors in the numerical analysis of electronic circuits caused by a considerable difference in the parameters of their components. For the sake of definiteness a system of linear equations is considered which is formed according to the nodal potential method:

$$Y\bar{U} = J, \tag{1}$$

where Y is the matrix of nodal conductances, $\bar{U}$ is the vector of nodal potentials and J is the vector of discrepancies in nodal currents. System (1) is solved by the LU expansion method [1]. But the majority of results are valid also for other methods of forming and solving systems of equations describing an electronic circuit.

The step of the formation of the system of equations is important for solving system (1). To demonstrate, let an element with high conductance, g , be included between nodes r and m (for definiteness r < m). Let us write the elements of matrix Y connected to nodes r and m in the following manner:

$$\left.\begin{aligned} y_{rr} = \bar{y}_{rr} + g;\ \ y_{rm} = \bar{y}_{rm} - g \\ y_{mr} = \bar{y}_{mr} - g;\ \ y_{mm} = \bar{y}_{mm} + g \end{aligned}\right\}, \tag{2}$$

where $\bar{y}_{rr}$, $\bar{y}_{rm}$, $\bar{y}_{mr}$ and $\bar{y}_{mm}$ represent the respective sums of conductances without g . Expressions for the k-th step of the LU expansion, when k = r , can be written in the following manner: $u_{rj} = y^{k-1}_{rj}$, $j \geq r$; whereby

$$u_{rr} = \bar{y}^{k-1}_{rr} + g,\ u_{rm} = \bar{y}^{k-1}_{rm} - g;\ l_{ir} = \bar{y}^{k-1}_{ir}/u_{rr},\ i > r; \tag{3}$$

$$y^{k}_{mm} = (\bar{y}^{k-1}_{mm} + g) - (\bar{y}^{k-1}_{mr} - g)/(\bar{y}^{k-1}_{rr} + g)\,(\bar{y}^{k-1}_{rm} - g). \tag{4}$$

If the word length is finite, then already in the formation of matrix Y errors will originate, since during addition in (2) the equalization of the orders of the addends takes place and the low-order bits of the lower of the addends are dropped. With sufficiently high g, the value of y^k_{mm} computed according to equation (4) will prove to equal zero. The error which originates will begin to be felt in performing the subsequent steps of the LU expansion.

Calculations with double precision make it possible to avoid these difficulties, but then calculation time and the memory required are increased. Let us consider other methods of organizing computations which make it possible to reduce the influence of rounding errors.

Let us go from original system (1) to the system of equations: $Y'\overline{U} = J'$, where $Y' = \{y'_{i,j}, i, j = 1, \ldots, N\}$ is the modified matrix of nodal conductances and $J = \{j_i, i = 1, \ldots, N\}$ is the modified vector of discrepancies in nodal currents. Each k-th row of matrix Y' equals the sum of the first k rows of matrix Y, and each k-th element of vector J' equals the sum of the first k elements of vector J. Here and below N represents the total number of nodes, but without taking into account the reference node.

Let the next element, information on which will be entered in Y' and J', be connected between nodes r and m $(r < m)$ and let it be described by conductance matrix $G = \{g_{ij}, i, j = r, m\}$. The current through the leads equals respectively j^r and j^m. Then g_{ij} is entered in Y' in the following manner: To terms y'_{ir} and y'_{im}, with $i = r, \ldots, m - 1$, are added respectively g_{rr} and g_{rm} and with $i = m, \ldots, N$ are added $g_1 = g_{rm} + g_{mm}$ and $g_2 = g_{rr} - g_{mr}$. The current of elements j^r and j^m is added respectively to j'_i, $i = r, \ldots, N$ and j'_k, $k = m, \ldots, N$.

When one of the nodes for connection of the component is the reference node, the same algorithm is employed but the number of the node $(N + 1)$ is specified formally.

If the element is a passive two-terminal network, then for it $g_1 = 0$ and $g_2 = 0$ and these sums do not distort the respective y'_{ir} and y'_{im}. For active elements the organization suggested for forming matrix Y' also has an advantage in cases when g_1 and g_2 are close to zero.

In matrix Y' formed by means of the above-described method the symmetric ordering of numbers is also eliminated. In this case, even with fairly high g_{ij}, as when adding to y'_{ij}, $y'_{ij} \sim g_{ij}$, and the like, the use of LU expansion equations of type (4) is justified. The result of scaling y'^k_{mm} is $y'^{k-1}_{mm} + y'^{k-1}_{mr}$ and an error does not originate.

With a full matrix the method suggested does not require added memory costs, the number of multiplication operations does not change and the number of addition operations is increased but slightly (only during formation). But matrix Y', unlike Y, turns out to be heavily filled and asymmetric not only in terms of values but also in terms of the points of distribution of non-zero elements. The method can be recommended for calculating small circuits, when working with a full matrix, as well as for quasi-block matrixes when processing matrixes of subcircuits.

It is possible to reduce the errors discussed in the case when the sparseness of the nodal conductance matrix is taken into account. From equations (3) to (4) it is obvious that the scaling of y^k_{mm} is much more critical with respect to rounding errors than the scaling of all remaining factors, especially in cases when there is a contribution from symmetric two-terminal networks with high conductance.

For the purpose of taking into account all cases it is suggested that the algorithms for preparing the raw data and the LU expansion be revised and that the equation for scaling y^k_{mm} be modified:

$$\left.\begin{aligned} y^k_{mm} &= \bar{y}^{k-1}_{mm} + \bar{y}^{k-1}_{mk} + \bar{y}^{k-1}_{km} + \bar{y}^{k-1}_{mm} + F(g) \\ F(g) &= (\bar{y}^{k-1}_{mk} + \bar{y}^{k-1}_{kk})(\bar{y}^{k-1}_{km} + \bar{y}^{k-1}_{kk})/(\bar{y}^{k-1}_{kk} + g) \end{aligned}\right\}. \tag{5}$$

The meaning of the symbols and the starting premises for obtaining equation (5) are the same as for (2) and (4). The following procedure is suggested for preparing raw data for calculation:

1. An array of numbers of nodes for connecting symmetric two-terminal networks is formed: MD(i, j) ; i = i, ..., M ; j = 1, 2 ; M is the number of two-terminal networks. Furthermore, MD(i, 1) < MD(i, 2) and array MD is ordered in terms of the increase in i --the first number of the pair.

2. Parallel branches are converted to an equivalent representation by a single branch.

3. Array ND(i) , i = 1, ..., N , is formed, in whose i-th cell is written the number of branches of symmetric two-terminal networks connecting the i-th node of the circuit with nodes whose numbers are greater than i .

Steps 1 to 3 are performed once before calculation of the circuit. The required arrays of indicators of the position of non-zero elements are also formed prior to calculation. Conductance matrix Y is formed by the traditional method. The conductances of all elements with the exception of symmetric two-terminal networks are entered in it.

A flowchart of the suggested LU expansion algorithm is presented in fig 1. S and KD are counters of the rows of matrix MD and of the number of two-terminal networks connected to each k-th node, respectively. The remaining symbols are explained in the text. At each k-th step a check is made of whether the k-th node is connected with other nodes by means of a two-terminal network. If it is not connected, then an ordinary step of the LU expansion is performed. Otherwise the contribution of each two-terminal network is taken into account in the following sequence: 1) A determination is made of the value of g --the conductance of the two-terminal network--and of r, m (r = k) , the pair of numbers of connection nodes; 2) y^k_{mm} is calculated according to equation (5); 3) u_{kk} and u_{km} are calculated according to equations (3); 4) the remaining elements of matrix U, $\ell_{\ell k}$

besides u_{kk} and u_{mk} are calculated according to equation (2) and the other elements of matrix Y^k to be scaled, i.e., besides y^k_{mm}, are scaled.

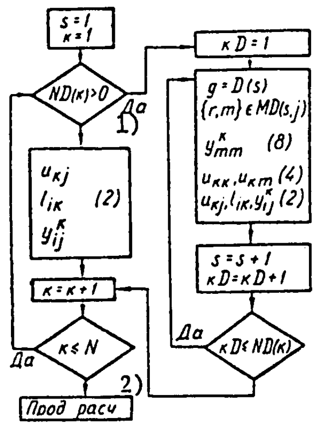

Figure 1.

Key:
1. Yes
2. Continue calculation

Among the advantages of the organization of computations suggested here must be numbered a reduction in the number of rounding errors both in the formation of matrix Y and in the performance of transformations on it. Numbered among its disadvantages is the complication of the algorithm and the increase in the memory required as compared with the traditional organization of an LU expansion.

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RESULTS OF INVESTIGATION OF A NUMBER OF ELECTRONIC CIRCUIT ANALYSIS PROGRAMS

Kiev IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: RADIOELEKTRONIKA in Russian Vol 24, No 6, Jun 81 (manuscript received 8 Jan 81) pp 27-37

[Article by Yu.N. Barmakov, V.A. Bakhov, V.N. Il'in, N.Yu. Kamneva, V.L. Kogan, N.P. Levshin, G.P. Mozgovoy, V.G. Ssorin, A.P. Timchenko, V.A. Trudonoshin, V.N. Fedoruk, V.T. Frolkin and Ye.A. Chakhmakhsazyan]

[Text] A description is given of the results of studying a number of electronic circuit analysis programs for YeS [Unified Series] computers, including the results of calculating the characteristics of various test circuits and the expenditure of machine time in using each program.

At the present time an entire series of programs for analyzing electronic circuits has found extensive application and new programs oriented toward YeS computers are being developed and put into service.

Characteristics reflected in descriptions of individual electronic circuit analysis programs and the information available in utilization instructions do not make it possible to evaluate the quite important properties of these programs relating to the effectiveness of their use for the purpose of analyzing various types of electronic circuits. These include accuracy in simulation of the static and dynamic characteristics of various circuits, expenditure of machine time, efficiency, convenience of utilization and the reliability of programs' performance and the like.

For the purpose of determining these properties both here at home and abroad, a number of studies have been made which have included the solving of a definite set of test problems making it possible to compare the characteristics of various programs [1]. In [2] a comparison is made between the characteristics of the domestic SPARS program and foreign programs. In this study the results are given of an investigation of a number of domestic programs for the analysis and calculation of electronic circuits, oriented toward YeS computers: the AKOPS and SPROS programs [3, 4] developed at MAI [Moscow Aviation Institute imeni Sergo Ordzhonikidze], PAUM1 [5] and PAUM2 developed at MIEM [Moscow Institute of Electronic Machine Building], SPARS developed at KPI [Kiev Polytechnical Institute] [6], the ELAIS program [7] developed at MIFI [Moscow Engineering Physics Institute] and the PARM program [8] developed at MVTU [Moscow Higher Technical School imeni N.E. Bauman].

Summary data on the key characteristics of the domestic programs investigated are presented in table 1.

Table 1. Key Parameters of Programs

1) Программа	3) ЭВМ 2)	Выполняемые функции: 4) Анализ: Статический режим 5)	Динамический режим 6)	Частотный 7)	Чувствит. 8)	Оптимизация 9)	11) Необходимая память, Кбайт 10)	Параметры элементов в схемах: Постоян. 12)	Зависим. 13)	14) Имеющиеся в прогр. модели: 15) Транзистора: Эберса-Молла 16)	ЭЛАИС 17)	Логана 18)	ПАЭС 19)	МДП 20)	Макромод. ИС 21)	Возможн. создания моделей на языке прогр. 22)	Ограничения по топологии схем 23)
АРОПС	ЕС	•	•	•	•	•	154	•	•	–	–	•	•	•	•	•	150 узл. 24) 250 элем. 25)
СПРОС	ЕС	•	•	–	•	•	200	•	•	–	–	–	•	•	•	•	—•—
ПАУМ1	ЕС	•	•	–	–	–	128	•	–	–	–	–	•	•	–	–	300 узл.
ПАУМ2	ЕС	•	•	–	–	–	128	•	•	•	•	•	•	•	•	–	300 узл.
СПАРС	ЕС	•	•	•	•	•	200	•	• Можно использовать любые модели, описываемые на вход. языке или вызываемые из библиотеки 26)						•	•	ДРП** 27)
ЭЛАИС	ЕС	•	•	•	•	–	128	•	•	•	•	–	•	•	•	•	ДРП
ПАРМ	ЕС	•	•	–	–	–	150	•	•	–	–	–	•	–	•	•	200 узл.

Key:

1. Program: AROPS, SPROS, PAUM1, PAUM2, SPARS, ELAIS, PARM
2. Computer: YeS
3. Functions performed
4. Analysis
5. Static mode
6. Dynamic mode
7. Frequency
8. Sensitivity
9. Optimizaion
10. Required memory, Kbytes
11. Parameters of elements in circuits
12. Constant
13. Dependent
14. Present in program model
15. Transistor
16. Ebers-Moll
17. ELAIS
18. Logan
19. PAES
20. Metal-insulator semiconductor
21. Macromodeled integrated circuit
22. Ability to create models in programming language
23. Limitations on topology of circuits
24. 150 nodes
25. 250 elements
26. It is possible to use any models described in the input language or called from the library
27. DRP [dynamic distribution of storage]

Of course, the accuracy of machine calculations of the static and dynamic characteristics of electronic circuits depends both on the algorithms present in programs (methods of forming and solving equations for the loops of circuits analyzed) and their software implementation, and on the accuracy of modeling semiconductor and other components of circuits. For the purpose of a differentiated discussion of these questions, the first stage of investigation is devoted to estimating the effectiveness of methods and algorithms present in programs, and the second to estimating the influence of methods of modeling individual components of electronic circuits on the accuracy of calculating their static and dynamic characteristics.

Below are published results relating to the first and only partially to the second stage of investigation. Therefore, the results presented here do not preter to completeness in the evaluation of programs but are undoubtedly of definite interest.

The programs listed above were investigated by analyzing a group of test circuits which are described below. However, in the program for investigating domestic programs were also included tests making it possible to reveal the capabilities of programs with respect to solving certain practical problems.

In the investigation it was also taken into account that the programs differ also in the models of semiconductor components used in them. Some programs (such as the first variants of the AROPS, SPROS, PAUM1 and PARM programs) have only one model of a bipolar transistor--the PAES model. The PAUM2 program contains descriptions of three varieties of models of a bipolar transistor: the Ebers-Moll model, a transfer model and the PAES model. In recent times a transfer model of a transistor has also been included in the AROPS and SPROS programs. The ELAIS program includes a model, particular cases of which can be an Ebers-Moll model and a transfer model. The SPARS program makes it possible to use any of the above-listed models of semiconductor devices.

For the purpose of unifying test problems for various programs in making calculations of transistor circuits (presented below in figs 1, 2 and 5), the Ebers-Moll model present in the PAUM2 and ELAIS programs was used as the basis, and a model used in foreign programs, with constant gain of the transistor. In analyzing the same circuits by means of the AROPS, PARM, SPROS and PAUM1 programs, the PAES model was used with parameters corresponding to the Ebers-Moll model used. Examples were calculated by means of the SPARS program by using both the PAES model (in the SPARS (P) columns in the tables presented), and the Ebers-Moll model with constant gain (the data are presented in the SPARS (EM) columns).

