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# USSR Report

## CYBERNETICS, COMPUTERS AND AUTOMATION TECHNOLOGY

(FOUO 3/81)

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# USSR REPORT

# CYBERNETICS, COMPUTERS AND AUTOMATION TECHNOLOGY

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# HARDWARE

## 30-MOP ARRAY PROCESSOR

Moscow KRASNAYA ZVEZDA in Russian 20 Nov 80 p 4

[Summary] The first Soviet array processor has been created by a group at the Yerevan Scientific Research Institute for Mathematical Machines. The processor will increase the speed of the YeS-1046, developed at the same institute, up to 30 million operations per second.

[910-P]

CSO: 1863

UDC 681.3

## FUNDAMENTALS OF THE DESIGN OF COMPUTER ASSEMBLY COMPONENTS

Moscow OSNOVY PROYEKTIROVANIYA SBOROCHNYKH EDINITS EVM in Russian 1980 signed to press 3 Dec 79 pp 3-4

[Foreword from the book by B.O. Ol'khov, Izdatel'stvo "Mashinostroyeniye", 15,000 copies, 255 pages]

[Text] Foreword

Important factors which govern the pace of scientific and engineering progress in contemporary society are the refinement of electronic computers and the extent to which they permeate scientific, planning and design institutions. It has been repeatedly underscored in the directive documents for the development of the USSR National Economy that to assure a significant growth in labor productivity in all sectors of the national economy, successfully resolve fundamental scientific problems and urgent engineering problems, it is necessary to expand the production of general purpose and control computer complexes for automated control systems for technological processes and optimal control in sectors of the national economy. The solution of the problems posed here determines the necessity of training highly skilled design personnel and operational workers for electronic computer equipment.

The textbook for the course "Design Fundamentals for the Components and Assembly Units of Electronic Computers, Devices and Instruments" is being published for the first time for intermediate special educational institutions. This was due to a number of difficulties which the author had to deal with in writing the book. On one hand, it was necessary to rather completely cover all questions in the existing program of the relevant course, and on the other hand, illuminate a number of urgent topics, not touched upon in the program.

The basic requirements placed on the assembly components are treated in this book and the stages in their design are described taking into account the standards and specifications existing during the design, as well as questions of the testing and reliability of assembly components. The major types of contemporary component radio electronic elements and methods of installing them are described. Questions of the design of assembly components (circuit boards, modules) of the arithmetic and logic devices, the power supply, individual devices and the computer as a whole are treated in detail. Integrated microcircuits and printed circuit boards are used as the primary technical basis for the design. Also treated in the book and supplementing the program are: the design of power supplies, the general layout of a computer, measures to protect against mechanical overloads and methods of equipment cooling, but material dealing with micromodules and their application is almost completely omitted, since these elements are not used in practice in new designs. Basic design recommendations are reinforced with examples of the designs of assembly components used in domestic and foreign computers. It was kept in mind during the writing of the book that the reader is familiar with the fundamentals of logic design and microelectronic principles, presented in related courses.

Chapter 9 was written in conjuntion with candiate of the engineering sciences B.N. Ivanchuk.

The author is deeply grateful to reviewers L.P. Arnautova and candidate of the engineering sciences Ye.I. Nikolayev for the critical remarks they made directed towards improving the contents of the book. The author will receive critical comments and requests of readers with gratitude, which he requests be directed to the address of the "Mashinostroyeniye" publishing house.

[51-8225]

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## FUNDAMENTALS OF THE DESIGN OF COMPUTER ASSEMBLY COMPONENTS

Moscow OSNOVY PROYEKTIROVANIYA SBOROCHNYKH EDINITS EVM in Russian 1980 signed to press 3 Dec 79 pp 254-255

[Table of contents from book by B.O. Ol'khov, Izdatel'stvo "Mashinostroyeniye", 15,000 copies, 255 pages]

[Text] Table of Contents

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## TESTING COMPUTER COMPONENTS

Moscow OSNOVY PROYEKTIROVANIYA SBOROCHNYKH EDINITS EVM in Russian 1980 signed to press 3 Dec 79 pp 52-53

[Excerpt from book "Fundamentals of the Design of Computer Assembly Components", by B.O. Ol'khov, Izdatel'stvo "Mashinostroyeniye", 15,000 copies, 255 pages]

[Excerpt] The parameters of products which are monitored in various stages of the tests are indicated in Table 9 (the parameters of the electrical signals: PES; the insulation resistance: $R_{iz}$, and the quality of the protective coatings, KZP.

TABLE 9

| Properties Being Checked in the Test Product | Monitored Parameters | | | | |
|---|---|---|---|---|---|
| | During the Testing Process | | At the Completion of the Testing | | |
| | PES | $R_{iz}$ | PES | $R_{iz}$ | KZP |
| Moisture resistance | + | + | + | + | + |
| Cold resistance: | | | | | |
| Minimum working temperature | + | - | - | - | - |
| The ultimate minimal temperature | - | - | + | - | + |
| Resistance to frost and dew | + | - | + | - | + |
| Heat resistance: | | | | | |
| Maximum working temperature | + | + | - | - | - |
| Ultimate maximum temperature | - | - | + | + | + |
| High altitude immunity | + | - | + | - | - |
| Resistance to solar radiation | + | - | + | - | + |
| Resistance to a saline fog | - | - | - | - | + |
| Dust protection | + | - | + | - | + |
| Spray protection | + | - | + | - | + |
| Fungus resistance | - | - | - | - | + |

Note to Table 9: A "+" means the parameter is checked; a "-" means the parameter is not checked.

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## ENVIRONMENTAL TESTING CATEGORIES

Moscow OSNOVY PROYEKTIROVANIYA SBORCHNYKH EDINITS EVM in Russian 1980 signed to press 3 Dec 79 pp 56-59

[Excerpt from book "Fundamentals of the Design of Computer Assembly Components", by B.O. Ol'khov, Izdatel'stvo "Mashinostroyeniye", 15,000 copies, 255 pages]

[Excerpt] The environmental factors acting on equipment are classified according to the degrees of severity (Table 10) in accordance with GOST 16962-71, "Electronic and Electrical Engineering Equipment Products. Mechanical and Climatic Effects. Testing Methods and Requirements."

TABLE 10

| Acting Factor Воздействующий фактор | | | |
|---|---|---|---|
| Значение Value | Степень жесткости Degree of Severity | Значение Value | Степень жесткости Degree of Severity |
| Temperature of the Air or Other Gas During Operation Температура воздуха или другого газа при эксплуатации, °C °C | | | |
| Elevated Повышенная | | | |
| 40 | I | 125 | IX |
| 45 | II | 155 | X |
| 50 | III | 200 | XI |
| 55 | IV | 250 | XII |
| 60 | V | 315 | XIII |
| 70 | VI | 400 | XIV |
| 85 | VII | 500 | XV |
| 100 | VIII | | |
| Reduced Пониженная | | | |
| +1 | I | −40 | VI |
| −5 | II | −45 | VII |
| −10 | III | −60 | VIII |
| −25 | IV | −85 | IX |
| −30 | V | | |

[Table 10, continued]:

| | | | |
|---|---|---|---|
| (1) Температура воздуха или другого газа при хранении и транспортировании, ℃ | | | |
| Elevated Повышенная | | Пониженная | Reduced |
| 50 | I | —50 | I |
| 60 | II | —60 | II |
| | | —85 | III |
| Reduced Atmospheric Pressure, Pa. Пониженное атмосферное давление, Па | | | |
| $7 \cdot 10^4$ | I | $6{,}7 \cdot 10^2$ | VI |
| $53{,}5 \cdot 10^3$ | II | 133,3 | VII |
| $26{,}7 \cdot 10^3$ | III | 13,3 | VIII |
| $12 \cdot 10^3$ | IV | 0,13 | IX |
| $2 \cdot 10^3$ | V | $1{,}3 \cdot 10^{-4}$ | X |
| Elevated Pressure of the Air or Other Gas, MPa Повышенное давление воздуха или другого газа, МПа | | | |
| 0,147 | I | 0,294 | II |
| (2) Повышенная влажность (относительная влажность, %/температура, °С) | | | |
| 80/25 | I | 98/35 | VI |
| 98/25 | II | 100/35 | VIII |
| 100/25 | IV | | |

| Acting Factor Воздействующий фактор | | | |
|---|---|---|---|
| Значение Value | Degree of Степень жесткости Severity | Значение Value | Degree of Степень жесткости Severity |
| (3) Вибрационные нагрузки (диапазон частот, Гц/ускорение, g) | | | |
| 1÷35/0,5 | I | 1÷2000/5,0 | XI |
| 1÷60/1,0 | II | 1÷2000/10,0 | XII |
| 1÷60/2,0 | III | 1÷2000/15,0 | XIII |
| 1÷80/5,0 | IV | 1÷2000/20,0 | XIV |
| 1÷100/1,0 | V | 1÷3000/20,0 | XV |
| 1÷200/5,0 | VI | 1÷5000/10,0 | XVI |
| 1÷200/10,0 | VII | 1÷5000/20,0 | XVII |
| 1÷600/5,0 | VIII | 1÷5000/30,0 | XVIII |
| 1÷600/10,0 | IX | 1÷5000/40,0 | XIX |
| 1÷1000/10,0 | X | 100÷5000/50,0 | XX |

[Table 10, continued]:

| (4) Ударные нагрузки (ускорение, g/длительность импульса, мс) | | | |
|---|---|---|---|
| Multiple Многократные | | | |
| 15/2÷15 | I | 75/2÷6 | III |
| 40/2÷10 | II | 150/1÷30 | IV |
| One-time Одиночные | | | |
| 4/40÷60 | I | 500/1÷2 | V |
| 20/20÷50 | II | 1000/0,2÷1 | VI |
| 75/2÷6 | III | 1500/0,2÷0,5 | VII |
| 150/1÷3 | IV | 3000/0,2÷0,5 | VIII |
| (5) Линейные (центробежные) нагрузки, g | | | |
| 10 | I | 150 | V |
| 25 | II | 200 | VI |
| 50 | III | 500 | VII |
| 100 | IV | | |

[Key to Table 10]:

1. Temperature of the air or other gas during storage and transportation, °C;
2. Elevated humidity (relative humidity in percent/temperature °C);
3. Vibration loads (frequency range in Hz/acceleration, g);
4. Shock loads (acceleration, g/pulse width, milliseconds);
5. Linear (centrifugal) loads, g.

---

The following values of the intensities of the acting factors can be cited for electronic computer equipment. The range of working temperature of the ambient medium is usually no more than -50 to +50 °C; in this case, the maximum working temperature of the electronic components can be no higher than +50 °C, due to overheating of the equipment from the heat liberated in it. The range of temperatures during storage and transportation is usually no wider than -60 to +60 °C.

The maximum vibration frequency (up to 7 KHz), but with a small amplitude (±0.025 mm) acts on equipment operating in a caterpillar tract driven vehicle. In this case, the equipment can be subjected to individual shocks with very high accelerations. A wide frequency range (up to 2.5 KHz) with vibration having a considerable acceleration (up to 20 g) acts on rocket equipment.

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# DETERMINING AND DESIGNING COMPUTER RELIABILITY

Moscow OSNOVY PROYEKTIROVANIYA SBOROCHNYKH EDINITS EVM in Russian 1980 signed to press 3 Dec 79 pp 66-84

[Chapter 5 from book "Fundamentals of the Design of Computer Assembly Components", by B.O. Ol'khov, Izdatel'stvo "Mashinostroyeniye", 15,000 copies, 255 pages]

## [Text] Chapter 5 Computer Reliability

### 1. General Information and Basic Concepts

Reliability is the property of a unit which allows it to execute specified functions, while retaining the values of the established operational indicators within permissible limits with the course of time, where these limits correspond to the adopted operational modes and conditions for utilization, technical servicing, repairs, storage and transportation of the unit.

The high reliability requirement, as a rule, is an absolutely necessary condition for modern computers. The operation of insufficiently reliable computers entails great economic expenditures, and if the failure of the computer can have catastrophic consequences, then it is altogether impermissible.

GOST 13377-75 "Reliability in Engineering. Terms and Definitions" reveals the content of the basic concepts used when considering questions of reliability.

Reliability is a complex property, which, depending on the operational conditions and functions of a unit can include such properties as the failure-free service capability, functional longevity, repair suitability and full function retainability either individually or as a certain combination of these properties.

*Failure-free service capability* is the property of a unit of continuously preserving its operability over a period of time or for some operating time. A unit is characterized by the property of failure-free service capability both during the utilization period and during periods of storage and transportation.

*Functional longevity* is the property of an object preserving its operability until the onset of the ultimate state for a specified system of technical servicing and repairs.

*Repair suitability* is the property of a unit, consisting in its suitability for warning of and detecting faults and damage, and eliminating their consequences by means of making repairs and technical servicing.

*Full function retainability* is the property of a unit of maintaining its full functional capability and operability following storage and (or) transportation.

The properties enumerated above for an object, which characterize its reliability, were defined using the following concepts.

*Fully functional* is the condition of a unit in which it meets all of the requirements established by the design documentation.

*Nonfunctional* is the condition of a unit in which it does not meet the requirements established by the design documentation, even if only one of the requirements is not met.

*Operable* is the condition of an object in which it is capable of performing the specified functions, maintaining the values of the specified parameters within the range established by the design documentation.

*Nonoperable* is the condition of a unit in which it does not meet the requirements established by the design documentation, even if only for one specified paremeter which characterizes its capability of performing the specified functions.

*Terminal status* is the condition of a unit in which its further operation should be terminated because of uncorrectible violations of safety requirements, or a departure of the specified parameters beyond the established limits which cannot be eliminated, because of an uncorrectible drop in the operational efficiency below the permissible level, or the necessity of performing intermediate repairs or a major overhaul.

The terms cited above which define the various conditions of a unit are in need of some explanation.

It should be noted that the concept "fully functional" is a wider than the concept "operable". An operable unit, in contrast to a fully functional one, meets only those requirements which assure its execution of the specified function; an operable unit can be defective, however its defects in this case are not so substantiable as to disrupt normal functioning (for example, a violation of requirements applying only to external appearance).

A distinction must be drawn between two cases of the "nonoperable" status: correctible and incorrectible. In the first case, the operability of the unit can be restored by means of a repair, and in the second, the restoration of the operability is impossible or economically inexpedient.

The terms following below define events which lead to the breakdown in the fully functional and operable status of a unit.

*Damage* is an event which consists in the disruption of the fully functional status of an object because of the impact of external actions which exceed levels established in the design documentation for the unit.

*Failure* is an event which consists in the disruption of the operability of the unit (failure criteria are usually established in the design documentation).

Damage can be minor, leading only to a disruption of the fully functional status while retaining operability; damage can be significant, leading to a disruption of the operability, i.e., to the failure of the unit. Some failures of units are not related to damage to them, but can be the consequence of disruptions in the established operational norms and regulations; such failures are not taken into account in estimating unit reliability.

The following also belong among the general concepts of reliability theory:

*Non-failure operating time* is the duration of operation of a unit;

*Operational safe life* is the non-failure operating time of a unit from the start of operation or its renewal following intermediate repairs or major overhaul until the onset of terminal status;

*Service life* is the calendar duration of unit operation from its start or renewal following interemediate repairs or major overhaul unit the onset of the terminal status;

*Shelf life* is the calendar duration of storage and (or) transportation of a unit under specified conditions, during and after which the values of the specified indicators are maintained within the established limits.

The concept of failure is one of the fundamental ones in reliability theory and is classified according to a number of criteria, which take into account the nature of the failure. Failures can be sudden and gradual, independent or related, can manifest as a dropout or an intermittent failure, and can be design, production or operational failures.

A *sudden failure* is characterized by a jump-like change in one or several parameters of a unit, which lead to a disruption of its operability (electrical breakdown of insulation, a short circuit, etc.). Sudden failures are usually caused by design deficiencies, i.e., by the violation of the rules and (or) norms for the design (*design failure*), by hidden production defects, which occur because of violations of the repair or fabrication technology for a unit (*production failure*), or by the violation of operational regulations and (or) conditions (*operational failure*). Such failures, as a rule, occur in the initial stage of operation of a unit.

*Gradual failure* is characterized by a gradual change in one or more specified parameters of a unit. Gradual failures develop rather slowly and depend on the time a unit has been functioning. If a slowly changing parameter of a unit has not gone beyond the range of the norm, which defines the unit operability, then explicit criteria for gradual failure are lacking and can be determined only during preventive maintenance of the unit. Timely preventive maintenance is necessary to preclude a loss of unit operability because of gradual failures during important periods of unit operation. The gradual failures ascertained during preventive maintenance should be eliminated by replacing the failed standard component, or by means of making a repair.

The concepts *independent failure* and *dependent failure* usually apply to individual components of a unit.

A component failure is called independent when it is not due to damage to or failure of other components of the unit.

Component failure is termed dependent when it is due to damage or failure in another component of the unit. For example, a short circuit of the leads of a transistor usually lead to the burn-out of the pulse transformer winding inserted in its collector circuit without a current limiting resistor.

*Self correcting failure*, which leads to a short term disruption of operability, is called a dropout.

A repeatedly occurring dropout of the same nature is called an *intermittent failure*. The reason for such a failure can be, for example, a poor contact. Such a failure is eliminated by replacing or repairing that portion of the unit in which it is detected.

## 2. Reliability Indicators

All of the properties of a unit which characterize its reliability, the failure-free service capability, functional longevity, repair suitability and full function retainability, have quantitative characteristics which are estimated with the corresponding indicators. An indicator applying to one of the properties comprising the reliability of the unit is called a *single indicator* of the reliability.

An indicator applying to several properties comprising unit reliability is called a *comprehensive indicator* of the reliability.

Since failures are random events, the quantitative characteristics of reliability have a probabilistic nature. The theoretical calculation of the probability characteristics of reliability is a complex and labor intensive problem, and at times the requisite initial data for its formulation are lacking. For this reason, the statistical values are usually determined for the quantitative reliability characteristics obtained by mathematical processing of the results of experimental observations.

Included among the indicators for failure-free service capability are:

--The probability of failure-free operation;

--Mean operating time before failure;

--Failure rate (for a nonrestored unit);

--The failure flow parameter (for a restored unit);

--Operating time before failure (for a restored unit).

We shall consider the failure-free service capability indicators enumerated above.

*The probability of failure-free operation P(t),* is the probability that within the range of a specified operating time, i.e., a specified time interval, a failure unit will not occur.

The quantity P(t) is determined by the expression:

$$P(t) = \lim_{\substack{\Delta' \to 0 \\ N_0 \to \infty}} \frac{N_0 - \sum_{i=1}^{m} n_i}{N_0},$$

where $N_0$ is the number of units at the start of the testing or operation; m is the number of time interals; $n_i$ is the number of units which fail during operation in the i-th time interval; t is the testing time; Δt is the duration of a time interval.

The parameters m, t and Δt are related by the expression

$$m = t/\Delta t.$$

The statistically approximate value of P(t) can be determined from the expression:

$$P(t) \approx \frac{N_0 - \sum_{i=1}^{m} n_i}{N_0}.$$

The larger $N_0$, the closer the statistical value of P(t) is to the theoretical value.

Along with the probability of failure-free operation, P(t), one can use the *failure probability* indicator Q(t), defined by the expression:

$$Q(t) = 1 - P(t) \approx \frac{\sum_{i=1}^{m} n_i}{N_0}.$$

*The mean operating time* before failure or the average time of failure-free operation, $T_{cp}$ is the anticipated operating time of the unit prior to the first failure and is statistically defined as the ratio of the sum of the operating time before failure of the units being tested to the number of observed units, if they all failed during the tests:

$$T_{cp} \approx \frac{\sum_{i=1}^{N_0} t_{cp\,i}}{N_0},$$

where $t_{cp\ i}$ is the operating time prior to the failure of the i-th unit.

This indicator is frequently utilized as the failure-free service capability characteristic of nonrestored units, since the first failure for them is also the last.

*The failure rate*, λ(t), is expressed as the ratio of the number of units, n(t), which failed during the time interval under consideration, Δt, to the product of the number of units, N(t), which were operable at the start of this time interval, times its duration:

$$\lambda(t) \approx \frac{n(t)}{N(t)\,\Delta t}.$$

The quantity λ(t) shows what part of the elements with respect to the overall number of operating elements in good working order fail on the averge per unit time (usually on a per hour basis).

The statistical experimental estimate of the reliability of units leads to a conclusion concerning the timewise change in the failure rate. Typical curves for the failure rates of a product as a function of time are shown in Figure 8. Three sections are clearly distinguished in them.

The first section corresponds to the running-in period, $t_\pi$; it is characterized by relatively high values of the failure rate, which are the result of hidden defects due to violations of the manufacturing technology. For important units, it is necessary at the manufacturing plants to electrically break-in units for a period of time exceeding the duration of the running-in period, for the purpose of ascertaining and eliminating hidden defects. For modern semiconductor devices (discrete diodes and transistors, integrated circuits), the burn-in period is usually figured in several hundreds of hours.

The second section corresponds to the normal operating period ($t_{Hp}$) of the unit with a sufficiently low constant failure rate. During this period, the failure rate and the average time of failure-free service are found as a function of:

$$\lambda = \frac{1}{T_{cp}}$$

and are related to the probability of failure-free operation by the expression:

$$P(t) = e^{-\frac{t}{T_{cp}}}, \quad P(t) = e^{-\lambda t},$$

where $e$ is the base of natural logarithms.

The latter equation expresses the probability of failure-free operation as an exponential function of time (Figure 9).

The third section ($t_c$) is characterized by an increase in the failure rate of the units, something which is a consequence of their aging or wear, which has an impact on the operability of the units.

The operational safe life of the unit should not exceed the normal operational period, i.e., should not continue into the period where aging and wear of the unit are manifest. For modern discrete and integrated circuit wide application semiconductor devices, the period of normal operation amounts to tens of thousands of hours; a period of increased failure rate following long term operation has not been observed for them in practice, and as of today, no kind of mechanisms have been established in their operation which could lead, in an observable period, to a regular degradation in the reliability of devices fabricated in strict accordance with production technology.

*The failure flow parameter*, $\Omega(t)$, is the average number of failures of a restored unit per unit time.

*The operating time before failure*, $T_o$, is the average value of the failure-free operating time of a restored unit between failures. If the failure-free operating time is expressed in time units, one can use the term "average time of failure-free operation":

$$T_o = \frac{\sum_{i=1}^{n} t_i}{n},$$

where n is the number of failures per testing time; $t_i$ is the time of proper operation of the unit between the (i - 1) and the i-th failures.

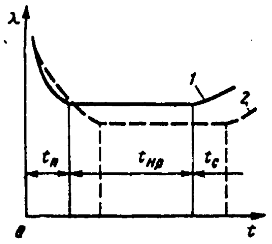

Figure 8. Typical curves for the failure rates of a product as a function of time:
Key: 1. In the nominal operational mode;
2. Under eased conditions.

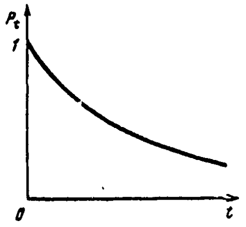

Figure 9. The failure-free operational probability as an exponential function of time.

When performing tests on several samples of a unit, one can determine the value of $T_0$ from the expression:

$$T_0 = \frac{\sum_{i=1}^{M} T_{0i}}{M},$$

where $T_{0i}$ is the operating time until the failure of the i-th sample; M is the number of samples being tested.

Among the rather numerous indicators of functional longevity we shall also mention such indicators as the gamma percentage safe life and the gamma percentage service life.

*The gamma percentage safe life* is the failure free operating time during which there is a specified probability of γ percent that the units will not reach the terminal status.

*The gamma percentage* service life is the calendar duration of operation, during which the unit has a specified probability of γ percent of not attaining the terminal status.

The repair suitability of a unit is characterized by the *average restoration time*, $T_B$, which takes the form of the average forced downtime not covered by regulations, which is expended for detecting and finding the causes of a failure and eliminating the consequences of a failure.

The full-function retainability of a unit is characterized by the *gamma percentage and average full function retention lives*, which are defined respectively as the full function retention life which the unit has a specified probability of γ percent of attaining, and as the anticipated full function retention life. These indicators can be incorporated in the design documentation for the unit.

A number of important aspects of the reliability of units is taken into account with comprehensive reliability indicators.

The *in-commission factor,* $K_{\text{г}}$, is the probability that a unit will prove to be operable at any point in time with the exception of planned periods during which no provision is made for the utilization of the unit for its function; $K_{\text{г}}$ is statistically defined as the ratio of the total time the observed units are in an operable condition to the product of the number of these units times the duration of operation (with the exception of planned downtimes for planned repairs and technical servicing):

$$K_{\text{г}} = \frac{\sum_{i=1}^{N} \xi_i}{N T_{\text{раб}}},$$

where $\xi_i$ is the total time the i-th unit is in an operable condition; $T_{\text{раб}}$ is the duration of operation, including the operational and restoration times.

For the servicing procedure which provides for the immediate start of the restoration of a failed unit, the following relationship is justified:

$$K_{\text{г}} = \frac{T_{\text{о}}}{T_{\text{о}} + T_{\text{в}}}.$$

The incommission factor characterizes the readiness of a unit for operation.

*The equipment utilization coefficient*, $K_{\text{ти}}$, is the ratio of the overall time of proper operation of a unit, $t_{\text{сум}}$, to the total operational time, taking into account forced downtimes for technical servicing, $t_{\text{обс}}$, and repair, $t_{\text{рем}}$, during the same operational period:

$$K_{\text{ти}} = \frac{t_{\text{сум}}}{t_{\text{сум}} + t_{\text{рем}} + t_{\text{обс}}}.$$

The equipment utilization coefficient shows what percentage of the overall operating and downtimes the unit is in good operating condition, ready for practical application.

Among the numerous comprehensive reliability indicators, we shall mention the average overall cost of technical servicing and the average total cost of repairs. The indicators respectively express the anticipated total expenditures for the performance of technical maintenance of a unit and for all kinds of repairs of a unit over a specified operational period, and as a total, comprise the anticipated cost of operating a unit $C_{\text{э}}$.

Increased reliability of units, and correspondingly, low operational costs, are achieved through increasing the expenditures for the developmental work $C_{\text{р}}$ and fabrication $C_{И}$ of a unit. Obviously, at some definite reliability, the overall cost of a unit $C_0$ will be minimal, where this cost is composed of the development cost, referenced per single unit of M units, as well as the manufacturing and operating costs:

$$C_0 = \frac{C_p}{M} + C_{и} + C_{э}$$

The reliability at which the minimum total cost of a unit is assured, $C_{o.min}$, can be termed the minimal cost reliability and is characterized by a certain probability of failure-free operation, $P_{ОПТ}$.

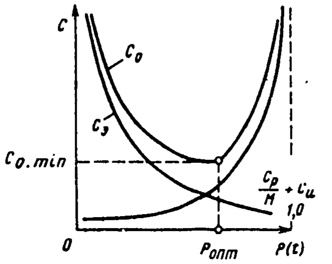

Figure 10. The costs of a unit as a function of the failure-free operation probability.

Curves for the costs of a unit $C_p/M + C_{И}$, $C_{Э}$ and $C_0$ are shown as a function of the probability of failure-free operation of a unit P(t), and the value $P_{ОПТ}$ is noted.