The following numerical values of parameters of the Ebers-Moll model are used: $I_{es} = 0.429 \cdot 10^{-10}$ mA, $I_{ks} = 0.578 \cdot 10^{-10}$ mA, $\theta = 1/m\phi_T = 38.3\ V^{-1}$, $C_{be} = 21$ pF, $C_b = 11$ pF, $\tau_N = 0.616$ ns, $\tau_I = 0.548$ ns, $R_e = 100{,}000$ kΩ, $R_k = 100{,}000$ kΩ, $R_{ee} = 0.0002$ kΩ, $R_{bb} = 0.0018$ kΩ, $R_{kk} = 0.00027$ kΩ, $\alpha_N = 0.99$ and $\alpha_I = 0.899$.

The following numerical values are used for parameters of the PAES model: $I_{Te} = 0.429 \cdot 10^{-12}$ mA, $I_{Tk} = 0.584 \cdot 10^{-11}$ mA, $B_N = 99$, $B_I = 8.9$, $m\phi_T = 0.02611$ V, $R_e = 10{,}000$ K, $R_k = 10{,}000$ K, $C_{be} = 21$ pF, $C_{bk} = 11$ pF, $\tau = 61.6$ ns and $\tau_i = 5.43$ ns .

In addition, let us note that the data on foreign programs presented in the tables correspond to the case when the transistors have been substituted by an Ebers-Moll model with parameters α_N , C_{be} and C_{bk} specified by tables.

The analysis of the test circuits presented in figs 8, 9 and 10 and of investigations belonging to the second stage was performed in two variants: by using, respectively, the PAES model for transistors and a more precise model available in a number of programs--the transfer or Ebers-Moll. In this case the goal was

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pursued of determining the influence of the accuracy of modeling a transistor on the results of analyzing the characteristics of these types of circuits.

Brief descriptions of test problems are presented below--calculation diagrams in which the parameters of all elements of circuits are indicated. Graphs of input and output signals and their parameters are also shown there. Then the results of analyzing circuits by means of the programs mentioned are presented in individual tables.

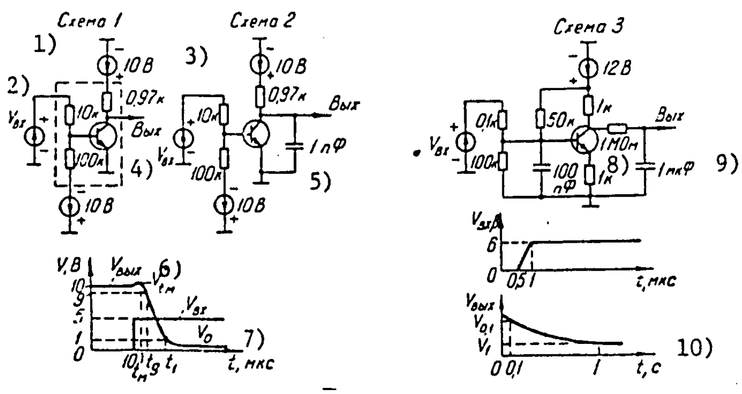

Figure 1.

Key:
1. Circuit 1
2. V_{vkh} [input voltage]
3. 10 V
4. Output
5. 1 pF
6. V_{vykh} [output voltage]
7. μs
8. MΩ
9. μF
10. s

Transistor circuits with sharply differing time constants and an inverter are shown in fig 1 (circuits 1, 2 and 3). They make it possible to check the ability of programs to increase their integration step (and at the same time to reduce the expenditure of machine time) under the condition when the influence of the loop with the lowest time constant becomes insignificant and vice-versa. The results of analyzing these circuits are given in table 2.

Circuits 4 to 8, presented in fig 2, contain inverters, the number of which in them varies (from one to nine). The results of analyzing three-, five- and nine-stage inverter circuits (circuits 5, 6 and 8) are given in table 3. Dependences of the expenditure of machine time for the analysis of transient processes in the circuits in fig 2 as a function of the number of inverters in the circuit are shown in fig 3.

Table 2. Results of Analyzing Inverters in Fig 1

1) Программа	10) / 11)					2					3	
	V_0, мВ 9)	$t_м$, мкс	$V_{tм}$, В	t_{98}, мкс	t_{18}, мкс	V_0, мВ	$t_м$, мкс	$V_{tм}$, В	t_{98}, мкс	t_{18}, мкс	V_{q1c}, В	V_{1c}, В
2) АРОПС	55.3	10.1	10.12	10,16	10,53	55,3	10,1	10,12	10,15	10,53	11,5	8,67
3) СПРОС	55,0	10.0	10,15	10,15	10.5	55,1	10,0	10,14	10,15	10.5	11,48	8,74
4) ПАУМ1	56,0	10.1	10,11	10,15	10,51	56.0	10,1	10,12	10,15	10,51	–	–
ПАУМ2	56.0	10.01	10,11	10,16	10,52	56.0	10,0	10,1	10,16	10,52	11,5	8,66
5) СПАРС (П)	55,5	10,03	10,14	10,15	10,49	55,5	10.03	10,14	10,15	10,49	11,5	8,56
6) СПАРС (ЭМ)	60.4	10,02	10,15	10,14	10,47	60,4	10,02	10,15	10,14	10,47	11,5	8,66
7) ЭЛАИС	54,3	-	10,1	10,16	10,38	54,2	–	10,1	10,08	10,44	11,5	8,72
8) ПАРМ	-	-	–	–	–	55,0	10,0	10,1	10,1	10,54	11,5	8,65
ASTAP	53,6	10,0	10,1	10,1	10,4	53,6	10,1	10,0	10,2	10,6	11,5	8,65
SUPER-SCEPTRE	53,6	10.0	10,1	10,1	10,4	53,6	10,0	10,1	10,1	10,4	11,5	8,67

Key:
1. Program
2. AROPS
3. SPROS
4. PAUM1
5. SPARS (P)
6. SPARS (EM)
7. ELAIS
8. PARM
9. mV
10. μs
11. V

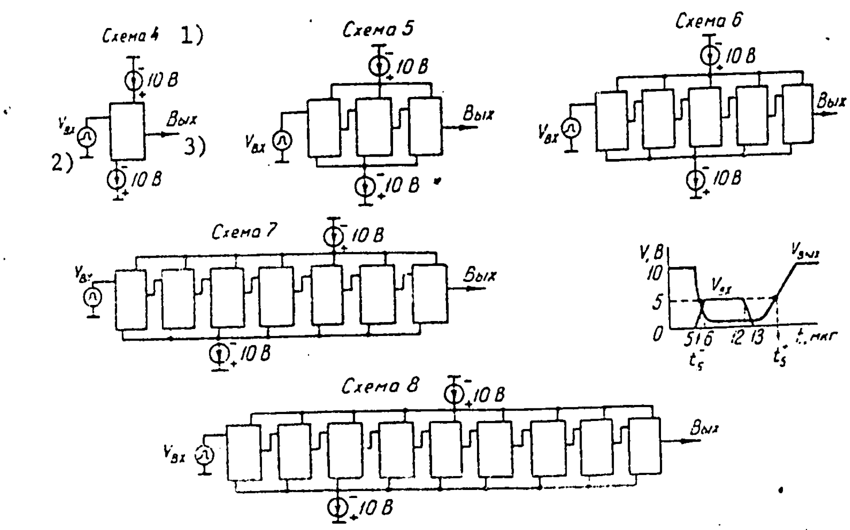

Figure 2.

Key:
1. Circuit 4
2. Input voltage
3. Output

Table 3. Results of Analyzing Inverter Circuits (Fig 2)

1) Программа	5 2) (трехкаскадные)				6 3) (пятикаскадные)				4) 8 (девятикаскадные)			
	V_1, В	V_0, мВ	t^{-}_{SB}, мкс	t^{+}_{SB}, мкс	V_0, мВ	V_1, В	t^{-}_{S}, мкс	t^{+}_{S}, мкс	V_0, мВ	V_1, В	t^{-}_{SB}, мкс	t^{+}_{SB}, мкс
АРОПС	10,0	34,7	6,41	13,4	34,7	9,98	6,85	13,8	34,7	9,96	7,68	14,6
СПРОС	9,99	34,5	6,39	13,3	34,5	9,98	6,80	13,7	34,5	9,96	7,63	14,6
ПАУМ1	10,0	35,0	6,48	13,4	35,0	10,0	6,88	13,8	35,0	10,0	7,77	14,7
ПАУМ2	10,0	35,0	6,45	13,4	35,0	10,0	6,90	13,8	35,0	10,0	7,80	14,8
СПАРС (П)	10,0	34,9	6,4	13,33	34,9	10,0	6,82	13,78	34,9	10,0	7,67	14,59
СПАРС (ЭМ)	10,0	39,8	6,37	13,33	39,8	10,0	6,78	13,73	39,8	10,0	7,51	14,4
ЭЛАИС	10,0	34,3	6,36	13,13	34,3	10,0	6,80	13,8	34,3	10,0	7,68	14,6
ПАРМ	10,0	35,0	6,36	13,31	35,1	10,0	6,79	13,73	35,4	10,0	7,7	14,6
ASTAP	10,0	35,3	6,35	13,4	35,3	10,0	6,79	13,9	35,3	10,0	7,66	14,7
SUPER-SCEPTRE	10,0	35,3	6,37	13,4	35,3	10,0	6,79	13,9	35,1	10,0	7,66	14,7

Key:
1. Program
2. Three-stage
3. Five-stage
4. Nine-stage

[Cf. table 2 for remaining designations]

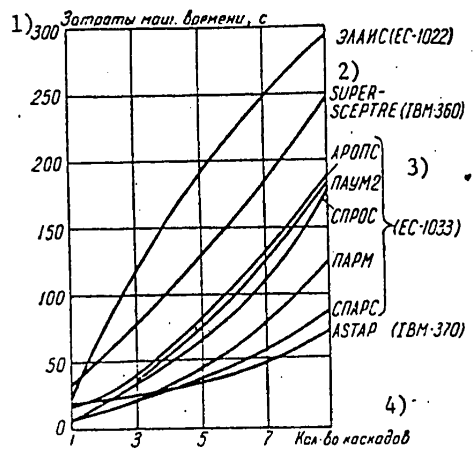

Figure 3.

Key:
1. Expenditures of machine time, s
2. ELAIS (YeS-1022)
3. AROPS, PAUM2, SPROS, PARM, SPARS (YeS-1033)
4. Number of stages

The nature of the dependence of an increase in the expenditure of time for the analysis of transient conditions as a function of the number of inverters in the circuit characterizes the capabilities of the program. The more slowly the time required for analysis increases, the more efficient the program and the lower the cost of solving big problems on the computer.

RC circuits are presented in fig 4. Circuits 9, 10 and 11 have various time constants for individual loops. Their analysis, together with an analysis of circuits 2 and 3, makes it possible to estimate the efficiency of programs from the viewpoint of expenditures of machine time in solving similar problems. In addition, circuits 12 and 13 are included here for estimating the accuracy of analyzing transient processes. The results of analyzing RC circuits are presented in table 4.

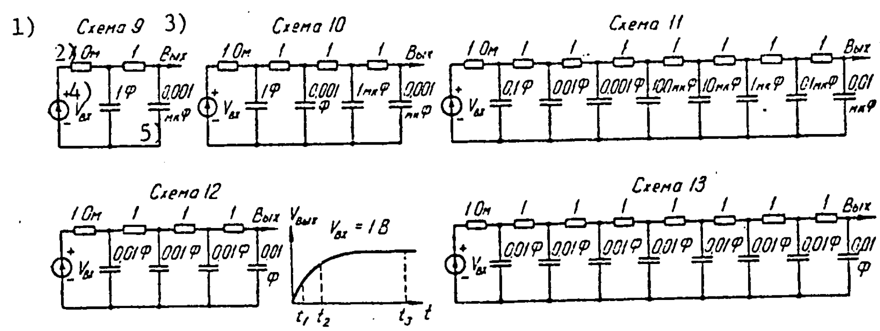

Figure 4.

Key:
1. Circuit 9
2. Ω
3. Output
4. Input voltage
5. μF

The circuit of a self-excited oscillator is shown in fig 5 with an indication of the circuit's parameters and the general appearance of its output characteristic. The results of analyzing this circuit are presented in table 5.

The circuit in fig 6 consists of a filter with a high figure of merit, whose transfer function has two very closely situated complex conjugate poles: S_1, $S_1^* = -0.0005004 \pm j1.001207$ and S_2, $S_2^* = -0.0004996 \pm j0.999793$. The output characteristic of such a filter is in the form of a signal made up of two sine curves, the amplitude of whose envelope diminishes over time, as is shown in fig 6. The period of oscillations of the output voltage equals 6.28 s with a duration of the analyzed process of 20,000 s.

Analysis of this circuit requires the selection of short integration steps for the purpose of ensuring the required accuracy of determining the filter's output characteristic, which involves large expenditures of machine time when using implicit numerical methods in the program. The results of analyzing this circuit by means of various programs are reflected in table 5.

Table 4. Results of Analyzing RC Circuits (Fig 4)

1) Программа	2) Выходные напряжения в указанные ниже моменты времени														
	3) 9			10			11			12			13		
	0,1 с мВ	1 с мВ	4 с мВ	0,1 с мВ	1 с мВ	4 с мВ	0,01 с мВ	0,1 с мВ	0,4 с мВ	1 мс мкВ	10 мс мВ	40 мс мВ	1 мс 10⁻¹² В	10 мс мкВ	40 мс мВ
4) Результаты теоретического расчета	95,2	632	982	94,2	631	982	-	-	-	3,63	11,9	240	-		
5) АРОПС	94,7	630	981	93,7	630	981	27,7	543	968	5,90	12,0	240	1,8	6,11	8,43
СПРОС	95,0	632	982	93,5	631	982	24,3	549	969	5,77	12,1	240	1,6	6,11	8,28
ПАУМ1	95,0	633	983	94,0	632	983	26,0	545	970	·	12,0	239			8,00
ПАУМ2	93,6	634	981	92,5	633	984	25,5	544	971	12,9	10,6	235	6,04	8,6	8,52
СПАРС	95,2	632	982	94,1	631	982	26,3	545	968	3,96	11,9	240	0,334	5,30	8,36
ЭЛАИС	95,0	632	982	94,0	632	982	26,2	545	968	4,63	11,9	240	1,11	5,55	8,36
ПАРМ	94,0	627	979	92,6	626	979	30,4	539	964	6,3	12,3	239	1,77	6,75	8,77
ASTAP	95,2	632	982	93,4	631	982	25,6	545	969	5,31	11,9	240	4,37	5,67	8,34
SUPER-SCEPTRE	94,8	632	982	94,1	631	982	25,3	545	968	3,53	11,9	240	0,114	4,90	8,35

Key:
1. Program
2. Output voltages at moments of time indicated below
3. 0.1 s, mV
4. Results of theoretical calculation
5. Individual programs [cf. table 2]

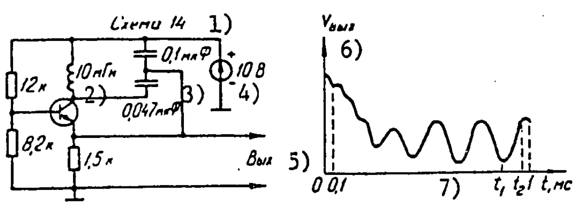

Figure 5.