## 3. Calculating the Reliability

The reliability design calculations are performed during the developmental stage of a unit to determine its conformity to the requirements formulated in the design tasking. The quantitative characteristics of the reliability of the units should be determined as a result of the calculations. The calculations are performed using the known data on the rate of failure of the components comprising the unit under consideration; in particular, the reliability of any assembly unit of a computer is governed by the values of the failure rate of the electronic components and the structural elements comprising the assembly unit.

There are extensive reference data at the present time on the failure rates of electronic components. These data are given for normal temperature conditions and for a definite electrical operating mode of the electronic components.

The electrical utilization mode of an electronic component is characterized by the load coefficient:

$$K_L = N_{op}/N_{nom},$$

where $N_{op}$ is the load on the element in the operating mode; $N_{nom}$ is the nominal or permissible load according to the technical specifications.

In this case, the load should characterize that electrical quantity which exerts the decisive influence on the operability of the electronic component. Such a quantity for resistors is the power, for capacitors it is the working voltage, and for integrated circuits, it is the value of the load at the output. In principle, the quantity $K_L$ is less than unity, since the use of electronic components in operating modes which exceed the nominal permissible ones in accordance with the technical specifications is forbidden.

The failure rate, $\lambda_e$, of electronic components under actual operating conditions is related to the failure rate, $\lambda_L$, of electronic components in the nominal electrical operating mode by a certain coefficient $K_\lambda$, which depends on the load coefficient $K_L$ and can, in the general case, have a nonlinear nature. In individual cases, during the preliminary design calculations of the reliability of a unit, one can assume that $K_\lambda \approx K_L$, and then $\lambda_e = K_L\lambda_L$, to take into account the influence of the electrical operating mode of the electronic components.

Reducing the load on an electronic component assures an increase in its operational reliability, i.e., a reduction in the value of $\lambda_e$. Increasing the working temperature leads to a degradation of electronic component reliability, and consequently, to an increase in the value of $\lambda_e$.

It is necessary to have data on the operational reliability of an electronic component (the values of $\lambda_e$) as a function of the load, temperature and other factors for the most precise calculation of a unit when operates under actual operating conditions. The reliability of such data can be assured only with a large volume of experimental observations. This volume cannot usually be obtained under laboratory conditions during the testing and developmental stages of the component or unit; it can be obtained only during long term operation of the unit.

A typical curve for the relative failure rate of an IC (the value of $\lambda$ at any temperature referenced to the value of $\lambda$ at +20 °C) is shown in Figure 11 as a function of temperature, from it follows that the reliability is substantially degraded with an increase in temperature. Limiting the working temperature at a level of about +50 °C will boost the reliability of IC's by approximately an order of magnitude as compared to the variant where they are used at a temperature close to the maximum (+125 °C).

Easing the operating conditions of electronic components changes the nature of the curve of the failure rate of the components as a function of time: the burn-in stage is somewhat lengthened, the failure rate in the normal operational stage is reduced and the wear stage has a later onset (Figure 8).

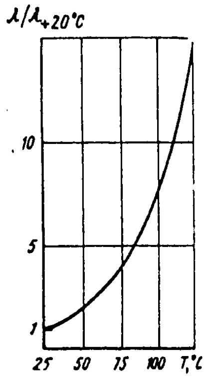

Figure 11. The typical relative failure intensity rate of integrated circuits as a function of temperature.

Data on the failure rates of all of the electronic components used are needed to compute the reliability of a unit, where this data applies to actual operational conditions, i.e., taking into account the operating temperature and load on the electronic components during their service in the unit.

Before moving directly on to the calculation of the reliability of a unit, it is necessary to deal with such concepts as primary (series), back-up (parallel) and mixed connection configurations of components.

A connection of the components in a unit is called series when the failure of only one element leads to the failure of the entire unit. It should be noted that a series connection in the sense indicated above does not coincide with the physical series connection of components in an electrical circuit, since in an electrical circuit of a unit, the elements can be connected both in series and parallel.

Parallel is the term for that connection configuration of components in a unit in which the failure of the unit occurs only after the failure of any primary and all back-up components for it.

A mixed configuration is the term for the combination of series and back-up connections.

In the present analysis, we will limit ourselves to calculating the reliability of a unit with a series configuration of the components. The calculation is performed for the normal operational period, when the failure rate $\lambda_i$ of each type of component is a constant quantity.

The failure rate of a unit, $\Lambda_0$, is the sum of the failure rates of all of the components incorporated in a unit; the probability of failure-free service of a unit, $P_0$, with a series configuration of the components is the probability that all components incorporated in the unit will operate without fail:

where $\lambda_i$ is the failure rate of the i-th type and operating mode components; $N_i$ is the number of components with a failure rate of $\lambda_i$; k is the number of kinds of components according to types and utilization modes,

*Example.* We shall compute the reliability of a computer module (the probability of failure-free operation for 1,000 hours is $P_0$ (1,000)), which contains 50 series 133 integrated circuits, 10 KM-5 capacitors for filtering out the high frequency component in the power supply circuitry for the microcircuits, as multilayer printed circuit board having 250 interlayer connections with a type GRPM-1 plug connector mounted on the circuit board where the connector has 90 contacts. The working temperature at the microcircuit packages under actual operating conditions should be assured within limits of +50 °C, something which is in line with an increase in the reliability of the integrated circuits by approximately an order of magnitude as compared to their reliability at + 125 °C.

TABLE 12

| Designation<br>Наименование и тип элемента<br>and Type of Component | (1)<br>Интенсивность отказов $\lambda_{iн} \times 10^{-6}$ ч$^{-1}$ | $K_н$<br>$K_L$ | $K_т$ | $\lambda_{iэ} = \lambda_{iн} K_н K_т \times 10^{-6}$ ч$^{-1}$<br>hr$^{-1}$ | $N_i$ | $\lambda_{iэ} N_i \times 10^{-6}$ ч$^{-1}$<br>hr$^{-1}$ |
|---|---|---|---|---|---|---|
| (2) Микросхема 133 ЛА1 | 0,1 | 1 | 0,1 | 0,01 | 2 | 0,020 |
| То же The Same |  | 0,8 |  | 0,008 | 4 | 0,032 |
| » |  | 0,4 |  | 0,004 | 14 | 0,056 |
| (3) Микросхема 133 ТР1 |  | 0,8 |  | 0,008 | 4 | 0,032 |
| То же The same |  | 0,4 |  | 0,004 | 16 | 0,064 |
| (4) Микросхема 133 ЛА6 |  | 0,8 |  | 0,008 | 2 | 0,016 |
| То же The same |  | 0,6 |  | 0,006 | 8 | 0,048 |
| (5) Конденсатор КМ-5 | 0,01 | 0,2 | — | 0,002 | 10 | 0,020 |
| (6) Разъем ГРПМ-1 | 0,1 | — | — | — | 1 | 0,100 |
| (7) Межслойные соединения в МПП | 0,001 | — | — | — | 250 | 0,250 |
| (8) Пайки выводов микросхем | 0,0001 | — | — | — | 14×50 = = 700 | 0,070 |
| (9) Пайки выводов конденсаторов | 0,0001 | — | — | — | 2×10 = 20 | 0,002 |

$T_0 = \frac{1}{\Lambda_э} = 1,4 \cdot 10^6$ ч; $\Lambda_э = \Sigma \lambda_{iэ} N_i = 0,713 \cdot 10^{-6}$ ч$^{-1}$;

$P_{0\,(1000)} = e^{-0,713 \cdot 10^{-6} \cdot 1000} \approx e^{-7 \cdot 10^{-4}} \approx 0,9993$;

$К_т$ — коэффициент учета температурного режима

Key: 1. Failure rate, $\lambda_{iL} \cdot 10^{-6}$ hr$^{-1}$;
2. 133 LA1 microcircuit;

[Key to Table 12, continued]:

3. 133 TR1 microcircuit;
4. 133 LA6 microcircuit;
5. KM-5 capacitor;
6. GRPM-1 connector;
7. Interlayer connections in a multiplayer printed circuit board;
8. Solder connections of microcircuit leads;
9. Solder connections of capacitor leads;

$K_T$ is a coefficient which takes into account the temperature conditions.

*

The results of the reliability calculation are conveniently represented in the form of Table 12.

## 4. Reliability Tests

Two basic kinds of reliability tests are differentiated: control and diagnostic.

Control tests are performed for the purpose of establishing the conformity of the reliability level of products to the requirements of the technical specifications for them. Reliability requirements, stipulated in the technical specifications for a product, as a rule do not reflect the values of the true operational reliability of the products; this is particularly characteristic of contemporary integrated circuits and assembly components based on them. The fact is that the operational reliability of these products is so great that to confirm it would require very large overall operating times to failure of the products, which are altogether unacceptable in an organizational and economic sense. For this reason, a certain conditional reliability level is established in the technical specifications for a product, the control testing of which both with respect to the testing time and the number of tested products proves to be acceptable. The purpose of control tests for reliability consist in checking the quality of the technological process of product fabrication, and for the absence of gross violations in it which can lead to a sharp drop in product reliability.

One or two levels of reliability are specified in the technical specifications for control testing of the reliability.

When testing for one level of reliability, the minimum (rejection) value of the probability of failure free operation $P_2$ in a time $t_g$ is specified within the specified operational conditions for a customer risk of $\beta$.

The customer risk $\beta$ is the probability that with selective quality control, a batch of products can be received having a reliability level equal to the minimum (rejection) value of the probability of failure-free service.

In the case of control testing for two reliability levels, in addition to the parameters specified for control testing for one reliability level, an acceptance value of the probability of failure-free service $P_1$ in a time $t_g$ under the specified operational conditions is also specified for a manufacturer's risk $\alpha$.

The manufacture's risk $\alpha$ is the probability that during the quality control, a batch of products can be rejected having a level of reliability equal to the acceptance value of the probability of failure-free service.

Tests are usually planned for a customer risk of $\beta = 0.1$ and a manufacture's risk $\alpha$ equal to 0.1, 0.2 or 0.3; in the case of a large production volume one can use $\alpha$ = 0.0,5. For extensive and expensive tests with a small production volume for the products, it is permissible to plan the tests for a customer $\beta$ of 0.2 or 0.3 with an agreement between the manufacturer and the customer for the product.

The right of selecting quality control with respect to one or two levels of reliability is made available to the developer--manufacturer of the product.

TABLE 13

| β | C | n при $P_1$ | | | | | |
|---|---|---|---|---|---|---|---|
| | | 0,999 | 0,99 | 0,95 | 0,9 | 0,8 | 0,7 |
| 0,1 | 0 | 2301 | 229 | 45 | 22 | 10 | 7 |
| | 1 | 3888 | 388 | 76 | 37 | 18 | 11 |
| | 2 | 5320 | 532 | 105 | 52 | 25 | 16 |
| 0,2 | 0 | 1608 | 160 | 31 | 15 | 7 | 5 |
| | 1 | 2993 | 299 | 59 | 29 | 14 | 9 |
| | 2 | 4278 | 427 | 85 | 42 | 20 | 13 |
| 0,3 | 0 | 1203 | 120 | 23 | 11 | 6 | — |
| | 1 | 2438 | 243 | 48 | 24 | 12 | 8 |
| | 2 | 3615 | 360 | 71 | 35 | 19 | 11 |

Checking for conformity of the reliability level of the product to the requirements of the technical specifications is made during periodic tests in the process of trial and series production.

The rules for the acceptance and rejection of products based on the results of reliability tests are established in the technical specifications for the products.

The planning of the control tests for one reliability level is accomplished in the following manner.

The acceptance number of failures C is established: the greatest number of failed products in a sample, in which the results of the tests are considered positive; to curtail the volume and cost of tests, it is recommended that the value C be chosen equal to 0, 1 or 2. Then, the size of the sample n is determined from Table 13 as a function of the specified values of $P_2$, β and the chosen value of C.

At the expiration of the testing time, $t_{test} = t_g$, the results of the rests are estimated: if the quantity of failed products $d \leq C$, then the results of the tests are considered positive and if $d > C$, they are negative.

When planning tests for two levels of reliability, the quality control plan is computed in the following manner.

The ratio $A = \frac{(1 - P_2)(1 + P_1)}{(1 - P_1)(1 + P_2)}$ is first calculated. Then the acceptance number of failures is determined from Table 14 as a function of the values of A, α and β.

TABLE 14

| β | C | A при α | | | |
|---|---|---|---|---|---|
| | | 0,05 | 0,1 | 0,2 | 0,3 |
| 0,1 | 0<br>1<br>2 | 44,71<br>10,94<br>6,51 | 21,82<br>7,31<br>4,83 | 10,33<br>4,72<br>3,47 | 6,46<br>3,54<br>2,78 |
| 0,2 | 0<br>1<br>2 | 31,25<br>8,42<br>5,23 | 15,26<br>5,63<br>3,89 | 7,22<br>3,63<br>2,79 | 4,51<br>2,73<br>2,24 |
| 0,3 | 0<br>1<br>2 | 23,37<br>6,86<br>4,42 | 11,41<br>4,58<br>3,28 | 5,40<br>2,96<br>2,36 | 3,38<br>2,22<br>1,89 |

If the calculated value of A does not match the tabular value, the closest tabular value is to be taken for the given risks α and β; in this case, if the greater tabular value of A is chosen, then a greater reliability level $P_1'$ than the specified $P_1$ will correspond to the specified risk α, and vice versa. Then, using Table 13, the size of the sample n is determined as a function of the values $P_2$, β and C.

The results of the tests are evaluated just as in the case of test planning for one reliability level.

Diagnostic tests are formed for the purpose of obtaining reference data on the true values of the indicators (quantitative characteristics) of the reliability of products and on their dependence on time, operational conditions and electrical modes (including at the nominal temperature and in the nominal operating mode, such has been established) for the further utilization of this data in calculating the operational reliability of the equipment.

Where the testing time is $t_{test}$, the number of objects being tested is n and the number of registered failures is d, the average failure rate is defined as:

$$\lambda = d/nt_{test} \quad [hr^{-1}];$$

and the probability of failure-free service as:

$$P = 1 - d/n.$$

It is apparent that to establish the true values of the reliability indicators of such highly reliable modern products as integrated circuits and assembly units of computers based on them, enormous non-failure operating times are required ($nt_{test}$), which can practically not be obtained during the design and developmental stages of the products. For this reason, diagnostic tests for reliability are frequently not carried out as an independent kind of testing, while the determination of the true operational reliability indicators of such products is accomplished by means of processing the observations made during normal operation of the actual equipment.

## 5. Designing a Computer for a Specified Reliability

The level of reliability of a computer is established during its design. It is practically impossible to fully compensate afterwards for omissions made as regards providing for a specified reliability during the design stage of a computer.

The specified reliability is assured during the design of the computer by means of taking into account all of the major factors which have an impact on the reliability and choosing the appropriate design solutions.

Computer reliability is primarily determined by the following factors:

--The reliability of the component base;
--An efficient configuration of the functional layout;
--The reliability of the structural design solutions which are adopted;
--A correct choice and realization of the fabrication technology and quality control of the components, assembly units and the computer as a whole;
--The operational conditions;
--The system adopted for servicing the computer.

The component base reliability determines computer reliability to a significant extent.

In second generation computers, the reliability of the primary active electronic components - the transistor - was characterized by a value of $\lambda_T \approx 10^{-7}$ $hr^{-1}$ in the best case. If the reliability of all of the other electronic components and structural elements were not even taken into account, then the reliability of the average sized second generation computer, which contained 10,000 transistors, would be characterized by a value of $\lambda_{computer} = 10^{-7}\ hr^{-1} \cdot 10^4 = 10^{-3}\ hr^{-1}$, and correspondingly, a mean time between failures of $T_{avg\ computer} = 10^3$ hours.

The transition to the utilization of integrated circuits in third generation computers lead to a qualitative change in the reliability characteristics. Integrated circuits, the reliability of which under moderately difficult operational conditions is characterized by a value of $\lambda_{IC} \approx 10^{-7}\ hr^{-1}$, are equivalent in terms of complexity to circuits using discrete electronic components containing tens and hundreds of transistors. For this reason, the application of IC's provides for an increase in the equipment reliability as compared to the case of the use of discrete components by a factor of 10 to 100 times and more for devices similar in terms of functions or makes it possible with the previous reliability indicators to increase the functional complexity of the equipment by several orders of magnitude.

The high reliability of the component electronic elements can be provide under conditions of automated mass production while observing the production process modes with all-embracing output quality control of the electronic components based on the major electrical parameters. Such modern production which also requires large initial capital investments can be efficient only in the case where the production unit is a mass applications product, the marketing of which will make it possible to recover the initial expenditures. In this regard, digital integrated circuits are the ideal production unit, since the demand for them is quite high. The means directed towards fundamental research in the field of refining IC technology are providing for a continuous rise in their reliability. By 1985, a reduction in the failure rate of IC's down to $10^{-10} - 10^{-11}$ $hr^{-1}$ is forecast.

The influence of the functional configuration of the equipment which is chosen on its reliability should be treated in the plan for assuring the minimum volume of the equipment, needed to realize the specified equipment functions, since the reliability of the product is found to be in a direct relationship with the number of electronic components and structural elements which are used.

The adopted structural design solutions in many respects determine the reliability of the products. In this case, one strives for maximum possible simplicity in the structural designs. In working out the structural design of a computer, primarily questions of electronic component layout are resolved: in assemblies, individual assemblies (assembly units) and the hook-up between them, to form the devices. Devices with complex kinematics belong, as a rule, to the computer peripherals: the data storage devices using magnetic tapes, disks, drums, digital printers and input-output converters.

The reliability of the manufacturing production process for a product characterizes the property of the production process of assuring the fabrication of the product with strict observance of the tolerances for all of its parameters which are monitored.

If some portion of the overall number N of fabricated products has deviations from the specified parameters, then the quality of the production process will be characterized by the ratio:

$$\frac{n_1+n_2}{N}=\frac{n_1}{N}+\frac{n_2}{N},$$

where $n_1$ is the number of products rejected during quality control; $n_2$ is the number of products having a hidden defect which is not ascertained during the quality control.

Production process reliability can be characterized by the ratio:

$$P_{\text{тех}}=\frac{n_2}{N-n_1}.$$

The smaller this ratio, the more reliable the production process.

Usually, the overall technological fabrication process for a product takes the form of a sequence of elementary production operations, which alternate with quality control operations. Automated fabrication and quality control operations on products have the greatest reliability, where these assure high precision in observing the parameters of the fabrication and quality control processes. Nonautomated stages of product fabrication, in which the decisive factors are the actions of operators, are the sources of the majority of defects in the finished product. It is especially important to automate and assure precision in the observance of the parameters of such operations, the results of which cannot be ascertained directly following their performance; failure to observe the parameters can in turn lead to the appearance of a hidden defect in the products. An example of an operation, the result of which is difficult to check directly, is the creation of contact connections at all levels of computer construction (soldering electronic components on circuit boards, soldering or wrapping hook-up wires on installation panels).

Output quality control for each product of is of particular importance, which should assure with a high probability the correctness in checking for conformity of product parameters to the established requirements. Directly related to this question is the problem of the reliability that the designated check (the products list and volume of parameters being checked) in the case of positive results will assure that the product can perform the functions asigned to it when incorporated in a more complicated product.

Operational conditions exert a direct influence on product reliability. The closer the range of working temperatures, humidity and pressures to normal conditions, the smaller the mechanical loads on a product and the higher its operational reliability. For this reason, products are designed and constructed taking into account the requirement of providing for easier conditions for the application of the component electronic and structural elements.

The correct organization of servicing plays no small part in achieving a high operational reliability for a computer. Many failures which occur during computer operation are the consequence of failure to observe the operational conditions and service instructions. A reason for this is the poor training or inadequate discipline of the servicing personnel; with the correct organization of the work, these factors can be reduced to a minimum. In particular, all of the requisite measures to protect against static electricity, which can have a negative impact on the operability of digital and integrated circuit semiconductor components should be taken.

The timely performance of the requisite preventive maintenance plays an important part in the proper technical servicing. The primary function of this work is to ascertain and replace individual components or assembly units in a time specially set aside for this, where the parameters of these units approach the permissible limiting values for them. A widespread method of preventive maintenance is the so-called "swinging" of the supply voltages in a definite range close to the nominal values, for exmaple, by ±10 percent. Components or assembly units which do not cause disruptions of computer operation at nominal supply voltage values, in the case of short term permissible supply voltage deviations from the nominal values during preventive maintenance can prove to be nonoperable. This makes it possible to ascertain components of assemblies which have deteriorated and which should be replaced with good ones from the set of spare parts and accessories which go along with the computer.

However, there are cases where the reliability of computers inserted in the control loop of automated control systems for important industrial or defense facilities be so high that neither the selection of the most reliable contemporary component base nor the strictest observance of technology, etc. is capable of assuring this reliability. In this case, back-up operation is employed: a method of boosting reliability through the transfer of the transfer of the functions of a failed unit to a back-up. Back-up operation assures higher reliability for a product as a whole than the reliability of the assembly units and components comprising it.

Several methods of providing for a back-up are well known.

In the case of *permanent back-up,* the same function is performed by two devices in parallel. In the case of the failure of any of them, proper operation of the equipment as a whole will be assured by that device which has remained in good working order. A drawback to the method consists in the simultaneous consumption of the service life of both of the devices which back each other up.

In the case of *substitution back-up,* one of the devices participates in the normal operation of the equipment. It should be equipped with components which control its operation and which generate a fault signal when the device fails. Based on this signal, the back-up unit is turned on, something which assures the further functioning of the equipment.

In the case of *substitute back-up with restoration*, the entire equipment circuit is designed so as to provide the capability of detecting and eliminating defects in the failed unit while the stand-by operates. Such an organizational configuration can assure uninterrupted operation of the equipment for a long time, since the probability of the simultaneous failure of the back-up devices is extremely low.

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# IC PACKAGING

Moscow OSNOVY PROYEKTIROVANIYA SBOROCHNYKH EDINITS EVM in Russian 1980
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[Excerpt from book "Fundamentals of the Design of Computer Assembly Components", by B.O. Ol'khov, Izdatel'stvo "Mashinostroyeniye", 15,000 copies, 255 pages]

[Excerpt] *The structural packaging of integrated circuits.* Integrated circuits can be broken down into two groups according to the structural design: packaged and unpackaged.

Unpackaged IC's take the form of a chip with flexible or rigid (bead or stub) leads. They are used in the production of hybrid microassemblies for equipment with minimum overall dimensions and weight. In this case, the functions of protecting the IC's against environmental effects are assumed by the body of the support structure of the assembly unit with the unpackaged IC's.

Packages serve for protection against external climatic and mechanical effects, to standardize the major initial structural design components in terms of the overall and installation dimensions, as well as to simplify the processes of fabricating assembly units with IC's at instrument making enterprises.

IC packages are subdivided as follows in accordance with the structural design and production process criterion:

--Metal-glass (the base is of glass or metal, connected to a metal cap by welding; the leads are insulated with glass); used at the present time primarily for hybrid IC's;

--Metal-polymer (the substrate with the elements and leads is placed in a metallic cover, and hermetically sealed with a compound); limited use, primarily, for hybrid IC's;

--Metal-ceramic (base made of ceramic, joined to the metal cover by welding or soldering); used for monolithic IC's, resistant to a broad range of external climatic and mechanical factors;

TABLE 16

| Package Type | Shape of the Package Body in a Plan View | The Arrangement of the Leads in the Plane of the Base | The Arrangement of the Leads and Their Cross-section | The Spacing of the Layout of the Leads |
|---|---|---|---|---|
| 1 | Rectangular | Within the bounds of the projection of the body of the package | Pin, circular | 2.5 mm |
| 2 | Rectangular | Outside the bounds of the projection of the package body | Pin, Circular or rectangular | 2.5 mm |
| 3 | Circular | Within the bounds of the projection of the package body | Pin, circular | 30, 36 and 45° |
| 4 | Rectangular | Outside the bounds of the projection of the package body | Planar, rectangular | 1.25 mm |

--Ceramic (base and cover made of ceramic material, joined by soldering); applications are similar to metal-ceramic packages;

--Plastic (base and cover made of plastic, joined by pressing); used for monolithic IC's, having a limited range of exposure to external climatic and mechanical factors.

GOST 17467-72 establishes four types of IC packages (Table 16) and the standard dimensions within each type, the overall and connection dimensions of the packages, the number and spacing of the leads, as well as the system of designations for the packages according to standard dimensions and number of leads. IC leads can lie in the plane of the package base (planar leads) or be perpendicular to it (pin leads).

Type 1 packages have three variants:

K101-K142 (Figure 13a) - with a lengthened shape 13 mm and 18.5 mm high with a linear multiple row arrangement of the leads, where the leads number from 12 ot 105;

K150-K-162 are flat with a height of 4.0 mm or 6.5 mm with the leads arranged along the long sides of the package base (Figure 13b), around the perimeter of the package base (Figure 13c), or with a linear multiple row arrangement Figure 13d), where the number of leads runs from 6 to 345.

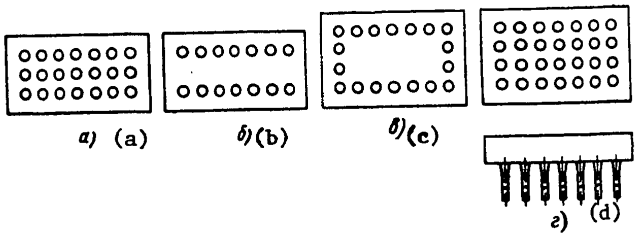

Figure 13. Type 1 packages.

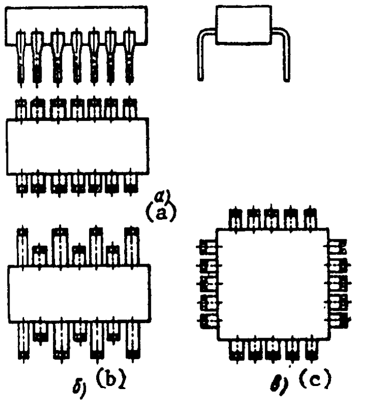

Figure 14. Type 2 packages.

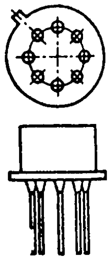

Figure 15. Type 3 package.

Type 2 packages have three variants:

K201-K237 (Figure 14a) have the leades along the long sides of the package base with identical geometry for the lead bends; the leads number from 14 to 46;

K240-K245 (Figure 14b) have the leads along the long sides of the base with the bends made in checkerboard order, where the leads number from 14 to 24;

K260-K274 (Figure 14c) have the leads about the perimeter of the base with identical bends, and the leads number from 28 to 76.

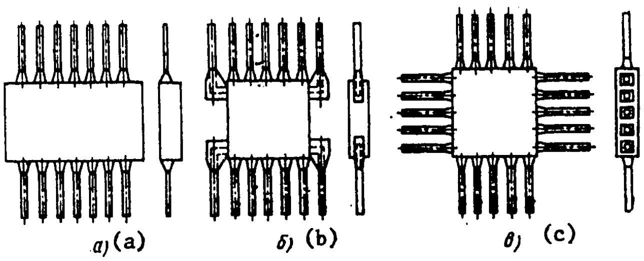

Figure 16. Type 4 packages.