Key:
1. Circuit 14
2. mH
3. μF
4. V
5. Output
6. Output voltage
7. t, ms

Table 5. Results of Analysis of Circuits (Fig 5, 6 and 7)

1) Программа	2) Генератор (рис.5)				3)	Фильтр рис.6	4) Двухполупериодный выпрямитель рис.7		
5)	$V_{t=0,1 мс}$, В	t_1, мс	6) V_{t1}, мВ	t_2, мс	V_{t2}, В 7)	Верна ли огибающая	8) Возникает ли импульс	9) $V_{вых\,0,1 мс}$, В	$V_{вых\,0,4 мс}$, В
10) АРОПС	6,55	0,92	-4	0,98	8,24	–	да	20,89	21,28
СПРОС	6,55	0,919	-78,8	0,979	8,3	11) да	–	–	–
ПАУМ1	–	–	–	–	–	–	–	–	–
ПАУМ2	6,58	0,92	-84	0,986	8,41	да	да	20,98	20,96
СПАРС (П)	6,56	0,92	-257,9	0,98	8,55	да	да	20,9	21,3
СПАРС (ЭМ)	6,56	0,92	-186,9	0,98	8,52				
ЭЛАИС	6,67	0,926	0,736	0,981	7,43	–	–	–	–
ПАРМ	6,53	0,89	851	0,946	7,6	• 12)	•	•	•
ASTAP	–	0,91	333,3	0,97	3,34	нет	да	20,9	21,3
SUPER-SCEPTRE	6,55	0,93	-437	0,99	8,58	нет	да	20,9	21,3

Key:

1. Program
2. Oscillator (fig 5)
3. Filter (fig 6)
4. Full-wave rectifier (fig 7)
5. $V_{t = 0.1\ ms}$, V
6. mV
7. Envelope correct?
8. Does pulse originate?
9. $V_{vykh_{0.1\ ms}}$, V
10. Programs [cf. table 2]
11. Yes
12. No

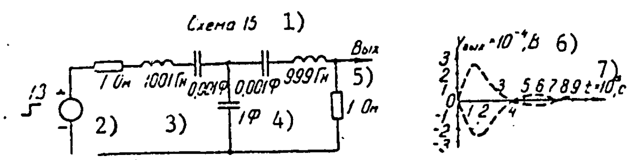

Figure 6.

Key:

1. Circuit 15
2. Ω
3. H
4. F
5. Ouput
6. Output voltage
7. s

The circuit presented in fig 7 is a full-wave rectifier with transformer coupling, where $M_{12} = 0.02475$, $M_{13} = 0.02475$, $M_{23} = 6.1875\cdot 10^{-3}$ and $[V_{c=500}]_{t=0} = 21$ V.

Analysis of this circuit requires modeling the transformer and accuracy in the analysis of transient characteristics with the detection of a peaky pulse originating in inductance L_2 at moment of time $t = 0.268$ ms , for the detection of which a rapid shortening of the integration step by several orders of magnitude is required. The results of analyzing this circuit are presented in table 5.

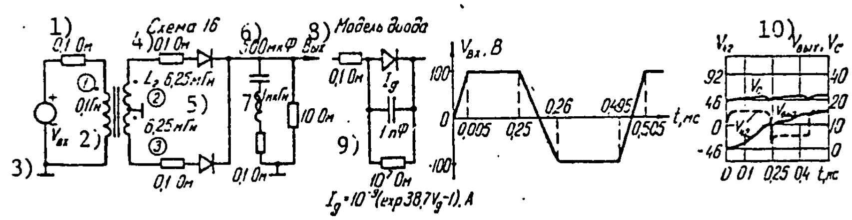

Figure 7.

Key:

1. Ω
2. H
3. Input voltage
4. Circuit 16
5. mH
6. μF
7. μH
8. Model of diode
9. pF
10. Output voltage
11. ms

In fig 8 is shown the design diagram of a TTL [transistor-transistor logic] logical gate (T_1 , T_2 and T_3 are three types of series 134 integrated circuit transistors). A graph of the output signal and of the transient response analyzed is also presented there. Accuracy in obtaining this characteristic and its agreement with the experimental require modeling the transistor with definite precision.

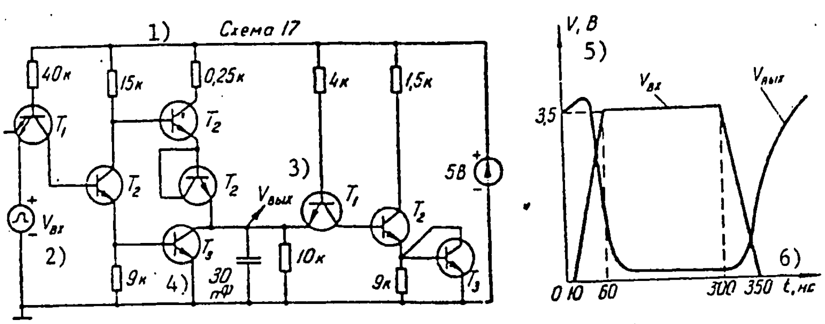

Figure 8.

[Key on following page]

Key:
1. Circuit 17
2. Input voltage
3. Output voltage
4. pF
5. V
6. ns

In table 6 are presented the results of calculating the output characteristic of a TTL logical gate when using various models of a bipolar transistor obtained by means of various programs.

Table 6. Results of Analyzing Circuits (Figs 8 to 10)

1) Программа	5) Модель транзистора	9) ТТЛ (рис. 8)						10) ГУВ (рис. 9)			11) Схема совпадения (рис 10)			
		V_0, В 12)	V_1, В	$t^-_{3В}$, нс 13)	$t^-_{0,4В}$, нс	$t^+_{0,4В}$, нс	$t^+_{3В}$, нс	V_0, В	T_1, нс	T_2, нс	$V_{26 нс}$, В	$V_{34 нс}$, В	$V_{82 нс}$, В	$V_{58 нс}$, В
2) ПАУМ2	6) ПАЭС	0,046	3,499	46	88	353	481	1,525	283	277	0,025	0,345	0,284	0,075
	Эберса-Молла	0,12	3,383	57	101	319	463	1,523	263	276	0,056	0,591	0,275	0,068
3) АРОПС	7) ПАЭС	–	–	–	–	–	–	1,522	273	262	–	–	–	–
	перед.	0,113	3,28	51	116	347	550	1,497	270	265	–	–	–	–
4) ПАРМ	8) ПАЭС	0,04	3,49	44,8	87	351	480	–	–	–	–	–	–	–

Note: Calculations with Ebers-Moll and transfer models were made with parameters for the types of transistors indicated in the circuits.

Key:
1. Program
2. PAUM2
3. AROPS
4. PARM
5. Model of transistor
6. PAES, Ebers-Moll
7. PAES, transfer
8. PAES
9. TTL (fig 8)
10. GUV [shock-excited oscillator] (fig 9)
11. Coincidence circuit (fig 10)
12. V
13. ns

The circuit presented in fig 9 is a shock-excited oscillator which produces steady oscillations with a practically constant frequency beginning with the instant of the establishment of input voltage. The parameters of the oscillator's circuit and the type of output characteristic are shown in fig 9, where all transistors are of type 2T324. The results of analyzing this circuit, performed by means of various programs, are given in table 6.

In fig 10 is presented a coincidence circuit which consists of two practically identical halves into two inputs of which signals enter in the form of half waves of a sine wave, the beginnings of which are slightly shifted relative to one another with respect to time. In the circuit's output at a definite moment of time a voltage pulse originates whose parameters are the subject of study: $V_{vkh1\ [input\ 1]} = 1.5 \sin (0.02463t)$, $V_{kh2} = 1.5 \sin (0.02463 [t-5])$; T_1 and

T_2 are transistors of type KT324 and R36. The results of calculation of the parameters of the output signal of this circuit are presented in table 6. Expenditures of machine time for solving the test problems listed above by means of various programs are presented in table 7. Data obtained for two foreign programs are also presented there for comparison.

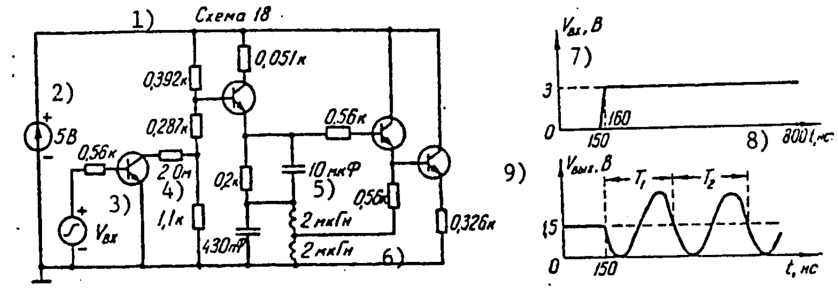

Figure 9.

Key:
1. Circuit 18
2. V
3. Input voltage
4. Ω
5. μF
6. μH
7. V
8. ns
9. Output voltage

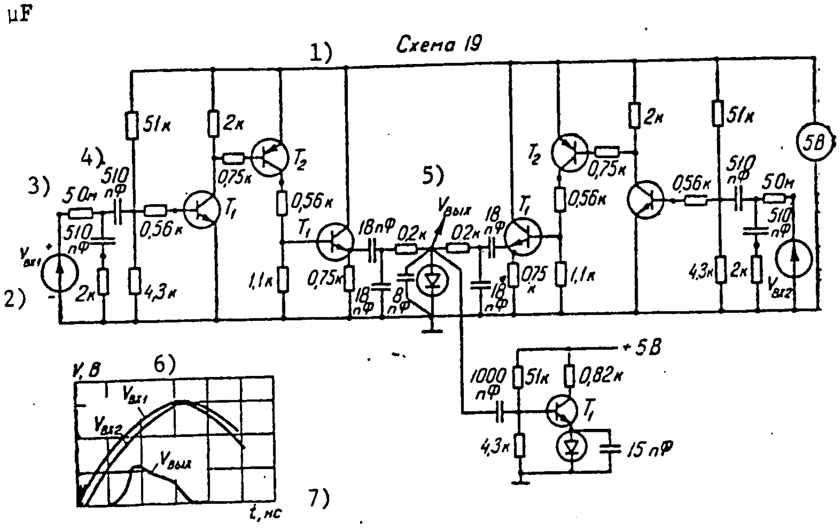

Figure 10.

[Key on following page]

Key:
1. Circuit 19
2. V_{vkh1}
3. Ω
4. pF
5. Output voltage
6. V
7. ns

Table 7. Expenditures of Machine Time for Analyzing Circuits, in Seconds

1) Програм-ма	2) ЭВМ	5) Номера тестовых схем 2	3	1	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
		рис. 1 6)			рис. 2					рис. 4					рис 5	рис 6	рис 7	рис 8	рис 9	рис 10
4) АРОПС	3) ЕС-1033	11	15	17	17,3	40	81	136	189	9,8	12,5	17	11,5	16	223	– 7) 8)	57	59 (пер) 45 (пак)	123 (пер) 104 (пак)	– –
СПРОС	-"-	4,5	4,6	8,9	8	36,2	69	110	181	–	–	17,6	9,3	16	221	3600	–	–	–	–
ПАУМ1	-"-	79	87	93	93	184	332	545	1007	72	74	76	70	74	–	–	•	•	•	•
ПАУМ2	-"-	14	16	13	14	47	94	161	316	3,8	5	7	5	6	67	1440	–	79 (эм) 19,9 (пак)	21 (эм) 9,27 (пак)	56 (эм) 27 (пак) 9)
СПАРС п / эм	-"- / -"-	8 / 8	8 / 8	8 / 8	8 / 8	20 / 22	36 / 42	57 / 71	85 / 108	6	8	6	6	5	33 / 35	1130	18	–	–	–
ЭЛАИС	ЕС-1022	–	9	21	21	119	100	–	295	11,2	15,5	24,2	14,9	31,1	–	–	–	–	–	–
ПАРМ	ЕС-1033	9	10,5	–	6,4	23	45	85	125	6,3	5,6	6,6	7,8	10,6	27	•	•	37	–	–
ASTAP	IBM-370	18	19	17	19	25	34	47	76	16	15	14	15	16	18	–	18	–	–	–
SUPER-SCEPTRE	IBM-360	33	40	35	34	81	136	160	248	14	16	20	16	19	331	–	1749	–	–	–

Key:
1. Program
2. Computer
3. YeS-1033
4. Programs [cf. table 2]
5. Numbers of test circuits
6. Fig 1
7. Transfer
8. PAES
9. EM

The dashes in all tables indicate that the respective test problems of the program in question have not been studied and the asterisks in tables 5 and 7 indicate that the program is not able to analyze these circuits.

As the result of the studies it is possible to arrive at the conclusion that all the programs studied are approximately of the same order in terms of accuracy and efficiency. This fact is explained by the fact that modeling methods of a single class--the nodal method (or modifications of it) and implicit methods of integration--are included in all programs. In spite of this, the studies carried out make it possible to note several advantages and disadvantages of individual programs.

From the viewpoint of using the programs for various problems a very important property is the efficiency of utilizing a program--the convenience of the input language, the simplicity of the procedure of writing an assignment for analyzing a circuit, and the clear representation of the information put out by the computer in terms of the raw data and the results of calculating the characteristics of the circuit analyzed. The language of the PAUM2 program can be mentioned in this regard. Since the PAUM2 program at the same time makes possible sufficient accuracy in modeling circuits with relatively minor expenditures of machine time, this makes it possible to recommend it for use in the development and study of various circuits operating under various conditions, taking into account the temperature of the environment and the effect of various external factors.

A very important property of a program is the existence in it of both simple and more precise models of semiconductor components of circuits. This makes it possible to select one model or another on the basis of the required accuracy of obtaining characteristics. From this point of view the PAUM1 and PARM programs, which contain a single (and simplified) model of a bipolar transistor--the PAES model, undoubtedly have a serious disadvantage.

A great advantage of the AROPS and SPROS programs is their ability to optimize circuits, a property by which many programs are not distinguished. Among the advantages of these programs must be mentioned the mildly sloping nature of the curve reflecting the relationship between expenditures of machine time and the number of elements in the circuit analyzed (fig 3), which indicates their great abilities with regard to the analysis of large-scale electronic circuits. These advantages in combination with a degree of accuracy sufficient for many problems and relatively slight expenditures of machine time, as well as with the possibility of performing multivariant calculations and statistical analysis and optimization, and the existence in the SPROS program of a macromodeling subsystem, make it possible to recommend the AROPS and SPROS programs for use in work relating to the circuitry design of electronic circuits [4].

Among the positive aspects of the SPARS program [6] must be mentioned the existence of a high-level input language, the ability by means of input language facilities of on-line supplementing and correcting of a library of models of multiterminal components, and procedures for parametric optimization and static analysis.

These factors, as well as sufficiently high accuracy in solving problems with relatively slight expenditures of machine time, and the mildly sloping nature of the curve characterizing the increase in computing costs with an increase in the number of elements of circuits studied (fig 3), make it possible to conclude that it is possible to utilize the SPARS program effectively for solving a broad range of problems originating at the stage of the circuitry design of radio electronic equipment.

The results obtained in analyzing various types of circuits by means of a number of domestic programs are of interest to developers of programs and, in particular, to users, since they make it possible to estimate possible degrees of precision and required expenditures of machine time necessary for analyzing various kinds of circuits and to select the most suitable program for solving specific problems.

In conclusion it must be mentioned that a comparative analysis of different programs is a rather difficult task. An investigation procedure has not been finally established up to the present time. In subsequent studies special attention must be paid to improving the investigation procedure with the goal of developing criteria for estimating the accuracy of modeling and the effectiveness of using programs for analyzing electronic circuits, which is necessary for a more objective evaluation of the quality of programs studied.