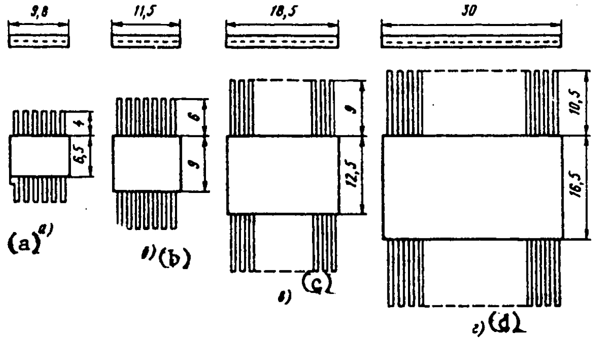

Figure 17. Packages for monolithic IC's:

Key: a. 401.14-1;
b. 402.16-1;
c. 405.24-1;
d. 244.48-1.

Type 3 packages (Figure 15) are circular in shape and have three base variants, which in the number of leads (8, 10 or 12, which are arranged at spacings of 45, 36 and 30° respectively); the leads are arranged about a circle 5.0 mm in diameter. In each variant of the base, the height of the package can be either 4.0 or 6.5 mm.

Type 4 packages have three variants:

K401-K428 (Figure 16a) have the leads along the long sides of the package base and have from 14 to 82 leads;

K440-K441 (Figure 16b) have 14 leads with widths of the package body of 3.5 and 6.0 mm;

K460-K469 (Figure 16c) have the leads about the perimeter of the base with from 60 to 188 leads.

The designation of the IC is applied to the surface of the package, as well as the data of manufacture and the trade mark of the manufacturing enterprise.

The leads of IC's are not numbered on the surface of the package. The well known rules for counting the leads for each of IC are used to determine the number of a lead. Their is a "key" on the package in the form of a cutout of a special shape or a marker which designates the number 1 lead. The counting off the remaining leads for IC's which have two or four sides of a rectangular package base, and for IC's in circular packages is accomplished from the first lead going counter clockwise if one looks at the IC from the cap side (or clockwise if one looks from the base side).

One standard package dimension can have several variants which are determined by certain structural design and production process differences. For example, the difference can be a special massive base with parts for fastening to an external heat sink; such a variant is used for IC's with increased heat dissipation.

A few kinds of packages which find wide applications as monolithic IC's, which differ in the number of leads and the heat sinking properties, are shown in Figure 17. The height of the packages with planar leads is 2 to 3 mm. The maximum power for which IC's in flat packages are designed varies from about 200 mW for the 401.14 package up to 1,000 mW for the 244.48 package.

Prior to the implementation of GOST 17467-72 in industrial practice, some standard package dimensions for IC's which do not conform to the classification of the indicated standard found application. The plastic 301PL14-1 (Figure 18), which corresponds to the so-called DIP* package of foreign IC's found and continues to find especially wide applications for IC's with a limited range of exposure to mechanical and climatic effects.

[51-8225]

8225
CSO: 1863

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*From the English "dual-in-line" package: a two row arrangement of the leads.

## SOFTWARE

UDC 681.3.066

### REALIZATION OF THE ADAPTABILITY PROPERTIES OF THE OPERATING SYSTEMS OF MINICOMPUTERS

Novosibirsk AVTOMETRIYA in Russian No 3, May-Jun 80 manuscript received 13 Jul 79 pp 113, 115

/Excerpt from article by L.D. Zabrodin, V.N. Korobov and V.F. Overchenko, Moscow/

/Excerpt/ The approach that has been described was tested during the development of the M-6000 computer's real-time OS /operating system/, which works on-line with a mockup of the linear accelerator section of a meson production facility. The VM /virtual machine/ developed for this computer contains 20 primitives and is a two-level, hierarchical (Khoar) monitor. Access to the VM's external primitives is possible both in the M-6000 computer's mnemonic code and in FORTRAN.

The M-6000 computer's VM was used as the basis for the construction of two real-time OS variants (punched tape and disk versions) that have the same structure (Figure 2) and are distinguished from each other by the loader and the designers of the nonresident (to an insignificant degree) and resident processes. In accordance with the requirements for the organization of the computer's on-line operation with the accelerator, the basic design algorithm in the OS is a cyclic dispatching algorithm with a cycle that is equal to or a multiple of the accelerator's injection period (10 ms). The privileged processes in the OS are the dispatcher and the designer of resident processes, while at the level of the nonprivileged systems processes are the loader, the operator directive language interpreter, the designer of nonresident processes and the processes for communication with operators. Figure 2 depicts the basic parts of the OS.

The realization of two real-time OS variants on a single base and the development on that same base of an OS for several other systems that differ from the accelerator confirm the possibility of creating minicomputer OS's that are adaptable to the requirements of a broad circle of uses and prove the competence of the proposed approach.

[55-11746]

11746
CSO: 1863

UDC 681.3.06

## REALIZATION OF THE IML INTERMEDIATE-LEVEL LANGUAGE ON A COMPUTER OF THE SM-3 TYPE

Novosibirsk AVTOMETRIYA in Russian No 3, May-Jun 80 manuscript received 14 Jun 79 pp 116, 117

/Excerpts from article by N.A. Kazakova and Ye.V. Pankrats, Moscow/

/Excerpts/ Introduction. In connection with the beginning of the series production of computers of the SM-3 (and SM-4) type that are equipped with KAMAK equipment and kreyt-controllers /translation unknown/ (IVK /measurement and computation complex/), the primary problems are those related to including the KAMAK equipment control facilities in the standard operating systems (OS) of the SM-type computers and standardizing the software for controlling the KAMAK equipment. An important stage in the solution of this problem is the creation of standardized intermediate-level software, as the basis for the construction of which the IML language, as standardized by the ESONE Committee /1/, was selected.

Brief Description of the IML Language. The IML language corresponds to the lowest hierarchical level of the software standardized by the ESONE Committee and provides the maximum possible detail for the assignment of control and description operations for the elements of the KAMAK equipment that is used. The language contains only operators for the control of KAMAK equipment and is intended for use together with some already existing basic language (in this case, the SM computer's Macroassembler) and a basis OS.

At the present time there is the possibility of adjusting the organizing subsystem (and, consequently, the entire set of software) for operation as part of the following basic OS's: disk operating system, multiprogramming real-time disk operating system, real-time paper tape operating system and FOBOS /expansion unknown/. There is also the possibility of adjusting the organizing subsystem for autonomous operation (without a basic OS), which makes it possible to use the language facilities that have been created to construct systems on the basis of an "Elektronika-60" microcomputer and KAMAK equipment. In this case the experiment control program is prepared on an SM-3 computer that has a disk OS and is introduced into the experiment-controlling microcomputer on punched tape.

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/55-11746/

11746
CSO: 1863

UDC 681.3.015:681.3.06

# INTELLIGENT INTERACTIVE SYSTEMS

Moscow IZMERENIYA, KONTROL', AVTOMATIZATSIYA in Russian No 5-6, 1980 pp 45-55

[Article by Candidate of Technical Sciences V. F. Khoroshevskiy]

[Excerpts] Since natural-language interactive systems are a practical realization of our concepts of a communication language and some mechanisms of our thinking, they appear as a tool of research in the area of artificial intelligence.

At the present time a large number of natural-language systems (mainly experimental) have been developed and are functioning. Among the best known one can point out such American natural-language systems as BASEBALL (Green), DEACON (Craig), ELIZA (Weisenbaum), STUDENT (Bobrow), SIR (Rafael), PROTOSYNTHEX III (Simons), CONSTRUCT (Smith), RENDEZVOUS (Codd), SHRDLU (Winograd), HWIM (Woods) and SRISU (Paxton), the English system PARRY (Colby) and also the Soviet systems VOSTOK AND ZAPSIB (Narin'yani), DISPUT (Milulich), POET (Popov), DILOS (Bryabrin), MIVOS, etc (the principal developers of the natural-language systems are indicated in parentheses) [1-12]. At the same time, information about natural-language systems (the ideas built into a given system, the structure, possibilities, etc) is disconnected, sometimes contradictory and almost always difficult of access.

The purpose of the present work is to make an analytical survey of Soviet and foreign investigations in the area of the interaction with computers of final users in languages close to the natural.

Since it is hardly possible to consider all aspects of natural-language interaction with electronic computers in a single article, we will not examine systems of computer translation from natural languages or systems whose main purpose is the development of rather powerful theories of natural languages. These questions have been discussed in references [13-15]. Interactive systems directed toward a user unprepared but close to an electronic computer are practically unconsidered in the present survey. A survey [16] has been devoted to this theme.

As an example of a system with a more complex semantic processing of messages we will examine the DISPUT system, developed in the Institute of Control Problems and oriented toward work with the final user in transport junction control apparatus [9]. Natural-language interaction in that system is assured by a special linguistic processor which within the framework of the entire intelligent system is an input processor (output is accomplished by interface module subroutines).

Inquiries for the system are formulated in a limited natural language. Examples of inquiries can be phrases of the type, "What number of import containers at the terminal are subject to unpacking, including by numbers and consigners?", "How many export containers to be shipped by sea [including by consigners, numbers and type-sizes (including by consignees)] are stored for a time at the container terminal?", etc.

From the point of view of the user of the DISPUT system it is convenient to distinguish four types of inquiries: about the number of objects, the time, the object itself and the list of objects with given characteristics.

The principal declarative and procedural parts of the linguistic processor of the DISPUT system are a dictionary, coder, editor, grammatical analyzer and dictionary expander.

A specific feature of the organization of the dictionary in the DISPUT system is use of data structures of the type of trees. Thus the coder can make spelling corrections. In addition, such organization permits reducing the storage volume needed for storage of a specific set of key words. The time of access to the syntactic-semantic word code increases in that case, but for the 200 word forms used in the system's dictionary that increase is insignificant.

The source text is pre-processed in the DISPUT system by "coder" and "editor". As a result of the work of those two units, in the request remain only those word codes necessary for unequivocal "understanding" of the text within the framework of the given problem area. "Understanding" is assured by interaction of the "editor" with the semantic network.

A pre-processed request is analyzed by the grammatical unit, consisting of a control (main) unit and subroutines for the analysis of separate semantic groups. The main unit works in that case on the basis of keywords which fix the start of the corresponding groups, and properly speaking the group is analyzed by a separate module. Thus, on the whole, the grammatical analyzer of the DISPUT system is realized procedurally, and in the transition to another communication language must be reprogrammed or readjusted.

As a result of work of the linguistic processor the initial request is translated into an internal cocnept which is perceived by a pragmatic processor. The latter is intended for translation of the results of analysis in the task of the data planner.

The planner's task is formulated as a combination of the factual parameters determining the required functional data base module and the necessary arrays and sub-arrays, lists of basic, additional requestable characteristics, and also the moment of time indicator.

Because of the simplicity of the linguistic constructiions of input messages the linguistic processor of the DISPUT system requires a small memory volume (the entire processor contains about 1000 FORTRAN-IV operators), works fairly rapidly (the analysis rate is about 0.01-0.05 s/word) and has a high degree of mobility in the transition to other electronic computers, since there are program-compatible (with the exception of distinctive input-output features) realizations of the FORTRAN language in practically all computers. Shortcomings of the DISPUT system (in all tabular natural-language systems) are the communication language limited to certain linguistic constructions and rather complex empirical algorithms for the addition of separate word forms (morphological analysis is absent in such systems, as a rule) of syntactic-semantic information.

The semantic approach to understanding the communication language also has been used in the family of natural-language systems of ZAPSIB [ZAPros k Spravochnoy Informatsionnoy Baze--Request for Reference Information Base] being developed in Novosibirsk [9].

Characteristic features of the latest model of the family, ZAPSIB-10, are semantically oriented analysis of input information, the use of ascending analytical equipment, and also relative simplicity of algorithms realized in the system (attainable, true, through constriction of the communication language).

The principal ZAPSIB-10 macromodules are the processor and the dictionary. The processor includes a lexical analysis module which converts the input request into a series of components equipped, where possible, with markers of the type of component; a word-combination conversion modulus which forms single components corresponding to stable word-combinations; a basic analysis unit in which, in essence, an interpretation is made of the description of the communication language represented in ZAPSIB systems in the form of a set of groups of semantic and syntactic rules (within a group the procedure in rule application is not fixed). Formation of rule description assumes the presence in each of them of conditions of applicability and of an operator and is, in our view, a certain modification of the model "thought-text," oriented toward predominance of the semantic component. The last unit of the processor is an analysis and generation unit, in which possible ambiguities are eliminated by means of the rules of semantic matching and a request is generated for a formal language understood by some file system.

The macromodule "dictionary" represents, in essence, an independent system which assures the storage of dictionary information with a capacity of thousands and tens of thousands of dictionary articles and access to it. The macromodule includes simple means of completion, proofreading and checking of dictionary articles. An experimental version of ZAPSIB-10 has been realized in the powerful theoretical-set language SETL and a production model is being realized in the PL/1 language.

The possibilities of the ZAPSIB-10 in maintaining interaction are approximately the same as those of the DISPUT system and the DILOS system examined earlier. However, the presence of rather flexible linguistic analysis permits assuming the possibility of considerably expanding the communication language in subsequent systems of the family.

The above-considered natural-language systems realize the conception of an input-output preprocessor for information or logical systems.

The conception of an intelligent monitor is realized in the DILOS system [Dialogovaya Informatsionno-LOgicheskaya Sistema--Interactive Information-Logical System], which is being developed in the USSR Academy of Sciences Computer Center [11]. That system is intended for use as an intelligent intermediary between the final users and traditional computers in solving practical problems. The main function of the DILOS system consist in the accumulation and retrieval of information in the base of knowledge of a system reflecting a certain subject area, the activation (translation and counting) of practical problems, logical analysis of models of a problem medium, and also the solution of some other problems.

Knowledge of the system of the "world" is expressed by description of the aggregate of objects from a model data base. The main role among those objects is played by structural descriptions (frames) depicting events, actions, classes of physical objects, etc. Besides the model data base, the system contains a main data base in which sets of data in various formats are concentrated, and also translators and practical programs in various programming languages.

All procedures of the DILOS system are grouped in several units called processors (Figure 7). A linguistic processor converts the input pharases from a natural language to the language of a formal interface (Ø-language). The semantic interpretation of Ø-expressions obtained as a result of the work of the linguistic processor is done by the semantic processor. In that case, certain frames are activated and examples of them are formed which depict specific objects, events and actions, and Ø-expressions also are generated which arrive at the inputs of the system's actuating processor: logical, information retrieval and computational.

The linguistic processor of the DILOS system consists of three principal parts: a monitor, a dictionary and an ATN-mechanism (ATN = Augmented Transition Network).

The monitor is a resident of the linguistic processor and controls its remaining units. In them the basic processor mechanisms are realized (for example, such as ATN activation, next word selection, analysis of its meaning, transmission of meaning to a given point of processing of the starting message, etc), depending on the formalism of description of the communication language. The monitor of a linguistic processor is, in essence, the nucleus of the interpreter of the description of communication languages.

The main load in "understanding" phrases of a communication language in a DILOS system linguistic processor is borne by the dictionary. This is connected with semantic orientation of the process of analysis and, as a consequence, with an attempt to attach fairly complex information to dictionary lexemes. The correlation of elements of natural languages and Ø-expressions is reflected precisely in the dictionary. In the latter version of the DILOS system linguistic processor there are four kinds of dictionary articles, corresponding to concepts, indicators of properties, lexical functions and auxiliary words.

The generation of Ø-expressions is structurally controlled by the ATN unit, which is a set of states of the type ("type" < LISP-program > ). Each such type describes the transition from one state into another, and the connection between types of ATN-states and types of lexemes is accomplished by the dictionary. Thus, motion along the initial phase causes calculation of a certain series of LISP-functions and leads to generation of the resulting Ø-expression.

An interesting feature of the DILOS system linguistic processor is the formation and accompaniment of a dialog context. In that case, side by side with the main dictionary, for the current work session the following dictionaries are formed: USRVOC (for storage of new words introduced by the user), XVOC (for unknown words and words not defined by the user) and also SEMVOC (the semantic base for definition of new words) and some other auxiliary structures. As a result the user can, in the process of dialog (interaction), define new words and their semantics, and at the end of the session expand the main dictionaries.

On the whole, however, the syntactic component starts to play some sort of noticeable role in the linguistic processor only of the last version of the DILOS system, which now is in the stage of active development [21].

The POET system (Programma Obrabotki Ekonomicheskikh Tekstov--Economic Texts Processing Program) [23] is similar to the above-considered "LUNAR" and SRISU in the sense that it is a natural-language input-output processor for a certain data base control system. In the creation of the system an attempt was made to embrace as a communication language a fairly representative subset of the Russian language. The POET system perceived interrogative and informative proposals with practically immaterial limitations on the allowable syntactic constructions and punctuation [23], for example, "How much anthracite was transported by rail in 1979?", "What is the mean rate of maritime container shipments?", etc.

The process of understanding input information is accomplished in the POET system in accordance with a complete scheme: morphological analysis, syntactic analysis, semantic analysis and semantic interpretation. The last three stages are accomplished, generally, not sequentially but in parallel, as a result of which correction of false paths of analysis is achieved and, in the final account, reduction of the response time.

All knowledge of the communication language in the POET system is divided into linguistic and problem types. The former is stored mainly in various zones of the system's dictionary (the morphological zone, the syntactic and semantic zone, etc), and the latter in the semantic network. An abstract and a specific network are distinguished in the system.

Synthetic analysis of input messages in the system is based on the method of filters. To accelerate analysis and curtail the number of alternative paths in the POET system, global filters are widely used (by means of this, words between which there cannot be syntactic connections are screened out, their application is practiced directly at the moment the connection is established, and the sorting of variants of analysis is accomplished on the basis of control models. In addition, the semantic zone of the dictionary is actively used in the construction of syntactic structures.

In the stage of semantic analysis the syntactic structure of the input message is transformed into a semantic graph consisting of a set of concept-apices interconnected by event-apices and characteristics. Each apex of a semantic graph is determined by a canonical representation and the arcs express a definite semantics. All the numerical and parametric information is taken from the graph into additional tables when the time relations between events also are indicated.

The POET system is the only Soviet natural-language system with the generation of responses in the communication language. Natural-language responses are formed in the following way. According to the semantic response graph a dependence tree is constructed, and then the morphological information of each of the apices is recorded and the word order is determined. At this point the syntactic synthesis is concluded and is followed by the morphological synthesis, which includes generation of the surface structur of the phrase to the table of endings and morphological information. In the POET system a complete response is generated, and this permits the final user to check whether his request was understood correctly.

The POET system has been realized on older models of the YeS EVM system. The total volume of software recorded in the high-level language PL/1 (at the present time the main programs are being translated into the Assembler language) is over 160 Kbytes.

Metasystems are based on the idea of natural-language system generation. A similar approach to natural-language system generation can be observed in [8]. Definite prerequisites for that approach are contained in the reports [7,20], which use the idea of compiling a description of the communication language. Work has been begun in that direction also within the framework of the DISPUT system. However, an attempt at systematic practical implementation of that approach has been made only in the MIVOS system [12].

The MIVOS system [a corresponding plan was accomplished at the Department of Cybernetics of MIFI (Moscow Order of the Red Banner of Labor Institute of Engineering Physics) in 1976-1978] consists of a complex of software (the operational component) oriented toward the processing and maintenance of knowledge expressed in special systems of representation (the information component).

In the general scheme of organization of the MIVOS system (Fig 9) three levels are distinguished: the model (description of the problem medium and the communication language), the logical (representation of those descriptions) and the physical (realization of the representations used). In essence, the physical level represents the operational component, including linguistic and semantic-pragmatic processors. The information component of the MIVOS system consists of linguistic and problem knowledge expressed in representation systems of the ATN-language and PROZA (problem knowledge).

Realization of the representations obviously presupposes the use of some algorithmic language. In the DILOS system LISP is such a language, and in the POET system, PL/1 and Assembler. In the MIVOS system a modified language of expanded networks of ATNL transitions serves as the realization language.

The ATNL-MIVOS belongs to the class of the high-level sentential type and has universality in the class of solvable problems, powerful descriptive properties for description of a broad class of language models and all possible strategies and algorithms of analysis, the possibility of use of recursions of arbitrary depth and complexity, a high degree of structure of programs, mechanisms for comparison with a sample, automatic return and developed means of adjustment.

PROZA--a problem task representation system--is realized in MIVOS as a modular library system maintaining program formalism, the main components of which are a semantic network and scenarios. The semantic network serves for fixation of the current state of the subject region and on the whole is organized just as in the POET system. The scenarios, respresenting a semantic-pragmatic model of classes of situations or events occurring in the subject region, are realized in the MIVOS system as macrodefinitions describing the process of depiction of structures obtained as a result of analysis of natural-language phrases in pragmatically determined actions expressing the reaction of the system to given messages.

In the realized version of MIVOS the system of representation of problem tasks has not been worked out as well as the system of representation of linguistic knowledge, which involves a need for manual programming of the scenarios needed in a specific natural-language system (true, in a high-level language).

By the moment of completion of the plan of the MIVOS system on an experimental computer (the BESM-6), experimental linguistic processors were realized for interaction with the data base of a documentary data-retrieval system and communication with an adaptive robot. In the former case the output structures were determined by the formal inquiry language, and in the latter by RX-codes and syntagmatic chains.

Characteristic examples of input messages of those processors are pharases of the type: "Was the resolution on measures to improve the use of motor transport published?", "When was the resolution of the USSR Council of Ministers on the transportation of mail by truck published?" or "Instruction: a powerful internal combustion engine and a new body A and B are set on a large red chassis; that motor vehicle is good because it is stable and powerful for hauling and towing; the following tools are needed for the assembly: key 17 or 19, a reliable power crane and apparatus for control," etc. The analysis time of the presented phrases is 0.12-0.28 s/word.

## Prospects of the Development and Use of Natural-Language Systems

Since the creation of developed communication systems is a rather complex and laborious matter and change of the problem region and/or the circle of users requires, as a rule, modification of the communication software, one of the promising trends in the area of natural-language systems in the very near future will be a transition to systems of construction of linguistic processors for intelligent interactive systems.

The development of such systems must be based, on the one hand, on ideas and methods from the theory of syntactically oriented translators [25], and on the other, on the methods and technology of cross-system construction [26].

An example of the realization of those ideas and methods is the complex for the generation of communication systems software [**kompleks** generatsii Programmnogo Obespecheniya Sistem Obshcheniya s arKhivami programm i bazami dannykh (POSOKh)] [27], being developed by the USSR Academy of Sciences Computer Center. The plan for the creation of the POSOKh complex is a natural development of the ideas of the MIVOS plan [12].

In essence, the POSOKh complex is a system for computer-aided planning of a natural-language interface. The following principles were made the basis of the complex:

--active use of systems of knowledge representation as special meta-algorithmic languages;
--realization of the complex as a developed cross-system;
--application of the technology of syntactically controlled translation on the level of realization of the complex.

This assures obtaining during the planning an instrumental system for the creation of special software effective from the point of view of the realization by means of communication and mobile during change of the electronic computer.

The principal components of the POSOKh complex, the general structure of which is shown on Figure 10 (not reproduced) are systems of knowledge representation (linguistic, problem, etc) assured on the program level by sets of corresponding translators, optimal with respect to various criteria (storage and translation time, the effectiveness of object programs, etc); the development of the system for adjustmen of programs for linguistic and problem information which permit work in meaningful terms; systems for the testing and investigation of developed software. The enumerated components are maintained on the information level by a rather powerful data bank with a corresponding data base control system which, in turn, is closely connected with subroutines for the accumulation, change, accompaniment and documentation of the created software.

Each system of data representation in a POSOKH system is realized on one of three schemes (interpretation, conversion and compilation). In that case, for interpreters, obviously, very great simplicity of realization and change of languages of data representation is characteristic, but a minimum functioning rate. During compilation the rate is determined in the basic level of the compiler output language and the depth of conducted optimization, but all input languages changes are greatly complicated. During conversion, which occupies an intermediate position, the rate will depend on the quality of realization of the converter output language and the simplicity of changes of the input language is determined by the degree of the changes. Thus in the POSOKh system various requirements for the realization of data representation systems are satisfied.

It also is important that in such a scheme the interpretation libraries or units for generation of the created translators are readily varied. This, in turn, permits separating the instrumental and working computers (now the BESM-6 is both an instrumental and a working computer, but the SM-4 mini-computer and a special processor of symbolic transformations, realizing an equipment language of a high level, will be used as a working machine in the very near future).

Realized completely, the POSOKh complex will be able to substantially increase the effectiveness of development of software of communication systems, and in the long range create individually oriented systems for communication with the computers of final users.

At the present time, besides a special monitor for the control of various working regimes of the complex, in the POSOKh a system has been realized for the representation of linguistic knowledge about communication languages on the basis of ATNL expansion [24] and corresponding systems for adjustment, testing and investigation of created linguistic processors. A system of problem information presentation is being developed on the basis of the conception of frames [28].

As analysis shows, natural-language systems are emerging from the stage of experimental developments and at the present time are starting to be used in practice. Of course, this does not mean that investigations in the area of the theory of communication languages and methods of designing natural-language systems have entered the concluding stage, and only technical problems remain. Actually, there still is no general and generally accepted theory of natural languages, and methods of natural-language realization are just being created. However, work in that area is being done on a broad front all over the world and evidently in the near future we will see the active introduction of natural-language systems in practically all spheres of communication with the electronic computers of final users.

[42A-2174]

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CSO: 1863

UDC 51:62

# RECOGNITION OF ECG STRUCTURAL ELEMENTS IN AN AUTOMATED COMPLEX

Kiev KIBERNETIKA I VYCHISLITEL'NAYA TEKHNIKA in Russian No 45, 1979 pp 76-80

[Article by E. M. Maslova and T. A. Volkhonskaya, of the Institute of Cybernetics, Ukrainian SSR Academy of Sciences, Kiev]

[Text] An important component of algorithms for medical diagnosis is the separation from ECG curves of structural elements already well known not just to physicians, the QRS complex and P and T waves. Such a procedure is fairly complex, not only because of the great variety of forms of the ECG but also because of the considerable noise of the signal. Incorrect description of the curves leads to errors in setting up the diagnosis, and the percentage of such errors in existing automated systems is fairly large [2]. Therefore the requirement for quality of the electrocardiosignals (ECS) subject to automated processing is considerably higher than that presented by a physician analyzing an ECG.

There is no agreement on the approach to the task of recognizing ECG structural elements in automated systems. All the approaches arose as a result of thorough investigation of the task and have an empirical character. Automated ECG analysis always simulates to some degree the procedure of ordinary ECG analysis by a physician. As a rule, identification of ECG structural elements during multichannel synchronous registration starts with **construction** of a certain scalar function of a vector argument

$$F(t) = \Phi(U(t)), \text{ where } U(t) = (U_1(t), U_2(t), \ldots, U_n(t));$$

N is the number of leads.