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8831
CSO: 1860/332

COMMUNICATIONS, COMMUNICATION EQUIPMENT, RECEIVERS AND TRANSMITTERS, NETWORKS, RADIO PHYSICS, DATA TRANSMISSION AND PROCESSING, INFORMATION THEORY

UDC 612.39.1:519.25

FUNCTIONAL POLYNOMIALS IN PROBLEMS OF STATISTICAL RADIO ENGINEERING

Novosibirsk FUNKTSIONAL'NYYE POLINOMY V ZADACHAKH STATISTICHESKOY RADIOTEKHNIKI in Russian 1981 (signed to press 30 Jan 81) pp i, 2

[Annotation and table of contents from book "Functional Polynomials in Problems of Statistical Radio Engineering", by Valentin Borisovich Kashkin, Institute of Physics imeni L. V. Kirenskiy, Siberian Branch of the USSR Academy of Sciences, Izdatel'stvo "Nauka", 1500 copies]

[Text] The author examines nonlinear inertial transformations of steady random processes described by Volterra's functional polynomials with an arbitrary number of terms. He solves problems of the analysis of such transformations, synthesis of optimal nonlinear filters for the discrimination of signals against the background of interference, optimal nonlinear devices for the detection and discrimination of signals. Special attention is given to the methods of realization of the found transformations, including by means of functional electronics.

The book is intended for scientists and specialists in the area of radio engineering.

Figures -- 36, tables -- 6, bibliography -- 91 items.

Contents

10,233
CSO: 1860/312

UDC 621.316.925.001.5

DYNAMICS OF COMPLEX MEASURING ELEMENTS OF RELAY PROTECTION DEVICES

Moscow DINAMIKA SLOZHNYKH IZMERITEL'NYKH ORGANOV RELEYNOY ZASHCHITY in Russian 1981 (signed to press 17 Nov 80) pp 2, 208-9

[Annotation and table of contents from book "Dynamics of Complex Measuring Elements of Relay Protection Devices", by Eduard Mendelevich Shneyerson, Energoizdat, 5000 copies, 209 pages]

[Text] The author examines the methods of analysis of the behavior of complex measuring elements of relay protection devices during short-circuiting in electrical systems with consideration for transient processes occurring in the primary network, measuring transformers of current and voltage, and in secondary networks. He discusses the peculiarities of the behavior of various types of measuring elements under transient conditions and problems of the designing of devices with consideration for dynamic conditions.

This book is intended for engineers of research and designing organizations working in the area of relay protection and automation of power systems, as well as for graduate and undergraduate students of vuzes specializing in electric power engineering.

Contents

10,233
CSO: 1860/311

UDC 621.372.54

MICROPROCESSOR IMPLEMENTATION OF DIGITAL SIGNAL PROCESSING EQUIPMENT

Kiev IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: RADIOELEKTRONIKA in Russian Vol 24, No 6, Jun 81 (manuscript received 8 Jan 81) pp 4-15

[Article by A.I. Petrenko and S.A. Bublik]

[Text] A survey is given of basic approaches to designing digital signal processing equipment utilizing microprocessor sets. It is demonstrated that the choice of the structure of the signal processing algorithm is of essential importance for the implementation of high-efficiency microcomputers. The need to develop problem-oriented facilities for the automated design of equipment of this class is substantiated.

Successes in integrated electronics in the past decade have created the conditions for qualitative changes in signal processing equipment with the extensive use of digital methods [1-4]. At the present time the attention of developers of digital equipment has been attracted by the appearance of new components in the form of programmable large-scale integrated circuits called microprocessors [5-7]. They are distinguished by doubtless advantages: low cost, high reliability and small size and low power consumption. The changeover from equipment with "hard logic" to programmable microprocessor systems makes it possible in certain cases to shorten development time, to carry out its unification, to make improvement possible and to employ self-diagnosis.

Digital signal processing equipment is a promising area for the application of microprocessors (MP's). However, all the same the relatively slow speed of response of microprocessor components creates difficulties for their use in equipment operating in real time.

In the present article, using as an example digital filters, which represent a widespread type of equipment for the digital processing of signals, a number of methods of constructing processing algorithms and hardware suitable for microprocessor execution are discussed.

A computing device whose operation is described by a linear difference equation:

$$y_n = \sum_{i=0}^{M} a_i x_{n-i} - \sum_{i=1}^{N} b_i y_{n-i}, \qquad (1)$$

where $\{x_n\}$ is the input signal, $\{y_n\}$ is the output signal and a_i and b_i are coefficients, is usually called a linear digital filter (TsF) [1].* It is obvious from (1) that a digital filter essentially completes the transformation of an input number sequence into an output whose parameters are assigned coefficients a_i and b_i. In the frequency region a digital filter is described by a transfer function obtained by means of a z-transform of expression (1):

$$H(z)=\sum_{i=0}^{M} a_i z^{-i}/1 + \sum_{i=1}^{N} b_i z^{-i}.$$

Digital filters are classified as recursive and nonrecursive. If coefficients b_i do not equal zero (if only one), then such a filter is called recursive. In this case previously computed values of the output signal are used for computing subsequent ones. If all coefficients b_i equal zero, then the filter is called nonrecursive. Each reading of the output signal is computed on the basis of $M+1$ previous readings of the input:

$$y_n=\sum_{i=0}^{M} a_i x_{n-i}. \tag{2}$$

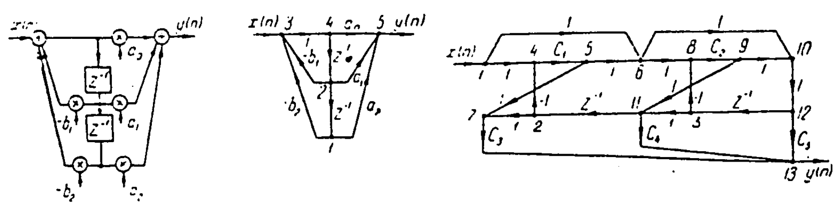
The transfer function, $H(z)$, of a nonrecursive filter takes the form of a polynomial with degrees of z^{-1}. Both types of filters make it possible to produce practically any assigned characteristic. The choice of a recursive or nonrecursive implementation is determined by the conditions of the specific application.

It is obvious from expressions (1) and (2) that arithmetic operations--multiplication, addition and subtraction--are used for the purpose of computing values of $\{y_n\}$. Since real digital computing devices operate with numbers having a finite precision of representation, the precision of computations of digital filters is limited. The resulting error in the value of the output signal represents a combination of three components, whose sources are quantization of the input signal, quantization of the results of arithmetic operations and quantization of coefficients. At the present time there are many determinate and statistical methods of estimating the influence of the effects of quantization on the characteristics of filters [8, 9]. In implementing digital filters with microprocessors having a word length of 8 to 16 bits, it is necessary to estimate the permissible number of bits with which the technical requirements for the digital filter are fulfilled. The required accuracy of the representation of values of the input signal and of the results of arithmetic operations (multiplication) is determined by the dynamic range specified, and the accuracy of coefficients by the permissible error of

*Microprocessor implementations of filters, spectrum analyzers and the like based on fast Fourier transform, Walsh, etc., algorithms are usually executed with narrowly specialized hardware [2] and are not discussed here.

the transfer function. However, an investigation of the effects of quantization in digital filters is not separable from the specific structure of the computing algorithm.

Generally the assigned transfer function, H(z) , can be represented by various structural diagrams [10]. Two familiar structures of second-order recursive digital filters are presented in fig 1 for the purpose of illustration.



a) b) c)

Figure 1.

The straightforward canonical structural diagram (fig 1a) is represented by an isomorphic signal graph (fig 1b) and functions according to the following algorithm:

For x(n) , where n = 0, 1, 2, ..., execute:

1. Enter $x(n)$.
2. $y_1(n) = y_2(n-1)$.
3. $y_2(n) = y_4(n-1)$.
4. $y_3(n) = -b_2 y_1(n) - b_1 y_2(n) + x(n)$.
5. $y_4(n) = y_3(n)$.
6. $y_5(n) = a_2 y_1(n) + a_1 y_2(n) + a_0 y_4$.
7. Derive $y(n) = y_5(n)$.
8. Go to step 1.

The chain structure of a Gray-Markel digital filter (fig 1c) operates according to the following algorithm:

For x(n) , where n = 0, 1, 2, ..., execute:

1. Enter $x(n)$.
2. $y_1(n) = x(n)$.
3. $y_2(n) = y_{11}(n-1)$.
4. $y_3(n) = y_{12}(n-1)$.
5. $y_4(n) = y_1(n) - y_2(n)$.
6. $y_5(n) = C_1 y_4(n)$.
7. $y_6(n) = y_1(n) + y_5(n)$.
8. $y_7(n) = y_2(n) + y_5(n)$.

9. $y_8(n) = -y_3(n) + y_6(n)$.
10. $y_9(n) = C_2 y_8(n)$.
11. $y_{10}(n) = y_6(n) + y_9(n)$.
12. $y_{11}(n) = y_3(n) + y_9(n)$.
13. $y_{12}(n) = y_{10}(n)$.
14. $y_{13}(n) = C_3 y_7(n) + C_4 y_{11}(n) + C_5 y_{12}(n)$.
15. Derive $y(n) = y_{13}(n)$.
16. Go to step 1.

For the purpose of reducing sensitivity to quantization effects, high-order filters are often executed in the form of a cascade or parallel connection of first- and second-order elements:

$$H(z) = \prod_{i=1}^{p} H_i(z); \quad H(z) = \sum_{i=1}^{p} H_i^{*}(z).$$

Each structural diagram determines the organization of the computing process differently and, consequently, its properties and characteristics, such as potential parallelism, the required memory capacity, quantization noise, dynamic range, etc.

The implementation of the computing algorithm with microprocessor sets involves the design of a microcomputer. It must have the following key functional blocks: a microprocessor for executing arithmetic-logical operations and controlling the data processing process in the microcomputer, a read-only memory (ROM) for storing the filter's programs and its coefficients (constants), a random-access memory (RAM) for storing values of the input and output signals and intermediate variables, an input/output interface for linking with peripherals, a timer (GTI) and a power supply. In fig 2 is presented a simplified block diagram of a processor for digital processing of analog signals executed on the basis of a microcomputer and analog-digital and digital-analog converters.

For effective processing of the signal it is necessary to match the structure of the computing algorithm with the architecture and parameters of the microcomputer. An analysis of functioning algorithms constructed for various structural diagrams of a digital filter makes it possible to identify three characteristic features of them:

1. There is a set of different algorithms which are equivalent to the same transfer function, H(z) , but which differ in sensitivity to the finite precision in the representation of numbers, in the parallelism of computations, in the memory capacity required, in the number of steps, etc.

2. The summing of products and the delay of a variable by one clock period are the most typical operations of linear digital filtration algorithms.

3. The number of input/output operations in digital filtration algorithms is relatively low as compared with the number of arithmetic operations.

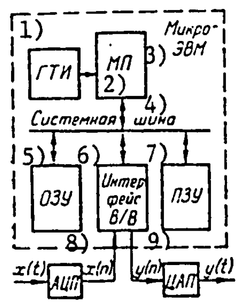


Figure 2.

Key:

1. Timer
2. MP
3. Microcomputer
4. System line
5. RAM
6. I/O interface
7. ROM
8. Analog-digital converter
9. Digital-analog converter

Consequently, especially high requirements must be imposed on the time for execution of the operations of multiplication, summation and the transfer of data between the storage and arithmetic-logic units. For the purpose of taking into account the specifics of digital filtration algorithms it is necessary to select a microprocessor which is optimal for a specific application. A comparative evaluation of the suitability of microprocessors must be made from a combination of technical and economic parameters [6]. In solving digital signal processing problems the following must be numbered among the decisive parameters: the time for the execution of instructions, characterizing the speed of the microprocessor; the presence of instructions for executing key digital filtration operations (including multiplication, addition, subtraction, shift, etc.); the number of internal registers (i.e., the capacity of the fast-access storage), determining the computing capabilities of the MP; the capacity of the addressable storage, determining the maximum amount of information which can be processed; the presence of a channel for direct access to the storage; the capability of interruption, determining the multichannel operating mode of the multiprocessor; the presence of microprogram control, making possible adaptation of the instruction set and of the structure of instructions to specifics of a specific algorithm; and the existence of facilities for microprocessor exchange for the purpose of implementing a processing algorithm possessing internal parallelism.

In addition to the parameters named, of essential importance for the application of microprocessors is the number (and presence) of large-scale integrated circuits from the microprocessor set necessary for the implementation of a specific microcomputer, the number of required power supplies and the power consumption, the presence of facilities for the automation of processing and for debugging, and the cost.

The structures and parameters of the microprocessors which are widespread at the present time meet the above-enumerated requirements to an insufficient degree. General-purpose microprocessors such as the I8080, MC6800, F8, Z80 and K580 are suited mainly for the logical processing of data. The execution of complicated arithmetic operations and computations, such as multiplication, is accomplished through software, on which much time is spent. For example, the software implementation of the operation of the multiplication of two eight-bit numbers with a general-purpose microprocessor of the MC6800 type takes about 300 μs [13]. The processing of signals in real time requires, as a rule, less time than the execution of arithmetic operations.

There are several methods, and combinations of them, for increasing the efficiency of processors for digital signal processing which are implemented with microprocessor sets: the use of high-speed microprocessors designed on the basis of modern technologies, such as TTL [transistor-transistor logic] with Schottky diodes, integrated injection logic, emitter-coupled logic, etc.; the use of microprocessors in which complicated arithmetic operations (including multiplication) are performed by means of hardware; the multiprocessing of signal processing algorithms and their implementation in multimicroprocessor systems; simplification of product summation operations; and the development and use of special-purpose microprocessors oriented toward speeding the execution of basic digital filtration operations.

Developers of high-efficiency signal processing systems have traditionally strived to use a high-speed element base. During the last decade of the development of the microprocessor element base the mastery of new technologies has made it possible to increase its speed by more than an order of magnitude. At the present time integrated technology has reached the level of ultralarge-scale integrated circuits (ULSIC's) with minimum geometric dimensions of elements on the order of one micron and a time delay in a gate on the order of a few nanoseconds. In the opinion of specialists, these parameters are close to the limit for silicon technology. It is anticipated that the development of new semiconductor technologies will make it possible to create devices with subnanosecond speed. Experimental models of gallium arsenide logical gates with a total delay of 33 ps have already been produced [11].

But the software execution of complicated arithmetic operations, as indicated above, takes a great deal of time and can be used basically for solving simple filtering problems.

An increase in the computing efficiency of general-purpose microcomputers of 30- to 100-fold and more is achieved by adding "mathematical chips"--microprocessor large-scale integrated circuits designed for performing mathematical operations of increased complexity. These LSIC's are programmable and nonprogrammable. The former are essentially processor elements with their own instruction set. The Am9511 and I8087 models are described in [12], which perform the operations of extracting the root, raising to a power, computing logarithmic and trigonometric functions, etc. Nonprogrammable LSIC's are special-purpose devices and make possible greater speed. In [12, 13], for example, a report is given on 8- and 24-bit completely parallel multipliers which form a result in 45 and 200 ns, respectively, and the 24-bit multiplier performs the multiplication of numbers with double precision and is suited for use in high-order recursive filters.