Pipberger et al [7] determine for those purposes the first derivative from the spatial value of the cardiac fector $F(t) = (\dot{U}_1(t)^2 + \dot{U}_2(t)^2 + \dot{U}_3(t)^2)^{\frac{1}{2}}$ and show that it is close to zero on the section of the isoelectric line and deviates considerably from zero on sections of the QRS complex and the P and T waves, and all the more so the greater the rate of signal change. On the basis of the same function the authors determine the limits of ECG structural elements. Logical analysis, as a rule, starts with determination of the base point in relation to which all the future operations are performed [3,5,6,9]. In the analysis of single-channel recordings the first ECS derivative often is used [6,9] and the steepness of the slope of that curve is analyzed. The lack of protection against pulsed noises and the presence of false signals often leads to errors, as the base point is determined from the condition of the minimum (maximum) of the first derivative--a precise estimate which does not take into consideration the behavior of the curve at adjacent points. Some authors [2] prefer visual separation of sections of the QRS complex and P and T waves on the ECG curve, and their subsequent coding. After ECS codes have been fed into a digital computer the curve is analyzed and a system of medical parameters is separated--semi-automated ECG analysis. A special place is occupied by the structural or linguistic approach which has appeared recently [1]. It is based on the assumption that objects of any class, for example a QRS complex, have an internal organization of elements or structure characteristic of all representatives of the given class.

We will present below an algorithm for automated recognition of ECS structural elements in which we strove, using accumulated experience in work with ECS, to take into account both the good aspects and the shortcomings of existing algorithms [2,3, 5-9]. The algorithm must have high noise immunity and flexibility (tuning to a coherent ECG). The program realizing it must be optimal with respect to ECG processing time and to the volume of the engaged memory. The algorithm has an empirical character and can be divided provisionally into three parts:

a) tuning on a single channel through an analog-digital converter--the signal, as a rule, of the first orthogonal lead is fed to a computer in real time. The R wave is identified by estimation, which will be discussed below, and $\overline{RR}$ is calculated, and also the right values of the lengths of the phases of cardiac activity of interest to us, according to Karpman [4];

b) identification of the ECG section corresponding to the QRS complex on three synchronously registered leads, and filtration;

c) determination of the initial and final points of ECG structural elements of interest to us for each lead separately.

Before the start of work of programs providing points b and c, 3 x N readings (the initial array) with respect to N for each realization were recorded in the machine storage. The number N is determined by the discretization frequency and the registration time. On the three synchronously registered signals the scalar function $F(t) = \sum_{i=1}^{3} X_i(t)$ is constructed, where $F_i$ is the reading of the formed auxiliary curve ($i = 1, 2, \ldots$). With sliding by one step in sections corresponding to the proper length of the QRS complex ($\ell_{QRS}$) the partial sums are calculated:

$$A_j = \sum_{i=j+1}^{j+l_{QRS}} |F_{i+1} - F_i|, \qquad j = \overline{0, 1, \ldots, N - l_{QRS}}. \qquad (1)$$

Let us determine $\max_j A_j$, where j gives a maximum to the partial sum and is the assumed start of the QRS complex. If it is taken into consideration that the P wave is sought through the QRS complex within the interval [0.4 of the length of $(\overline{RR} - \ell_{QRS})$] and the T wave after the QRS complex within the interval [0.6 of the length of $(\overline{RR} - \ell_{QRS})$], we select the fragment of the initial array we need. For further analysis we need a smoothed signal free of network noise. Attempts to eliminate noise by analog filtration usually do not provide the required smoothing even when total filters have been created [5]. Signals often are smoothed `y digital methods, as they are readily accomplished and better monitored. A very simple filtration method is weighted summation [5]. In [6] it is pointed out that better smoothing can be obtained if parabolic approximation has been used.

A separate program to which we turn with an already separated fragment of realization smooths the ECG, using the method of least squares and approximating the discretized data with a second-order polynomial. The number of points n on which the second-order polynomial is constructed and the sliding step $n_2$ ($n_1 > n_2$) depend on the frequency of the analog-digital conversion and the natural frequency of the signal. The values at $n_2$ central points of the smoothing interval are taken as the reading values.

The program responsible for determination of the initial and final points of the QRS complex and the P and T waves works with a filtered fragment of separate lead realization. As the true start of stomach depolarization we take min $\{N\ QRS_i\}$, where i is the lead number; N QRS is the reading number and $\max_i \{K^i QRS_i\}$ is the end. The procedure is similar for the P and T waves.

Pipberger et al [7] point out that when three synchronously registered signals are used for analysis the total length of some ECG structural elements proves to be greater than when each lead is used separately. We think this can be caused both by asynchronism of registration of the three orthogonal leads and by the use of the first derivative as a result of the property of asymmetry, which introduces phase shift in relation to the starting discretized data. Therefore we also analyzed each lead separately.

In our algorithm the isoline is used indirectly to determine the initial and final points of the QRS complex and the P and T waves. The necessary information is extracted mainly from correlations between the given and adjacent points. However, the isoline is needed to simplify the logic of analysis of the curve, and also to lower the threshold of the "technologically satisfactory" lead. The least-squares method is used to determine the coefficients in the isoline equation. The isoline section is determined from the condition of the minimum estimate (1), where the auxiliary scalar function is replaced by readings of the realization fragment.

The algorithm for recognition of the QRS complex and the P and T waves consists of the following operations.

1. Determine the isoline equation and eliminate noise arising on account of floating of the isoline.

2. Determine the maximum noise level $\delta$:

$$\max_i \{|x(i+1)-x(i)|\}, \text{ where } i=\overline{NXIS+5, \dots, NXIS+15},$$

3. In the interval corresponding to the proper length of the QRS complex (NT, NT + $l_{QRS}$):

   a) mirror reflect the curve relating to the isoline

$$X(i)=|X(i)|, \text{ where } i=\overline{NT, \dots, NT+l_{QRS}};$$

b) form an array of readings, including points at which the first ECS derivative changes its sign from plus to minus:

$$KK(i), \text{ where } i = \overline{1, 2, \ldots, l_{QRS}};$$

c) find the reading maximum in amplitude:

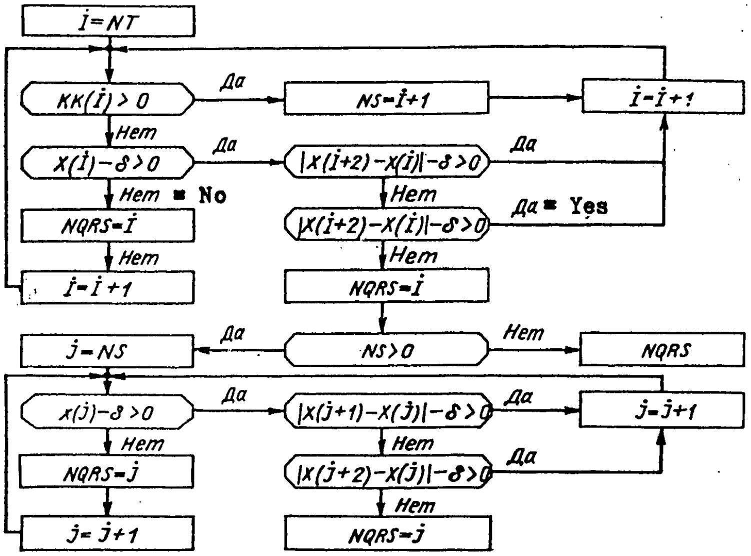
$$\max\{X(i)\}', \quad NR = i.$$

4. For differently directed analysis of the curve from the base point NR make a reversion of the series of readings of the left section (NT, NR) of the interval of proper length of the complex

$$QRS\,[NT, NT + l_{QRS}]:$$

$$X(NT) = X(NR - 1); \quad X(NT + 1) = X(NR - 2), \text{ etc.}$$

5. Determine the initial point of the QRS complex on the left section (NT, NR). The structural diagram of the algorithm for determination if the initial and final points of the QRS complex are given on the diagram.



Structural diagram of algorithm for determination of the initial and final points of the QRS complex.

6. Determine the final point of the complex on the right section (NR, NY + $l_{QRS}$) (see figure, where I = NR + 1).

7. As the level of reading of the amplitude on the QRS complex section take the reading preceding the initial point of the complex. This also applies to P and T waves.

8. To find the P and T waves search for the maxima within the limits of the given fixed intervals of time before the initial and after the final point of the QRS complex.

9. Proceed to points 4-7. The block diagram for determination of the initial and final points of P and T waves is a simplified variant of the program cited in point 5, with the addition of some additional tests.

In checking the algorithm on monitoring samples of unrecognized and incorrectly recognized QRS complexes, P and T waves did not occur.

The program of identification of the complexes was realized in the FORTRAN-II language and a mnemonic code and is used in an automated complex based on an M-6000 electronic computer for automated processing of an orthogonal ECG. The main memory volume occupied by the program is 3.5 kbytes. The time taken to identify ECG structural elements in a single lead is approximately 3 seconds.

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# COMPLEX STATISTICAL EVALUATION OF DETECTION OF THE QRS COMPLEX

Kiev KIBERNETIKA I VYCHISLITEL'NAYA TEKHNIKA in Russian No 45, 1979 pp 54-57

[Article by S. M. Makeyev, Institute of Cybernetics, Ukrainian SSR Academy of Sciences, Kiev, and A. G. Taranenko, Kiev Institute of Civil Aviation Engineers]

[Text] One of the tasks being solved in the creation of automated computer systems for ECG processing is the development of algorithms for ECG parametrization -- determination of the quantitative characteristics of ECS (electrocardiosignal) structural units.

A common feature of algorithms for ECG parametrization is that they work on arrays representing readings of instantaneous ECS values fed to a computer through an analog-digital converter with a given discretization frequency.

The application of arrays of readings of a fictitious curve obtained by mathematical conversions of starting ECS readings synchronously registered in several leads has been pointed out in various works [4].

Almost all algorithms for ECG parametrization are heuristic and based on the use of medical information on the topology of ECG curves for different leads and on the temporary position and orientation of its structural elements.

In an overwhelming majority of algorithms the recognition of the parameters of medical description starts with determination of a "reference" point in the region of the array of readings corresponding to the QRS complex [1-7]. It is noted in those works that two criteria are used most often to distinguish the "reference" point.

The first criterion is that the value of the derivative at the given point is within pre-set limits [2,3,6,7].

In that case some authors use the maximum positive value of the first derivative (the leading front of the R wave) [3]; others use the point for which the first derivative has a maximum negative value (the proposed rear front of the R wave) [2]; still others use both those criteria [1].

The second criterion is the retrieval of readings with maximum amplitude of the ECS, which are considered to belong to the R wave [1,4,5].

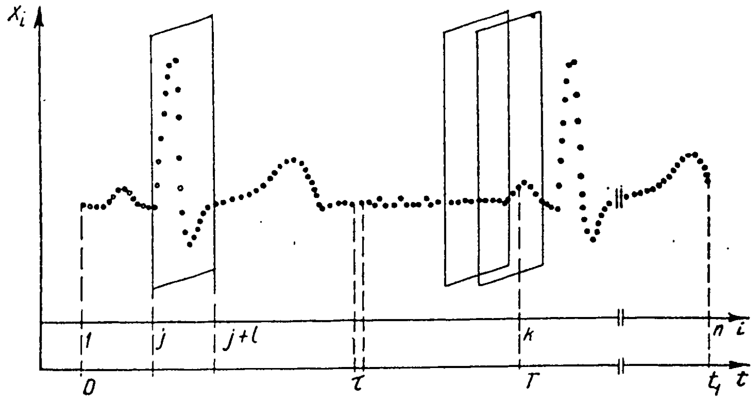
We have established that the use of algorithms realizing the given principles for determination of the "reference" point proves to be ineffective in cases where the task of parametrization of ECG's damaged by the action of artifacts of various kinds and noises with a pulsed character. There is a possibility of erroneous situations in which a point corresponding to a blip of pulsed noise is used as the "reference" point. It is reasonable to assume that the authors who use those principles to determine the approximate position of the region of readings corresponding to the QRS complex also use additional criteria [1]. In addition, the image of the ECG curve in the region of the QRS complex is very variable as a function of the type of lead in which the given curve is registered, and other factors. It is obvious that, to increase the noise immunity and effectiveness of algorithms for ECG paramterization, it is necessary to decide regarding the detection of the QRS complex according to an estimate which depends on the aggregate of values of all the readings belonging to the QRS complex.

In the present article a method is proposed for determining the region of readings of the QRS complex based on the use of such an estimate.

Method of detecting the QRS complex. In the general case an ECG represents an array of ECS readings:

$$X = x_1, x_2, \ldots, x_k, \ldots, x_n.$$

ECG readings are taken with the discretization interval $\tau$ (figure). The length of recording of an ECG is $t_1 = \tau n$.



Array of discrete electrocardiosignal readings. Shown are three positions of the "movable" window with a length of $l$ readings.

The size of the interval T is determined from k readings on the basis of the condition that at least one QRS complex occur in it (the interval length is assumed to be 1.2 s). Then:

$$k = \frac{1,2}{\tau}.$$

The "movable window" is determined with a length of $\ell$ readings, corresponding to the mean length of a QRS complex, assumed to be 0.15 s:

$$l = \frac{0{,}15}{\tau}.$$

During successive shifting of the "movable window" within the limits of the interval T for each of its positions a calculation is made of the estimate

$$V_i = \sum_{i}^{i+l} |x_{i+1} - x_i|; \text{ where } i = 1, 2, \ldots, k - l.$$

In the j-th position of the "movable window," determined by the values of the initial and final readings j and $j+\ell$ respectively and embracing readings belonging to the QRS complex, the value of the estimate $V_i$ will be maximal.

The values of j and $j + \ell$ are stored. Later a new interval T is given, one determined by the initial $j + \ell$ and final $j + \ell + k$ readings, and the entire procedure for detection of the QRS complex is repeated.

At known values of the initial and final readings of regions embracing the QRS complex, further determination of the parameters of the P, Q, R, S and T waves presents no difficulties.

The R wave is identified as maximal in relation to the isoline of readings in the region of the given QRS complex.