For the purpose of implementing high-efficiency digital signal processing equipment it is necessary, as mentioned above, to match carefully the structures of filtration algorithms with the architecture of computing facilities. The most universal and effective approach is the parallel organization of equipment and processing [14]. This approach is based on the employment of potential parallelism intrinsically characteristic of the structures of algorithms [10].

Obviously, in a filter computation of the output value, y_n , is performed in a definite order. For the purpose of computing a signal in any node of the signal graph of a digital filter it is generally necessary to know the values of some other nodal signals, i.e., for each structure there is its own combination of order relationships for the calculation of nodal signals which is determined totally by the topology of transfers. For example, for the structure represented by the graph in fig 1c the graph for the ordering of computations of nodal signals is presented in fig 3a, where $\{q_i\}$ represents the set of nodal signals which can be computed simultaneously. It makes it possible to estimate the potential parallelism of the computing algorithm of the structure considered for all arithmetic operations. Assuming the multiplication operation to be the longest and to be deciding the total input of time, it is possible for the purpose of reducing this input to reveal the possibilities of the parallel execution of the multiplication of coefficients by nodal values. It is obvious from the graph in fig 3a that of all 20 transfer branches only 5 implement transfers by means of the multiplication operation (since the transfer coefficients of the other branches equal $\pm$ 1). This makes it possible to construct a graph for the ordering of multiplication operations. Such a graph for the structure considered is presented in fig 3b. An analysis of it makes it possible to draw the conclusion that the simultaneous multiplication of variables can be performed for coefficients C_2 and C_3 , and also, in the next time interval, for coefficients C_4 and C_5 . Consequently, in a digital filter having a Gray-Markel structure it is feasible to use two multiprocessors. This makes it possible to reduce the total time for multiplication operations from $t_u = 5$ time intervals (when using a single microprocessor) to $t_u = 3$. Thus, the value of $t_u = 3$ corresponds to the degree of parallelism with respect to the multiplication operation intrinsically characteristic of the structure considered.

The potential parallelism relative to arithmetic operations for any computing algorithm is determined similarly if a structural diagram corresponding to it or an isomorphic signal graph is constructed.

In a number of cases the degree of parallelism of the algorithm can be additionally increased on account of the use of the conveyer principle of processing--another approach to the multiprocessing of processes [10, 15]. In this case the individual phases of the total execution cycle relating to different time intervals are executed simultaneously. The canonical structure of a digital filter (fig 1b) can thus be made totally parallel with respect to the multiplication operation on account of the addition of added unit delays to the direct transfer branches. An obvious disadvantage of increasing speed by the use of parallelism is the increase in the amount of equipment.

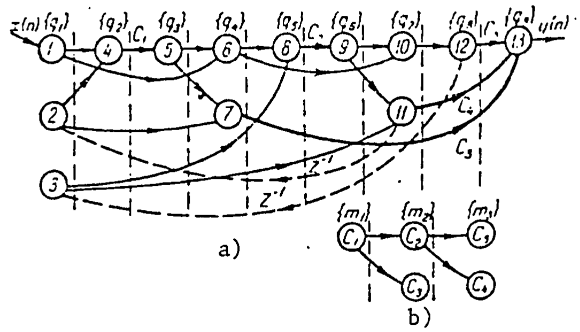


Figure 3.

The steady reduction in the cost of integrated ROM's in recent years has made it possible for developers to increase considerably the carrying capacity of digital filters on the basis of employing tabular algorithmic methods of computing sums of products [2]. In this case the operation of the multiplication of a sequence of variables by constant factors is implemented by the operations of the addition and shift of codes of an auxiliary vector function, ψ , whose values are computed beforehand and are stored in the storage.

Let us write difference equation (1) for an element of a second-order digital filter in the form:

$$y_n = a_0 x_n + a_1 x_{n-1} + a_2 x_{n-2} - b_1 y_{n-1} - b_2 y_{n-2}. \quad (3)$$

Let all signals be limited to a level of $\pm$ 1, and for their representation let an additional L-bit code (including the sign bit) with a fixed point be used:

$$U_n = -U_n^0 + \sum_{i=1}^{L-1} U_n^i 2^{-i}.$$

Then equation (3) can be rewritten in the following manner:

$$y_n = a_0\left(\sum_{i=1}^{L-1} x_n^i 2^{-i} - x_n^0\right) + a_1\left(\sum_{i=1}^{L-1} x_{n-1}^i 2^{-i} - x_{n-1}^0\right) + a_2\left(\sum_{i=1}^{L-1} x_{n-2}^i 2^{-i} - x_{n-2}^0\right) - b_1\left(\sum_{i=1}^{L-1} y_{n-1}^i 2^{-i} - y_{n-1}^0\right) - b_2\left(\sum_{i=1}^{L-1} y_{n-2}^i 2^{-i} - y_{n-2}^0\right).$$

Having defined function ψ of five binary arguments as $\psi(U^1, U^2, U^3, U^4, U^5) = a_0U^1 + a_1U^2 + a_2U^3 - b_1U^4 - b_2U^5$, this equation can be written in the form:

$$y_n = \sum_{i=1}^{L-1} 2^{-i}\psi_i(x_n^i, x_{n-1}^i, x_{n-2}^i, y_{n-1}^i, y_{n-2}^i) - \psi_0(x_n^0, x_{n-1}^0, x_{n-2}^0, y_{n-1}^0, y_{n-2}^0).$$

The value of y_n is now computed only by means of algebraic addition operations and shift operations. Vector function ψ for an assigned set of coefficients a_0, a_1, a_2, b_1 and b_2 takes on $2^5 = 32$ values. They can be computed beforehand and entered in the form of a table in the microcomputer's ROM. The algorithm for computing y_n in this case has the form:

1. Clear accumulator register.
2. Read out value of ψ_i for $i = L$.
3. Add ψ_i with contents of accumulator register.
4. Shift contents of accumulator register to right by one bit (multiplication by 2^{-1}).
5. Repeat steps 2 to 4 for $i = L - 1, L - 2, \ldots, 1$.
6. Read out value of ψ_0.
7. Subtract value of ψ_0 from contents of accumulator.

High-order digital filters can be constructed, as a rule, on the basis of the cascade and parallel connection of first- and second-order elements.

A disadvantage of this approach is the exponential growth in storage volume with an increase in the number of arguments of function ψ, and consequently in access time. In addition, implementation is complicated considerably if the coefficients change during the period of operation of the filter.

For increasing the efficiency of computations performed in digital filtering, developers have more than once resorted to different variants of the integral representation of the filter's coefficients and variables. In [16, 17] efficiency was increased on account of simplification of the multiplication operation in designing transfer functions of the digital filter with coefficients equal to small whole numbers (including ± 1). Characteristic of this trend is complication of the step of forming the transfer function (PF), since the approximation problem is able not to have a solution with specific requirements and limitations.

The body of mathematics of the arithmetic of residue classes (modular arithmetic) is used in other developments [18, 19]. It makes possible multiprocessing of algorithms for the operations of multiplication, addition and subtraction and the performance of computations with high efficiency and precision with multiprocessor systems. The time for the execution of the multiplication operation for n-bit numbers in this case is proportional approximately to n, and not to n^2 as in the traditional method.

A system of residue class arithmetic is constructed from a series of modules, $u = \{m_1, m_2, \ldots, m_L\}$, which are relatively prime. Any whole number

$v \in [-w, w]$, where $w = 1/2(Q - 1)$ and $Q = \Pi m_i$, can be unambiguously coded by a sequence of residue classes, v_i : $v = v_1 v_2 \ldots v_L$,

$$v_i = \begin{cases} |v| \bmod m_i & \text{для } v \in [0; w], \\ m_i - |v| \bmod m_i & \text{для } v \in [-w, 0]. \end{cases}$$

Arithmetic operations--addition, subtraction and multiplication--are performed very simply in this case:

$$(u_1, \ldots, u_r) + (v_1, \ldots, v_r) = ((u_1 + v_1) \bmod m_1, \ldots, (u_r + v_r) \bmod m_r),$$
$$(u_1, \ldots, u_r) - (v_1, \ldots, v_r) = ((u_1 - v_1) \bmod m_1, \ldots, (u_r - v_r) \bmod m_r),$$
$$(u_1, \ldots, u_r) \times (v_1, \ldots, v_r) = ((u_1 \times v_1) \bmod m_1, \ldots, (u_r \times v_r) \bmod m_r).$$

Since residue class arithmetic operates only with whole numbers and the coefficients of a digital filter generally cannot be whole numbers, then in the implementation of a digital filter it is necessary to perform scaling. The values of coefficients a_i and b_i are represented as whole numbers $[Sa_i]$ and $[Sb_i]$ and the output signal from each element must be divided by factor S before being used in the next iteration. For each second-order element this operation can be written in the form:

$$Sy(n) = [Sa_0]\,x(n) + [Sa_1]\,x(n-1) + [Sa_2]\,x(n-2) - [Sb_1]\,y(n-1) - \\ - [Sb_2]\,y(n-2); \qquad y(n) = \{S^{-1}[Sy(n)]\}. \tag{4}$$

It is not difficult to combine the parallel structure of computations of residue class arithmetic with the Peled-Liu vector multiplication algorithm [2]. If x(n) and y(n) are interpreted as binary whole numbers, i.e.,

$$x(n) = \sum_{j=0}^{L} x_j^n 2^j \text{ и } y(n) = \sum_{j=0}^{L} y_j^n 2^j,$$

then equation (4) can be rewritten in the form

$$Sy(n) = \sum_{j=0}^{L} \psi(A_j)\, 2^j,$$

where

$$A_j = x_j^{n-2}, \ldots, x_j^n,\ y_j^{n-2},\ y_j^{n-1},$$

$$\psi(A_i) = \sum_{k=0}^{2} [Sa_k] x_i^{n-k} - \sum_{k=1}^{2} [Sb_k] y_i^{n-k}.$$

For a system of residue classes assigned by modules $m_1 = 2^8 - 1$ and $m_2 = 2^8$, the equation can be represented in the form:

$$y_1'(n) = |Sy(n)|_{2^8} = \left| \sum_{j=1}^{7} 2^j \psi_1(A_{1j}) \right|_{2^8};$$

$$y_2'(n) = |Sy(n)|_{2^8-1} = \left| \sum_{j=0}^{7} 2^j \psi_2(A_{2j}) \right|_{2^8-1},$$

(5)

where

$$\psi_1(A_{1j}) = |\psi(A_{1j})|_{2^8-1}; \quad y_i(n) = \left| \sum_{j=0}^{L_i-1} y_{ij}^n 2^j \right|_{m_i}; \quad \psi_2(A_{2j}) = |2^8 - \psi(A_{2j})|_{2^8};$$

$$x_i(n) = \left| \sum_{j=0}^{L_i-1} x_{ij} 2^j \right| m_i; \quad A_{ij} = x_{ij}^{n-2}, \ldots, x_{ij}^n,\ y_{ij}^{n-2},\ y_{ij}^{n-1}.$$

The residual value of $y(n)$ can be computed on the basis of the scaling algorithm presented in [18]:

$$|y(n)|_{2^8-1} = |y_1'(n) + y_2'(n)|_{2^8-1}.$$

(6)

Computations according to equations (5) and (6) can be executed sequentially on a single eight-bit microprocessor or, according to (5), can be computed simultaneously on two independent microprocessors (fig 4), and equation (6) by means of a modulo-$(2^8 - 1)$ processor.

The difficulties which arise for developers in using residue class arithmetic for the implementation of digital filtering are related primarily to ensuring effective scaling, especially for recursive digital filters, to determining the sign of the result, etc.

In spite of all the advantages of the methods discussed for organizing the execution of key digital signal processing operations on general-purpose microcomputers, the best agreement between the structure of algorithms and the structure of hardware can be achieved when implementing them with special-purpose microprocessors. Special-purpose microprocessors have smaller overall dimensions and lower cost and high speed and reliability. They can operate individually or in conjunction with general-purpose microprocessors. Successes in integrated technology and the increase in the degree of integration in a semiconductor chip to 20,000 to 30,000 components has made it possible already today to develop single-chip special-purpose microprocessors (more accurately, microcomputers) for digital signal processing.

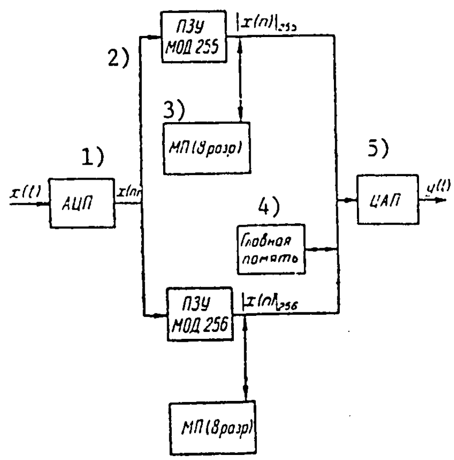


Figure 4.

Key:
1. Analog-digital converter
2. Model 255 ROM
3. Microprocessor (8-bit)
4. Main storage
5. Digital-analog converter

In this connection it is interesting to discuss the capabilities and some features of one of the first microcomputers of this type, the I2920 [20]. This microcomputer can be programmed for digital processing of analog signals in real time for the performance of filtering, modulation, detection and the like. It has been executed according to the n-MOS technology on a single chip measuring 39.1 mm^2 in area, on which are placed a microprocessor, a reprogrammable ROM (RROM), an analog-digital and digital-analog converter (fig 5).

The I2920 microcomputer executes a special-purpose instruction set: addition, subtraction, determination of absolute value, copying of data and several logic operations. Any instruction is executed in 400 ns. The band of frequencies which can be processed depends on the time for execution of the entire program which, in turn, is determined by the number of instructions (the maximum number of instructions in the program is 192 and the frequency band in this case equals 6.5 kHz).

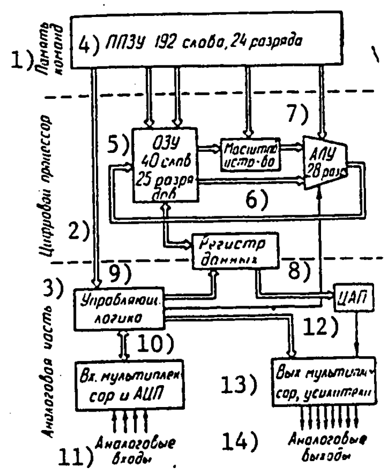


Figure 5.

Key:

1. Instruction storage
2. Digital processor
3. Analog section
4. RROM, 192 words, 24 bits
5. RAM, 40 words, 25 bits
6. Scaler
7. ALU, 28 bits
8. Data register
9. Control logic
10. Input multiplexer and analog-digital converter
11. Analog inputs
12. Digital-analog converter
13. Output multiplexer, amplifiers
14. Analog outputs

High efficiency in the processing of numbers is made possible by the conveyer architecture of the microcomputer and by an efficient algorithm for multiplying numbers. In multiplying variables by constants a sequence of addition and subtraction of variables scaled by a power of two is employed. For example, if variable y is multiplied by constant b ($b = 1.7656 = 2^1 - 2^2 + 2^{-6}$), then the product may be written in the form: $yb = y2^1 - y2^{-2} + y2^{-6}$. Scaling is performed in the range from 2^2 to 2^{-13} and is implemented by an appropriate shift to the left or right. The multiplication method employed makes it possible to reduce the time severalfold and requires a small amount of hardware. Arithmetic operations are performed with 25-bit numbers, making possible high accuracy of results. The I2920 microcomputer is fairly simple to program.

The resources of this micrcomputer are sufficient for solving many practical problems. They make possible, for example, the software implementation of 20 pairs of two-terminal recursive filters or a spectrum analyzer for the sound spectrum.

However, for solving more complicated problems associated, for example, with the processing of a flow of digital information from various sources, a digital signal processing processor is usually executed in the form of a multichip configuration formed from a central control unit and peripheral processing modules. The functions of the control unit are usually performed by a general-purpose multiprocessor and the modules are essentially special-purpose processors which perform individual complete processing procedures based on programs written in the ROM. Able to serve as an example of hardware of this design is the TMS 9900 system of microprocessor modules for military purposes by Texas Instruments, Inc. [21].

It should be mentioned that the development and production of special-purpose microprocessor sets and of microcomputers are feasible when they are used in great volume. The choice of the variant of the structure of the processing algorithm and of the hardware configuration depend on specific conditions of use.

Development of the computing algorithm is an important step in the complicated and multistage process of designing microprocessor signal processing systems. Decisions made at this stage determine many technical and economic parameters of the future microcomputer. As is obvious from the discussion above, it is not separable from selection of the architecture of the microcomputer. Creation of the software, whose cost represents a major portion of the cost of the system, begins with development of the algorithm.

The complexity of the problems facing developers of microprocessor systems is responsible for the necessity of the extensive application of design automation equipment at all stages of development. However, the microprocessor design systems used at the present time are mainly of a problem-invariant nature and are oriented toward the development and debugging of software and hardware according to a prepared algorithm [22]. In cases when algorithms are considerably complicated and consequently have high a priori indefiniteness of their structure (as, for example, digital signal processing algorithms), it is necessary to supplement these facilities with a problem-oriented part designed for the development of an optimum algorithm. This makes it possible to determine its structure and parameters and to reveal errors before writing and debugging the program.

As an example it is possible to refer to the packages of applied programs which are included in the software of the Automated Design of Digital Systems (DISAP) system [23]. The DISAP-APPROKSIMATSIYA [-APPROXIMATION] PPP [package of applied programs] makes it possible to solve problems relating to the approximation of the frequency and time characteristics of digital recursive filters from the transfer functions of analog prototype filters. The DISAP-ANALIZ [-ANALYSIS] PPP is designed for multivariant frequency-time analysis of computing algorithms with a library or random structure (up to 150 branches and 80 nodes) represented by isomorphic signal graphs.

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AUTOMATED DESIGN SYSTEM FOR DIGITAL SIGNAL PROCESSING EQUIPMENT

Kiev IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: RADIOELEKTRONIKA in Russian Vol 24, No.6, Jun 81 (manuscript received 14 Nov 80) pp 96-98

[Article by A.I. Petrenko, S.A. Bublik, L.G. Butakova and L.A. Shumakova]

[Text] Designing digital signal processing equipment (UTsOS) employing large-scale integrated circuits (LSIC's) and microprocessors is a complicated, multi-stage, iterative process. Considerable difficulty for developers resides in finding the optimum hardware implementation of signal processing algorithms under conditions of the not too high speed of response of elements and short word length [1, 2]. High efficiency and quality in designing UTsOS, the functional complexity of which is increasing steadily, can be achieved only on the basis of the overall employment of facilities and methods of automating designing at all stages of development--by the creation of special-purpose SAPR UTsOS's [automated design systems for digital signal processing equipment].

The problems to be solved by developers and trends in the development of UTsOS make it possible to formulate the basic rules and requirements for SAPR UTsOS's as follows:

The direct developer of electronic equipment is the user of problem-oriented SAPR UTsOS's.

Packages of applied programs for SAPR UTsOS's must make possible the solution of a broad range of problems associated with the approximation and analysis of the characteristics of digital equipment and its structural and parametric organization and with the production of design documentation.

Interaction between the developer-user and an SAPR UTsOS is organized on the basis of a problem-oriented input language the semantics of whose basic syntactical constructions are based on concepts familiar to a developer of electronic equipment.

An SAPR UTsOS is a component of industrial integrated SAPR's [automated design systems]; the organization of its software, hardware and data support is determined by the general requirements for SAPR's for technical equipment and systems [3].

These principles formed the basis of the Automated Design System for Digital Systems (DISAP) under development. The first version of the system consists of two packages of applied programs: the DISAP-APPROKSIMATSIYA [-APPROXIMATION] PPP [package of applied programs] and the DISAP-ANALIZ [-ANALYSIS] PPP.

The DISAP-APPROKSIMATSIYA package of applied programs is designed for solving problems of approximation of the frequency and time characteristics of digital filters (TsF's) based on analog prototype filters. This is accomplished by digitization of a given analog transfer function (PF), H(s) , on the basis of a single z-transform--an algebraic (bilinear or biquadratic) or adjusted--or of the method of invariance of the pulse characteristic [1]. The appropriate frequency transformation is performed in necessary instances. Taking into account the extensive use of the algebraic transformation, a speedier algorithm was developed for the package which utilizes the symmetry in the expansion of expressions by which the coefficients of the numerator and denominator of the analog transfer function are multiplied. In these transformations the transfer function is decomposed into simple fractions by the method of undetermined multipliers. The modified Hitchcock-Berstow method is used for finding the roots of polynomials, making it possible on the basis of an optimization procedure to obtain the values of roots through precise values of coefficients of trinomials.

The result of the package's work is the transfer function, H(z) , of a recursive digital filter represented in the form of a cascade or parallel connection of elements of the first and second order. Furthermore, its maximum order in a given version of the system equals 20. The package's programs make it possible also to calculate frequency and time characteristics, zeros and poles of the digital filter's transfer function.

A problem-oriented input language with free formats has been developed for the purpose of organizing efficient interaction between the user and the DISAP system. Functionally it is divided into a language for describing the subject of study and conversion and a language for describing the assignment for study and conversion. The DISAP-APPROKSIMATSIYA PPP input language represents a subset of the language of the DISAP system.

The description of the original transfer function of the analog filter, H(s) , in the input language of the DISAP-APPROKSIMATSIYA package can be represented both on the basis of coefficients and by means of roots. The language for describing the assignment makes it possible to present the necessary procedures of the computing process in terms familiar to a UTsOS development engineer.

The DISAP-ANALIZ package of applied programs is designed for solving a broad range of problems originating in the development of structural diagrams of UTsOS, such as digital filters, phase correctors, etc. The elements of the circuits under study can be adders, multipliers and delay elements. For linear and parametric digital circuits of random form the package's programs make it possible to perform multivariant studies of characteristics in the frequency and time regions, to model parametric sensitivity, to form circuit functions, to analyze stability; to study the effects of the quantization of coefficients, the results of arithmetic operations and values of the input signal; and to estimate the dynamic range, nonlinear distortion and the potential parallelism of structures. These studies can be performed for steady-state and transient conditions, for conditions of constant and variable factors and of constant and variable time intervals, in various combinations of them.

Equations for the mathematical model of a digital circuit can be obtained in various ways. In the DISAP-ANALIZ version under consideration a mathematical model of a digital circuit of random structure functioning with variable factors and time intervals is formed on the basis of the method of nodal signals [4]. In matrix form it can be written for the time region in the form of a system of difference equations, $y(n) = f_c^t(n)y(n) + f_d^t(n)y(n-1) + x(n)$, where $y(n)$ is the column vector of the values of N internal nodal signals, $x(n)$ is the column vector of N external signals, $f_c(n)$ is the matrix of dimension N X N of coefficients for the transfer of elements without delay, and $f_d(n)$ is the matrix of dimension N X N of coefficients for the transfer of elements with unit delay.

In the case of a linear circuit invariant in terms of shift, matrix elements f_c and f_d do not depend on time. Then, using the z-transform, the mathematical model of a digital circuit for the frequency region and steady-state conditions can be written in the form of a system of linear algebraic equations: $Y(z) = f_c^t Y(z) + f_d^t Y(z) z^{-1} + X(z)$.

The advantages of these models are the simplicity of formation, solution and modification. In addition, computations performed in keeping with the system of difference equations are adequate for the number and kind of computations and their sequence in a real unit of equipment, which makes possible the software modeling of various effects, such as loops of instructions and overflow. The effects of quantization associated with the truncation and rounding of numbers can be determined precisely [5] or on the basis of a probabilistic model [4].

The description of the digital circuit to be studied and the assignment for its study and conversion are entered into the computer in the problem-oriented input language of the DISAP-ANALIZ PPP, which is a subset of the input language of the DISAP system. At the data preparation stage the structural diagram of the UTsOS is represented in the form of an isomorphic signal graph. The elements of the circuit under study are replaced by branches of the graph, for which are indicated the directions of the transfer of signals, connection nodes, identifiers of the type of branch, transfer coefficients or a set of parameters, and the order number of the branch. The package makes it possible to analyze digital circuits whose equivalent circuits contain up to 150 branches and 80 nodes. The results of calculations are read out in the form of tables and graphs for an alphanumeric printer listing.

The DISAP-APPROKSIMATSIYA and DISAP-ANALIZ packages can operate both in combination and independently of one another. The DISAP system is constructed according to the modular principle and has a multiphase structure, which makes it possible to operate in the overlay mode with a limited memory. Program modules are written in FORTRAN-IV and an assembly language. The first version of the system has been implemented with YeS [Unified Series] computers under the control of a YeS DOS [disk operating system]. For the purpose of enabling the exchange of information between individual modules and the storage of the necessary information on magnetic disks, a data bank has been organized which includes an archive of source data, a library of input signals, a library of digital filter structures, libraries of transfer functions of analog and digital filters, and files for storing intermediate results.

Bibliography

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2. Petrenko, A.I. and Bublik, S.A. "Primeneniye mikroprotsessorov v ustroystvakh tsifrovoy fil'tratsii" [Application of Microprocessors in Digital Filtering Equipment], Kiev, Znaniye, 1980.

3. Gavrilov, M.A. "Integrated Systems--a Modern Trend in the Development of Automated Design Systems," PRIBORY I SISTEMY UPRAVLENIYA, No 1, 1979, p 3.

4. Krosh'yer and Oppengeym. "Analiz lineynykh tsifrovykh tsepey" [Analysis of Linear Digital Circuits], TIIER, Vol 63, No 4, 1975, p 45.

5. Artyukhov, V.G., Bublik, S.A. and Mikhaylyuk, G.T. "Modeling Digital Filters with a Variable Word Length" in "Avtomatizatsiya proyektirovaniya v elektronike" [Design Automation in Electronics], Kiev, Tekhnika, No 16, 1977, p 62.

8831
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OPTOELECTRONICS, QUASI-OPTICAL DEVICES

UDC 681.4.002.2(075.8)

PRODUCTION OF OPTICAL ELECTRONIC INSTRUMENTS

Moscow PROIZVODSTVO OPTIKO-ELEKTRONNYKH PRIBOROV in Russian 1981 (signed to press 27 Aug 80) pp 2, 5-6, 300-303

[Annotation, introduction (excerpts) and table of contents from book "Production of Optical Electronic Instruments", by Boris Fedorovich Kaledin, Mikhail Dmitriyevich Mal'tsev and Al'bert Ivanovich Skorokhodov, Izdatel'stvo "Mashinostroyeniye", 6900 copies, 304 pages]

[Excerpts] This book is intended as a textbook for tekhnikums.

Introduction

Rapid growth of optical instrument-making, along with the complication of instruments and improvement of their quality characteristics, raise a critical problem of improving the technological effectiveness of their design and development of optimal processes of manufacturing parts of optical instruments, their assembly, adjustment, and control. These problems can be solved only by highly skilled specialists possessing a profound theoretical knowledge and good practical training on the basis of modern achievements of science and technology.

The production of optical instruments is characterized by high standards and the use of special technological processes some of which are unique.

The problem of the quality of optical electronic instruments includes a large complex of problems of designing and production whose solution depends greatly on continuous improvement of the technological effectiveness of the designs of instruments and the use of new advanced technological processes. The quality of technological processes in all stages of production of optical electronic instruments is determined greatly by the sensitivity, accuracy, length, and reliability of their work. In turn, the development of new advanced technological processes contributes to the designing of better instruments with time-stable characteristics and makes it possible to reduce their overall weight, dimensions and labor input into their manufacturing. The above requirements presuppose the use of new materials for mechanical and optical parts, including titanium, beryllium, precious metals, special alloys and brands of glass. Parts made of new materials are processed by special technological processes which differ from the processes of classical technology. They are: new methods of obtaining rational blanks with the use of liquid self-hardening mixtures; machining complex framework parts with a highly productive equipment -- integrated sets of machinery, machines with ChPU [numerical program control] of the "machining centers"-type; the use of diamond tools for fine grinding. Methods of sizing with electron and laser beams, ultrasound, and electrochemical treatment are used more and more widely in the manufacturing of optical instruments. The production of parts with aspheric surfaces made of artificially grown crystals, organic glass, etc, is growing.

Another distinctive characteristic of the manufacturing of optical electronic instruments is a large volume of adjustment and regulation jobs. The use of supersensitive receivers of radiant energy in the sensitive elements of optical electronic instruments makes it impossible to perform adjustment operations manually and requires automation of data removal and movement. Control and adjustment benches for checking modern optical electronic instruments are measuring complexes which are no less complicated than the instruments themselves.

Electronic parts in optical electronic instruments of the last generation became more complicated, which is connected with automatic processing and transmission of information and with the fact that instruments became self-contained. This brought about considerable changes in the manufacturing technology of radio elements and electronic units, which led first to the unit method, and then to the functional-assembly or modular method of designing and production. The method of modular designing became possible after the development of advanced methods of printed-circuit wiring. Micromodular designing and further development of microminiaturization connected with the use and improvement of fundamentally new and advanced technological processes on the basis of integrated technology will make it possible to improve considerably the quality and reliability of optical electronic instruments.

Contents

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PUBLICATIONS, INCLUDING COLLECTIONS OF ABSTRACTS

UDC 621.391

ABSTRACTS FROM COLLECTION 'DIGITAL SIGNAL PROCESSING AND ITS APPLICATION'

Moscow TSIFROVAYA OBRABOTKA SIGNALOV I YEYE PRIMENENIYE in Russian 1981 (signed to press 28 Jan 81) pp 219-222

UDC 621.391.2

CONVOLUTION OF MULTIVALENT DISCRETE SIGNALS IN A RANDOM BASE

[Abstract of article by Ayzenberg, N. N., and Semirot, M. S.]

[Text] This article considers multidimensional signals and spectral conversions of multidimensional discrete signals. The authors attempt to prove the theorem of the convolution of multidimensional signals. It is demonstrated that the convolutions given in the article exhaust all convolutions of multivalent discrete signals for each of which the spectrum of convolution is equal to the product of the spectra. The article has five bibliographic entries.

UDC 621.391.141

GENERALIZED FOURIER-HAAR CONVERSION ON A FINITE ABELIAN GROUP

[Abstract of article by Boyko, L. L.]

[Text] This article considers algorithms for fast or orthogonal conversions of the fast Fourier and Haar types from the group theory point of view. The author demonstrates that the existence of fast algorithms is based on the availability of an extended composite series in a finite abelian group of a non-prime order. A broad class of orthogonal nonsymmetrical conversions, a generalized Fourier-Haar conversion, is defined. Each of this class of conversions has a fast computational algorithm, and the number of essential operations depends significantly on the length of the composite series of the group for the particular conversion. Particular cases of the given class are the conventional discrete Fourier conversion, Walsh, Walsh-Adamar, and Walsh-Pailey conversions, number theory conversions, the traditional Haar conversion, and the conversion by Haar k-functions. The article has 20 bibliographic entries.

UDC 621.391.141

NUMBER THEORY FRENEL CONVERSION AND ITS APPLICATION IN DIGITAL PROCESSING OF MULTIDIMENTIONAL DATA ARRAYS

[Abstract of article by Givental', A. B., and Krenkel', T. E.]

[Text] This article is devoted to a multidimensional generalization of the Blyusteyn algorithm, construction of number theory Frenel functions on a finite commutative group above a commutative ring with unity, and to a description of possible applications of such functions in digital processing of multidimensional data arrays. The article has 18 bibliographic entries.

UDC 535.317

SOME QUESTIONS OF THE THEORY OF DISCRETE ORTHOGONAL SIGNAL CONVERSIONS

[Abstract of article by Yaroslavskiy, L. P.]

[Text] This article reviews questions of discrete representation of integral Fourier and Frenel conversions and the theory of fast algorithms of orthogonal conversions. The author introduces shifted discrete Fourier conversions and discrete Frenel conversions and analyzes their properties. On the basis of the concept of staged Kronecker matrices, it is demonstrated how to construct a single notation of orthogonal matrices that allow factorization to produce weakly filled matrices. The author formulates factorization theorems, shows the possibilities of their application with examples, and gives factored representations of matrices of orthogonal conversions known from the literature. The article has four tables and 26 bibliographic entries.

UDC 519.240

SELECTING THE PARAMETRIC REPRESENTATION OF CURVES IN DIGITAL DESCRIPTION AND PROCESSING OF FLAT FIGURES

[Abstract of article by Nagornov, V. S., and Polyakov, V. G.]

[Text] The article raises the question of seeking for a smoother, in a certain sense, parametric description (whose spectrum has minimum width) relative to a closed curve assigned on a surface. It is demonstrated that the criteria of spectrum width are related to its fourth-order moment and lead to the problems of seeking the lowest proper value (minimum spectrum width) and corresponding function proper (optimal speed of movement along the curve) of the Shturm-Liuvill operator with a periodic coefficient, which is the square of the curve as a function of arc length. Examples are given of optimizing the parametric representation and the authors briefly describe the possibilities of using this procedure. The article has three illustrations and four bibliographic entries.

UDC 621.391.172:621.397

COMPARISON OF LINEAR METHOD OF RESTORING DISTORTED IMAGES

[Abstract of article by Lebedev, D. S., and Milyukova, O. P.]

[Text] The authors consider the problem of linear reconstruction of distorted images in the absence of random noise, where the reconstruction algorithms are defined by various optimality criteria of the generalized Euclidian distance type. The article compares restored images for certain distances: the minimum norm image, the smoothest image, and the image that deviates least on the average from the original. The article has three illustrations and three bibliographic entries.

UDC 621.391.172:621.397.681.518.2

SOME METHODS OF DIGITAL PREPARATION OF IMAGES

[Abstract of article by Belikova, T. P.]

[Text] The article presents data from an experimental test using computers of these methods of preparing images: (a) the method of adaptive amplitude conversions (exponential intensification and hyperbolization of the histogram); (b) the method of optimal linear filtration and localization of objects in images. A mammogram of the mammary gland and an aerial photograph of a segment of the earth's surface were used as objects of study. The author describes the work of the corresponding algorithms for preparing images. The article considers the possibilities of generalization and further elaboration of the methods of adaptive amplitude conversions. The article has six illustrations, two tables, and 13 bibliographic entries.

UDC 681.325+621.379

AUTOMATIC PROCESSING OF INTERFEROGRAMS ON A DIGITAL COMPUTER

[Abstract of article by Ushakov, A. N.]

[Text] This article considers the question of restoring the phase of an interferogram recorded on photographic film. The problem was solved by stages: (1) correction of nonlinear distortions of the photographic film; (2) filtration of register noise; (3) filtration of low-frequency noise; (4) restoration of the relative phase value; (5) reconstruction of the absolute phase value. The article reviews the questions of automatic filtration of register noise for narrow-band and broad-band interferograms and automatic filtration of low-frequency noise. The author presents the results of experiments with formulation of interferograms. There is an evaluation of the precision of restoration. The article has 15 illustrations and 36 bibliographic entries.

UDC 681.3.01:687.051.21

AUTOMATIC MEASUREMENT OF HUMAN SUBJECTS FOR MACHINE CUTTING OF CLOTHING — PRINCIPLES OF OBTAINING AND PROCESSING DATA

[Abstract of article by Aydu, E. A., Nagornov, V. S., and Polyakov, V. G.]

[Text] This article gives a schematic description of the tangential tape method of measuring the human being. This method solves the technical-economic, esthetic, and psychological problems that have hindered widespread automation of the process of measuring the human figure for the needs of machine clothing design and anthropometric studies. The experimental device that accomplishes this method is then viewed as a specific discrete source of two-dimensional signals whose computer processing for the purpose of spatial reconstruction of the human figure necessarily requires two-dimensional procedures of filtration and interpolation as well as many other special operations. The article has 12 illustrations and two bibliographic entries.

UDC 535.317.1+681.141+772.99

MOVIE-TYPE DIGITAL HOLOGRAPHIC FILM

[Abstract of article by Karnaukhov, V. N., and Merzlyakov, N. S.]

[Text] The article presents experimental results of a computer synthesis of movie-type holographic film. The object, two evenly colored spheres rotating at a variable speed aroused an immobile third sphere, was modeled on the computer. For visualization of the full cycle of the spheres 48 movie-type projections of the object were synthesized on a surface, corresponding to 48 successive positions of the object in space. Both the horizontal and the vertical parallaxes were taken into account in transmitting the volume. The frequency of tracking the angles of approach was variable. The film, which was a composite macro-cine-form containing 1,152 elementary cine-forms, was secured to a circular metal frame and illuminated with a laser light with a spherical wave front. With an immobile observer and rotating film the illusion arises of smooth rotation by the spheres, and the direction of rotation can be clearly tracked. The article has two illustrations and eight bibliographic entries.

UDC 535.2:317.1

SYNTHESIS OF COLORED HOLOGRAMS ON A DIGITAL COMPUTER

[Abstract of article by Merzlyakov, N. S.]

[Text] The author proposes a method of synthesizing colored macroholograms on a digital computer. By contact copying three color-divided synthesized Fourier holograms recorded on black-white photographic film are transferred in sequence behind red, green, and blue light filters to the corresponding layers of reversed color film. A three-color laser is used to restore the image. The proposed technique makes it possible to obtain colored macroholograms that contain up to $16 \cdot 10^6$ elements. They are also suitable for direct visual observation. The article has eight bibliographic entries.

UDC 535.317

DIGITAL MODEL OF RECORDING AND RECONSTRUCTING HOLOGRAMS

[Abstract of article by Popova, N. R.]

[Text] The article describes a digital model for recording and reconstructing Fourier and Frenel holograms. The author considers the effect of distortion in the hologram on the quality of reconstruction of diffuse objects. She derives the characteristics of speckle contrast depending on the limitation of dimensions, the superimposing of random noise, the limitation of the dynamic range, and quantization of the hologram, as well as for the case of an unfocused image. The results obtained may be used in radio, acoustic, and seismic holography. The article has 16 illustrations and seven bibliographic entries.

UDC 621.395.44

DIGITAL MODEL OF A COMMUNICATIONS CHANNEL BASED ON A POWER TRANSMISSION LINE

[Abstract of article by Andronov, A. A.]

[Text] This article considers the set of questions involved in the work of a high-frequency communications channel for a power transmission line, especially the basic type of interference in the channel — interference of the corona discharge of the wires. The author constructs a digital model of a high-frequency communications channel for a power transmission line on the basis of the physical mechanism of formation of interference from the corona and experimental data on its statistical characteristics. The article analyzes the question of the adequacy of a digital model and a high-frequency channel. It is shown that results obtained on the digital model correspond to experimental data. The digital model is used to obtain and analyze various statistical characteristics of the channel. The article gives results from investigations which permit a deeper study of the processes taking place in a high-frequency communications channel. The article has five illustrations and 10 bibliographic entries.

UDC 528.9:681.3:62-506

INVESTIGATION OF THE MUTUAL DEPENDENCE OF MICROPARAMETERS OF THE RELIEF BY THE STATISTICAL MODELING METHOD

[Abstract of article by Lotov, V. N.]

[Text] This article considers the problem of determining the interrelationship of the macroparameters of a surface by statistical modeling. These parameters are the mean local number of horizontals per unit of area, the correlation interval, and the mean quadratic elevation. A normal statistically homogeneous isotropic random surface with a gaussian correlation function of elevations was selected as the mathematical model. The statistical digital model was obtained on the digital computer by two-dimensional sliding summation on a set of normally distributed pseudorandom numbers. The functional relationship between the

parameters of the reliefs that were studied was found by multifactor regression analysis. The results can be used to form digital models of real surfaces for topographical maps. The article has one illustration and eight bibliographic entries.

UDC 681.142.6:621.397.2

DISPLAY PROCESSOR FOR DIALOG PROCESSING OF SEMITONE IMAGES

[Abstract of article by Bokshteyn, I. M.]

[Text] The article gives an analysis of the possibilities of constructing a display processor and the general requirements for its structure. The author reviews in detail the primary block of the display processor, the arithmetic unit. The article enumerates the basic operations which must be performed by the "fast" and "slow" parts of this unit and discusses the possibilities of building these blocks. A convenient method of building the device which insures high speed and provides communication between the display processor and the central computer is described. The author considers a device designed to control the work of the display processor and presents certain possibilities for organizing dialog (interaction) between the operator and the processor. The article has 10 illustrations and nine bibliographic entries.

UDC 621.391.24:681.325.650.21:621.391.25

SPECIALIZED MICROPROCESSORS THAT PERFORM FAST CONVERSIONS

[Abstract of article by Rakoshits, V. S., Kozlov, A. V., Mozhayev, I. A., and Belyayev, A. A.]

[Text] This article analyzes diagrams of fast conversions and the architecture for constructing specialized microprocessors that perform fast conversions. It is shown that where the fast conversion is accomplished on a general-purpose microprocessor there is a scheme of fast conversion that makes it possible to reduce the necessary main memory volume in half. During development of the specialized microprocessor the choice of its architecture depends significantly on the problem to be solved by the microprocessor, especially where it is necessary to search for one or several maximum values of spectrum coefficients. When microprocessors are developed in the form of large integrated circuits, a circular structure is preferable for the microprocessor. The article has seven illustrations and 10 bibliographic entries.

11,176
CSO: 1863/189

UDC 621.394:658.284

CONTROL SYSTEMS AND OPERATIONAL COMMUNICATION/SIGNALLING FACILITIES

Moscow SISTEMY UPRAVLENIYA I SREDSTVA OPERATIVNOY SVYAZI I SIGNALIZATSII in Russian 1981 (signed to press 16 Dec 80) pp 2, 199-200

[Annotation and table of contents from book "Control Systems and Operational Communication/Signalling Facilities", by Mikhail Andreyevich Belotsvetov, Izdatel'stvo "Radio i svyaz'", 12,000 copies, 200 pages]

[Text] Annotation

General principles of organizing industrial enterprise control systems and automated control and data processing systems are presented. Information is given about operational communication, signalling and documentary transmission facilities. One chapter is devoted to modern operation of communication facilities and the prospects for their development.

The book is intended for technical school students in the "management-aid facilities" specialty.

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6900
CSO: 1860/301

UDC 681.527.7.001.2

DESIGN OF DISCRETE AUTOMATION DEVICES

Leningrad BIBLIOTEKA PO AVTOMATIKE: PROYEKTIROVANIYE DISKRETNYKH USTROYSTV AVTOMATIKI in Russian No 613, 1980 (signed to press 13 Oct 80) pp 2, 86-87

[Annotation and table of contents from book "Design of Discrete Automation Devices", by Leonid Fedorovich Auen, deceased, Izdatel'stvo "Energiya", 10,000 copies, 88 pages]

[Text]

Annotation

Questions of designing programmed control devices using semiconductor and opto-electronic elements with a negative dynamic resistance subcircuit are examined. Achievements in circuitry and ways of creating devices using elements with S- and lambda-type characteristics are presented. Basic methods of designing automation elements and devices, and methods for improving their noise tolerance, are cited.

The book is intended for workers in the area of instrument building, automation and computer technology; it can also be used by students of corresponding specialties.

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6900
CSO: 1860/288

UDC 654.1

FUNDAMENTALS OF COMMUNICATION STRUCTURE DESIGN

Moscow OSNOVY PROYEKTIROVANIYA SOORUZHENIY SVYAZI in Russian 1981 (signed to press 25 Nov 80) pp 2, 169

[Annotation and table of contents from book "Fundamentals of Communication Structure Design", by Shavkat Galyamovich Galiullin, Leontiy Moiseyevich Gol'dberg, Ananiy Ivanovich Ovsyannikov, Eduard Vital'yevich Samoylov, Yevgenny Ivanovich Stepanov and Feliks Iserovich Shalakhman, Izdatel'stvo "Radio i svyaz'", 12,000 copies, 169 pages]

[Text] Annotation

Basic assumptions concerning the development of plans and cost estimates for capital construction and singularities of planning communications facilities are explained; new directions in design work and standard solutions and plans are described, as are methods for increasing efficiency through studying the technical and economic justifications for construction requirements and the justification for decisions taken; fundamental directions in the organization of design work are cited, as are singularities of technical design of station structures for wire communication facilities, line structures and line-of-sight radio relay systems.

The book is intended for students of electrical engineering institutes of communications.

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6900
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UDC 621.314.26+621.3.012

INTRODUCTION TO CONTACTLESS ELECTROMECHANICAL SYSTEMS OF STEPPED-UP FREQUENCY

Kishinev VVEDENIYE V BESKONTAKTNYYE ELEKTROMEKHANICHESKIYE SISTEMY POVYSHENNOY CHASTOTY in Russian 1979 (signed to press 4 May 79) pp 2, 136

[Annotation and table of contents from book "Introduction to Contactless Electromechanical Systems of Stepped-Up Frequency", by Vladimir Ivanovich Zagryadtskiy, Nikolay Ivanovich Kobylyatskiy, Aleksandr Petrovich Gladkiy, Aleksey Ivanovich Kramarenko, Viktor Grigor'yevich Ol'khovskiy and Vladimir Grigor'yevich Shevchik, Izdatel'stvo "Shtiintsa", 1,015 copies, 136 pages]

[Text]

Annotation

This monograph examines the basic circuits of a contactless electric drive of stepped-up frequency which uses recently-developed three-phase static ferromagnetic frequency multipliers with a rotating magnetic field as the power source. Particular attention is given to systems in which the power of the frequency multiplier is comparable to that of the electric motor. Elements of the theory and design of such electric drives are explained, and results of experimental investigations of systems which use doublers, triplers and cascaded converters as multipliers are given.

A system with a magnetothyristor converter of direct current into 3-phase alternating current and an output transformer with a rotating magnetic field is described.

The book is intended for specialists involved in designing, planning and operating contactless electric drives of stepped-up frequency. It may also be useful for students in electromechanical and electric power specialties.

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6900
CSO: 1860/287

UDC 621.396.61.(075.8)

LONG-DISTANCE RADIO COMMUNICATION TRANSMITTING DEVICES

Moscow RADIOPEREDAYUSHCHIYE USTROYSTVA MAGISTRAL'NOY RADIOSVYAZI in Russian 1980 (signed to press 25 Apr 80) pp 2-3, 175-176

[Annotation, foreword and table of contents from book "Long-Distance Radio Communication Transmitting Devices", by Semen Ezrovich Gorodetskiy, Izdatel'stvo "Svyaz'", 15,000 copies, 176 pages]

[Excerpts]

Annotation

Features of the design and construction of modern long-distance radio communication transmitters are examined in detail. A methodology for measuring their parameters is presented, and questions of designing and servicing long-distance radio communication lines are explained.

The book is intended for communication technical training schools teaching the specialty "radio communication and radio broadcasting".

Foreword

The achievements of science and technology have made it possible in the past 10 years to develop and organize serious production of automated exciters and transmitters for long-distance radio communication.

In spite of the large number of texts and teaching aids on radio transmitters, there is no book which gives the technical characteristics or design and circuitry of new types of high-stability exciters and transmitters for long-distance radio communication.

The present book attempts to fill this gap. The book also touches upon improving the reliability of transmitting equipment, measuring its parameters, and the cechnology of preventive maintenance and rehabilitation, and organizing the servicing of long-distance radio communication.

The material in the book is selected and arranged so that transmitter design principles common to all types is examined first, followed by electrical circuits and designs.

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Chapter 7

Antenna-feeder structures for long-distance radio communication

6900
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UDC 621.317.31:621.317.2

MEASUREMENTS IN TRANSIENT SHORTING MODES

Leningrad IZMERENIYA V PEREKHODNYKH REZHIMAKH KOROTKOGO ZAMYKANIYA in Russian 1981 (signed to press 18 Nov 80) pp 2, 191-192

[Annotation and table of contents from book "Measurements in Transient Shorting Modes", by Il'ya Borisovich Bolotin and Lev Zalmanovich Eydel', Izdatel'stvo "Energiya", 5,000 copies, 192 pages]

[Text] Annotation

This book is devoted to measurements of electrical values during testing of high-voltage equipment in short-circuited conditions. Examined are methods, circuits and singularities of measuring large currents, high voltages, and electric-arc power and energy in the steady-state, transient as well as pulse modes. Recommendations are given for the calculation and application of instrumentation.

The present edition looks more closely at measuring short-circuiting transient currents, as well as special measurements, including testing of current-limiting equipment, than did the 1973 edition.

The book is intended for engineers and scientific workers involved in testing and investigating high-voltage equipment. It may also be useful for students and graduate students.

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UDC 621.396.62:621.391.822

NOISE FACTOR

Moscow KOEFFITSIYENT SHUMA in Russian 1981 (signed to press 20 Nov 80) pp 2, 110-111

[Annotation and table of contents from book "Noise Factor", by Anatoliy Prokof'yevich Belousov and Yuriy Aronovich Kamenetskiy, Izdatel'stvo "Radio i svyaz'", 10,000 copies, 112 pages]

[Text] Annotation

Methods for practical calculation of the noise parameters of radio receivers and elements with consideration of noise from passive objects (clouds, radomes, antennas, feeder circuits, etc.) are presented systematically. Along with an up-to-date presentation of the theory of noisy four terminal networks, a wave description is also given which is most convenient for calculations allowing for scattering parameters. Particular attention is given the minimization of the noise factor. A number of problems often ignored by specialists are discussed, e.g., the influence of matching on the noise factor, the difference between actual and nominal noise factors, etc. The most important relationships used to calculate noise parameters are given.

The book is intended for specialists involved in developing and operating radio receivers. It may also be useful for students of higher educational institutions in radio engineering specialities.

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OPERATING PARAMETERS AND DISTINCTIVE FEATURES OF APPLICATION OF FIELD-EFFECT TRANSISTORS

Moscow EKSPLUATATSIONNYYE PARAMETRY I OSOBENNOSTI PRIMENENIYA POLEVYKH TRANZISTOROV in Russian 1981 (signed to press 1 Oct 80) pp 2, 64

[Annotation and table of contents from book "Operating Parameters and Distinctive Features of Application of Field-Effect Transistors", by Dmitriy Vasil'yevich Igumnov and Igor' Stepanovich Gromov, Izdatel'stvo "Radio i svyaz'", 15,000 copies, 64 pages]

[Text]

Annotation

Information about the operating parameters of field-effect transistors and features of their application in various electronic and communication equipment circuits is examined.

The volt-ampere characteristics, equivalent circuits and operating parameters of various types of field-effect transistors are given, as are methods for building various devices using these transistors. Information is presented on the use of MOS-transistors as functional devices.

The book is intended for engineering and technical workers specializing in the development of communication equipment.

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PHOTON-COUPLED PAIRS AND THEIR APPLICATION

Moscow OPTRONY I IKH PRIMENENIYE in Russian 1981 (signed to press 9 Jan 81) pp 2-3, 278-279

[Annotation, foreword (excerpts) and table of contents from book "Photon-Coupled Pairs and Their Application", by Yuriy Romanovich Nosov and Aleksandr Sergeyevich Sidorov, Izdatel'stvo "Radio i svyaz'", 30,000 copies, 280 pages]

[Excerpts]

Annotation

The operating principle, physical bases, arrangement and parameters of photon-coupled pairs and optoelectronic integrated circuits are examined. Construction and design features of circuits using photon-coupled pairs are explained. Technical characteristics of domestic photon-coupled pairs are cited, and 100 actual circuits are examined which illustrate the possibility of the effective application of photon-coupled pairs in many areas of technology.

The book is intended for a broad group of readers.

Foreword [Excerpts]

Photon-coupled pairs and optronic integrated microcircuit are concepts which are becoming familiar to wider groups of specialists in the area of radioelectronics with every passing year. The development of photon-coupled pair techniques has entered the stage of industrial mass production. Photon-coupled pairs are being used more and more in electronic equipment.

In connection with this, the authors of the present book consider it useful to generalize theoretical design and experimental material on the physics, arrangement, characteristics and application of photon-coupled pairs. General assumptions are supported by specific data on domestically produced photon-coupled pairs, and by circuits in which they are actually applied. Materials from domestic as well as foreign developments in the area of photon-coupled pairs were used in preparing the book.

Major engineering collectives without whose participation it would have been impossible to write this book have contributed to the development of photon-coupled pair technology.

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UDC 621.374

PULSED DEVICES

Moscow IMPUL'SNYYE USTROYSTVA in Russian 1981 (signed to press 1 Oct 80)
pp 2, 220-222

[Annotation and table of contents from book "Pulsed Devices", by Lev Moiseyevich Gol'denberg, Izdatel'stvo "Radio i svyaz'", 40,000 copies, 224 pages]

[Text] Annotation

Fundamentals of the theory and circuitry of pulsed devices are presented. Primary attention is given devices using integrated circuits. Considered are the component base of pulsed devices, combination and serial devices, methods and circuits for forming square and other pulses, and functional communication and control devices.

The book is intended for students in higher institutes of learning and radio engineering departments. It will also be useful for specialists working in the area of pulsed and digital techniques.

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6900
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SEMIMETALS AND NARROW-ZONE SEMICONDUCTORS

Kishinev POLUMETALLY I UZKOZONNYYE POLUPROVODNIKI in Russian 1979 (signed to press 14 Feb 79) pp 2, 218-219

[Annotation and table of contents from book "Semimetals and Narrow-Zone Semiconductors", edited by S. I. Radautsan, academician, MSSR Academy of Sciences; D. V. Gipu and A. M. Andriyesh, corresponding members of MSSR Academy of Sciences; candidates of physical and mathematical sciences S. D. Shutov (editor-in-chief), E. K. Arushanov (deputy editor-in-chief), and senior engineer I. M. Golban (secretary), Izdatel'stvo "Shtiintsa", 760 copies, 220 pages]

[Text] Annotation

The electrophysical properties of bismuth and bismuth-based alloys, solid solutions of lead chalcogenites ($Pb_{1-x}Sn_xTe$, Pb Te - Sb) and other complex narrow-zone semiconductors are examined during various external effects over a broad temperature interval. Effective methods are developed for calculating the kinetic parameters of charged carriers in such substances. Singularities of the anisotropy of transfer phenomena and the influence of crystal size in the quasi-uniform case are studied.

This collection is intended for scientific workers, engineers, graduate school instructors, graduate students and students in physical and technical areas.

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TRUSS-TYPE RADIO MASTS

Moscow SHPRENGEL'NYYE RADIOMACHTY in Russian 1981 (signed to press 26 Dec 80) pp 2, 175

[Annotation and table of contents from book "Truss-Type Radio Masts", by Anatoliy Alekseyevich Voyevodin, Izdatel'stvo "Radio i svyaz'", 5,700 copies, 176 pages]

[Text] Annotation

Presented are the theory and methodology for calculating, as well as the fundamentals of designing, truss-type radio masts used as dipoles and supports for antennas of various types. The results of experimental investigation are given. Features of construction and operation truss-type masts are examined.

The book is intended for engineering and technical workers involved in designing construction and operating antenna-mast communication structures.

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UDC 621.382

USE OF METAL-SEMICONDUCTOR CONTACT IN ELECTRONICS

Moscow PRIMENENIYE KONTAKTA METALL-POLUPROVODNIK V ELEKTRONIKE in Russian 1981 (signed to press 24 Oct 80) pp 2, 302-304

[Annotation and table of contents from book "Use of Metal-Semiconductor Junction in Electronics", by Kamil' Akhmetovich Valiyev, Yuriy Ivanovich Pashintsev and Garri Vasil'yevich Petrov, Izdatel'stvo "Radio i svyaz'", 8,000 copies, 304 pages]

[Text] Annotation

The rectifying contac: metal-semiconductor called a Schottky diode or barrier, is examined. The use of Schottky diodes and field-effect transistors with a Schottky gate in various electronic devices is examined.

The book is intended for specialists involved in developing integrated circuits using devices with Schottky barriers. It may also be useful for teachers, graduate students and students in senior courses at corresponding higher institutes of learning.

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WELDING AND SOLDERING PROCESSES IN PRODUCTION OF SEMICONDUCTOR DEVICES

Moscow PROTSESSY SVARKI I PAYKI V PROIZVODSTVE POLUPROVODNIKOVYKH PRIBOROV in Russian 1981 (signed to press 4 Dec 80) pp 2-5, 222-223

[Annotation, foreword (excerpts) and table of contents from book "Welding and Soldering Processes in Production of Semiconductor Devices", by Adam Ignat'yevich Mazur, Valentin Pavlovich Alekhin and Minas Khachaturovich Shorshorov, Izdatel'stvo "Radio i svyaz'", 10,000 copies, 224 pages]

[Excerpts]

Annotation

The mechanism and kinetics of solid-phase interaction between different metals and between metals and semiconductors are examined, as are processes of welding and soldering in various technical installation operations in the production of semiconductor devices. The basic regularities of contact microplastic deformation of the subsurface layers of semiconductor and metal materials are given, and methods are shown for localizing, intensifying and controlling deformation with application to optimizing technological processes of solid-phase joining of materials in electronic practice.

The book is intended for engineering-technical and scientific workers involved in developing and producing semiconductor devices. It may also be useful for students and teachers of technical higher institutes of learning.

129 figures, 22 tables, 290 bibliographic references.

Foreword

The increasing rates at which semiconductor devices are being produced require that the wiring process be automated. The labor involved in wiring operations (creating internal interconnections by means of welding, soldering, etc.) is on the average between 50 and 60 percent of all of the labor involved in fabricating various types of devices. Furthermore, failures associated with wiring operations comprise up to 70 percent of all instrument malfunctions. Reducing the level of connection failures and guaranteeing their quality would make it possible to increase the output of good devices sharply and to eliminate a number of labor-intensive test and monitoring operations, which would reduce the overall labor intensity of fabricating devices and would create the objective prerequisites for automating assembly operations.

The creation of scientific foundations for solid-phase welding of different materials, and the development and introduction in the electronic industry of new methods for obtaining connections with stable quality and methods of controlling and speeding up existing processes have allowed these to be used to the fullest extent in producing new technical articles. The present book is devoted to examining these matters.

The first section considers the physical foundations of the processes by which unbreakable connections are formed in the production of semiconductor devices. Although the literature contains works devoted to this question, it has become necassary to systematize and analyze critically the experimental results in this area because principally new results have recently been obtained which allow the mechanism and kinetics of solid-phase interaction to be examined more fully, particularly the physical essence of the activation stage in the formation of a connection.

The treatment of the activation stage of interaction presented in Chapter 1 is based on conceptions of the thermoactivated nature of the process in a field of applied voltages. The approach does not require the obligatory presence of active centers in the form of dislocations on the contact surface of the harder of the materials to be joined, and allows a broader and physically better founded exposition of the fundamental criteria and principles for selecting optimal welding-mode parameters in order to obtain a uniformly strong connection and to provide minimum distortion of the initial physical and mechanical properties of the materials. Considerations of the role of the temperature-time factor and of point defects in the mechanism and kinetics of solid-phase interaction develop the conceptions of this matter which were developed earlier by M. Kh. Shorshorv and Yu. L. Krasulin.

Existing conceptions about the kinetics of the formation of connections are developed in Chapters 2 and 3 from analogous positions. In analyzing the kinetics of the interaction of a traditional metal-semiconductor pair, the main accent in Chapter 2 is on studying the basic regularities of the body interaction stage of the materials, which has undeservedly been neglected even though it is actually impossible to obtain a solid connection without this stage. Chapter 3 examines the structural and kinetic regularities of contact microplastic deformation and the formation of connections as applied to a metal-metal system, which also have not yet been studied sufficiently.

Matters which are new in principle and have practically not been touched upon in the welding literature are presented in Chapters 2 and 4. These are devoted to investigating the basic physical regularities of plastic deformation and destruction of subsurface layers of semiconducting and metallic materials, and to developing methods for localizing, intensifying and controlling the process of contact microplastic deformation in order to optimize technological processes of solid-phase connection of materials. Optimization takes into consideration the requirement for realizing two contradictory trends.

On the one hand, in order to realize successfully all three stages of solid-phase interaction and to form a solid connection, the kinetics of microplastic deformation near the free surface of the solid body must be intensified as much as possible. On the other hand, in order to reduce the depth and degree of damage of thin subsurface layers by structural defects and internal residual stresses, which have a significant effect on the electrophysical properties of semiconductor devices, the microplastic deformation in them must be localized and limited as much as possible. Chapter 4 presents practical recommendations for optimal modes of solid-state connection of materials, and criteria for their selection. Active methods are developed for monitoring the quality of connections directly in the process of obtaining ohmic contacts by a number of kinetic parameters of the process, and for programming the application of external load and carrying out the welding process according to a special assigned cycle in order to step up the setting kinetics.

High reliability of semiconductor devices is determined to a significant extent by the sophistication of the technology used in different stages of creating the device, as well as by the quality of the initial materials. In this connection, the second section of the book is devoted to examining specific technological processes and equipment for welding and soldering in the fabrication of semiconductor instruments.

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