The isoline is calculated as the mathematical expectation of the array of ECG readings in a section of the given size, being:

a) for P and R waves in the region of the middle of the section corresponding to the distance between the given and preceding R waves;

b) for the T wave between the given and subsequent R waves. The value of the isoline is

$$I = \frac{\sum_{i=1}^{k} x_i}{m},$$

where $x_i$ is the discrete values of the ECG array; m is the size of the section for calculation of the isoline value.

The search for P, T and Q, S wave peaks is accomplished by finding the maxima and minima on the left and right respectively of the given R wave, produced on sections of the given size.

The search for PR and RT intervals after the P, R and T waves have been found presents no difficulties. If $n_P$, $n_R$ and $n_T$ are readings corresponding to the peaks of the P, R and T waves, the PR and RT intervals are

$$T_{PR} = (n_R - n_P)\tau,$$
$$T_{RT} = (n_T - n_R)\tau,$$

where $\tau$ is the discretization interval.

The lengths of the P, R and T waves are determined from the points of their intersection with the isolines, that is, if $k_1$ is a reading corresponding to the first point, lying below the intersection of the wave with the isoline to the left of its peak, and $\ell_1$ -- to the right, then the wave length is

$$D = (l_1 - k_1)\tau.$$

After determination of the informational parameters of the QRS complex, namely: the amplitudes of the P, Q, R, S and T waves in relation to the isoline, the PR and RT intervals, the lengths of the P, R and T waves, and the formation in the computer store of arrays of values of those parameters is accomplished by the statistical processing of those arrays, a result of which is determination of the values of the mathematical expectations and dispersions of those parameters.

The given method was realized in developing an algorithm for the classification of ECG's for the M-6000 computer.

Experiment and results. We experimentally checked the work of a program realizing the proposed algorithm for the recognition of the QRS complex on the basis of an estimate dependent on the totality of its readings in order to determine the quantitative characteristics of reliability of recognition of the QRS complex and the R wave.

Results of experiment to determine the quantitative values of probabilities of false alarm and R wave passage

| | A Количество регистрируемых интервалов $R - R$ | B Число пропущенных зубцов $R$ | C Число «ложных» зубцов $R$ | D Вероятность пропуска зубца $R$, % | E Вероятность «ложной тревоги», % |
|---|---|---|---|---|---|
| 1 До нагрузки | 23 040 | 31 | 1 | 0,134 | 0,0043 |
| 2 После нагрузки | 23 040 | 34 | 3 | 0,147 | 0,013 |
| 3 15 мин после нагрузки | 23 040 | 32 | 1 | 0,139 | 0,0043 |
| 4 Итого | 69 120 | 97 | 5 | 0,14 | 0,0072 |

Примечание. В графе «Итого» в предпоследнем и последнем столбцах приведены средние значения данных величин

Key: A -- Number of registered R-R intervals
B -- Number of passed R waves
C -- Number of false alarms
D -- Probability of R wave passage, %
E -- Probability of false alarm, %

1 -- Before loading
2 -- After loading
3 -- 10 minutes after loading
4 -- Total

Note: The mean values are given in the next-to-last and last columns of the "Total" line.

The test group consisted of 16 healthy male persons aged 20 to 26 years. For each tested person 480 R-R intervals were registered in each of three standard leads. The ECG was registered three times: before and after dosed load and after 15 minutes. A series-produced portable "Salyut" electrocardiograph was used for ECG registration and commutation of the leads; no special measures were applied to eliminate inductions of 50 Hz frequency. The results of the experiments are presented in the table.

Conclusion. As follows from the results of the experimental check, the probabilities of R wave passage and of false alarm expressed in identification as the R wave of a different kind of artifact amount to 0.14 and 0.0072 percent respectively, which gives us a basis for recommending the described method for use in the construction of automated systems for the clinical processing of ECG.

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## APPLICATIONS

### SKAT ROBOT SUBMARINE

Moscow SPUTNIK in English Dec 80 pp 138-139

[Text] "Manta-1500" is the name reserchers at the Institute of Oceanology of the USSR Academy of Sciences gave to a new submersible craft which can go down as deep as 1,500 meters to flashback information about the structure of the seabed.

In a sky-blue cove of the Black Sea a ship's winch takes up "Manta", a small craft resembling two steel cigars (Fig 1) and gently lowers her into the water. The feeder cable rope trailing behind is responsible for the power supply to all the mechanisms and the control and reception of information from television cameras.

Operators watch the remote-controlled robot with the aid of a television scanner and floodlights.

"Manta" has "legs" looking like water skis to move on the seabed up and down, back and forth and to turn around within a range of 30 meters from the mother ship.

"The craft is as easy to handle as if I were inside her," said the operator Victor Voikov, "and through a monitoring screen you can see much better than through a porthole.

"Manta" also has a mechanical arm to scoop up samples from the seabed and put them in special containers.

Researchers are currently busy working on "Skat," a second generation robot (Fig 2). This midget submarine will not be so tied to her mother ship. The battery-powered craft will be able to submerge to take samples from the seabed, to photographs or to look for sunken objects.

The Institute of Oceanology is also making another "Manta", and this one will be capable of probing the craters of underwater volcanoes.

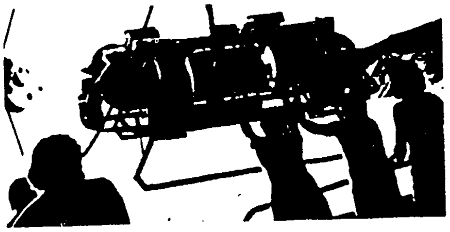

Fig. 1. Manta.

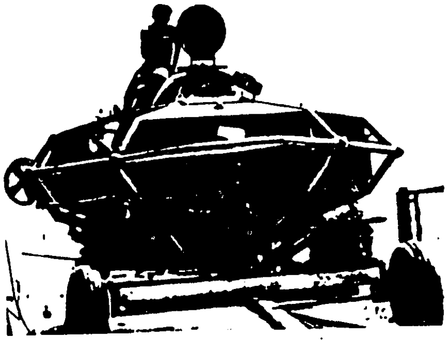

Fig. 2. Skat.

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# COMPUTER-AIDED DESIGN OF DATA DISPLAY SYSTEMS FOR AUTOMATED CONTROL IN THE CHEMICAL INDUSTRY

Moscow IZMERENIYA, KONTROL', AVTOMATIZATSIYA in Russian No 5-6, 1980, pp 56-62

[Article by I. M. Bernshteyn, engineer]

[Text] The wide application of ASUTP (automated systems for the control of technological processes) to various sectors of industry has brought about a need to improve the process of system design. This multifaceted problem is solved by various methods, one of which is the standardization and automation of various stages in ASU development [1]. For example, in reference [2] it is asserted that in planning about 80 percent of the time is expended on the solution of routine tasks which can and must be automated. The number of works on the automation of the planning of control systems is constantly increasing, but the methodical principles have not yet been formed in that area, although there is no doubt that they are urgently needed.

A rather labor-intensive stage in the creation of ASUTP--the planning of data display systems--up to now has been a completely heuristic procedure. At the same time, data display systems, which determine the connection of operating personnel with the object of monitoring and control in real time, are an inseparable part of the control system of any level of complexity, regardless of the algorithmic and technical base of the ASUTP. Instructional or methodical materials on planned meaningful synthesis of data display systems and ASUTP are lacking.

The present article presents a brief survey of the principal sources of scientific methodical questions about data display system analysis and synthesis and an algorithm for the automated planning of such systems is described.

In general form the series of stages in data display system planning can be represented as an iteration process (Figure 1). In each stage of planning, the starting positions (feedback from the preceding state) are corrected and the requirements for the following stage are advanced. Using the general scheme presented as Figure 1, we will attempt to examine the basic work in the area of data display system synthesis for ASUTP.

## Scientific principles of data display system synthesis

An approach to data display system synthesis from positions of psychological engineering analysis of the interaction of the operator with the object of control was

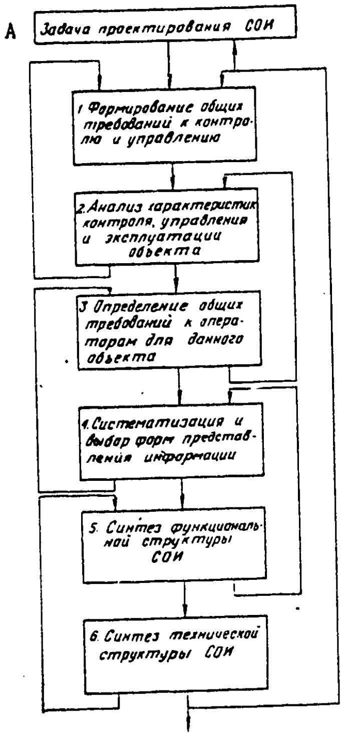

Figure 1. Series of steps in data display system planning

A -- Task of data display system planning

1 -- Formation of general requirements for monitoring and control

2 -- Analysis of characteristics of monitoring, control and operation of an object

3 -- Determination of general requirements for operators of a given object

4 -- Systematization and selection of forms of data representation

5 -- Synthesis of the data display system functional structure

6 -- Synthesis of the data display system technical structure

described in reference [4]. The idea of the approach consists in revealing a conceptual model of the activity of operators, which is subjective in particular cases, but for a group of operators of a single production it has general objective characteristics. Taken as the methodical basis of system synthesis is the construction of a number of mutually stipulated graphic models of operator activity, sequentially revealing the meaning of the operations of control--from an algorithmic (formal) to a cause-and-effect model of the activity. The latter is represented by a monitoring and control graph which is constructed on the basis of analysis of the sequence of events before recognition of imporatnt events in the object known a priori. The graph depicts a series of operations conducted by levels of increase of communality and correspondingly increase of the detailedness of analysis of events. Review of all the important events through the monitoring and control graph leads in the final account to a particular volume of functions of display of ingoramtion about a given event. Review of a number of important events in an object leads further to sufficient data display system volume, and in that case the synthesis is concluded. An advantage of the given approach is multifaceted analysis of psychological engineering procedures for optimal "linkage" of the operator and object. The wide application of such an approach is made difficult by the scale of the work, the absolute necessity of experimental investigation or simulation of each specific object, which require considerable expenditures.

In [4] is a description of a training test stand for investigation of the work of operators in conditions of monitoring and control. The laws of operator-object interaction formulated by the author are implemented on that stand for the formation of data display systems of various objects of control.

Stages II, III and IV have been investigated in detail (see Figure 1) and the conclusive stages of planning in less detail; therefore the practical recommendations for data display system planning are not carried out, but this is not the purpose of the work. On the whole for the given work the following can be concluded:

--on the basis of the proposed methods it is advisable to synthesize data display systems for relatively complex and costly objects, as the proposed procedure of synthesis, even if effective, is very labor-intensive;

--data display system planners working according to the proposed procedure must have a broad mental outlook and be highly qualified;

--the principal object of synthesis is the graphic "image" of the object (mnemonic diagram), and other forms of image representation were considered in the data display system in a smaller volume.

In reference [5] the task of data display system synthesis is posed and examples are presented of its solution on the basis of an approach called the "linguistic system." The essence of the approach consists in the wide embrace of problems of operator-computer linkage, with inclusion in data display system synthesis of program tasks, on the one hand, and methods of analyzing operator decision making, on the other. The basis of the proposed data display system technical structure is the computer video terminals, which also determine the final result--construction of the dynamic structure of the representation system, efficiently controlled by programming, depending on the state of the object and the questions of the operator.

A structure of data display system stages, worked out in detail, in presented, one based on successive transition from qualitative-survey not completely formalized (and not always formalizable) stages of description of operator actions for functionally-oriented data display system synthesis. Therefore it is proposed to make the primary analysis of data display system requirements by hierarchic questionnaire. The questionnaire results are used in the stage of programmed synthesis of data display systems. An original language has been developed for the operator's communication with the computer in an interactive mode, which additionally includes in the functions the data display system and representation of the operator-object interaction. The author substantiates the applicability of the obtained results for a system of professional training of operators on special stands, together with practical use in specific ASU.

The first three stages of data display system planning were examined in great detail in [5]. The results presented in that book can be efficiently used by a large scientific research institute, but their application in "series" planning of data display systems is hindered by a shortage of specialists.

Reference [6] is devoted to the construction of data display systems for experimental installations, but most of the problems posed in it are also urgent for ASUTP information subsystems. The authors examine the characteristics of the information flows between the object and the operator on the basis of methods of information theory. Concepts of algorithmic complexity and indicators of informativeness are being introduced to obtain the possibility of comparing variants of the technical realization of data display systems. The technical means of constructing representation systems have been examined in fairly great detail and attempts have been made to classify them. The evolution of technical structures of data display systems is examined and their comparative characteristics are presented. The idea of comparison is based on controllability of the information flow: for panel systems the flow is uncontrollable, for systems of centralized monitoring the information flow is controlled by the operator, and for computer-based information systems, automatically. In the practical realization of data display systems it is recommended that a graph of joint states of the data display system and the operator be constructed. That graph is determined by specific planned states of the object, which methodically is analogous to graphs of monitoring and control described in [4], and just as effectively but labor-intensively for application in the case of a new effect or the absence of experimental data.

Reference [7] is devoted to questions of the ergonomic design of data display systems. Discussed in it are psychophysiological problems of operator activity during interaction with information models of objects in solving control problems. The presented positions are reinforced by extensive experimental materials. As industrial objects on which investigations have been conducted or the results of work have been introduced, in [7] objects with a continuous technology (energy units, ammonia production) and objects of a discrete type (urban transport) are examined, and that makes it possible to determine the general laws of the actions of operators in working conditions.

It is interesting to note that all the conclusions in this work are based on study of the interaction of operators with mnemonic circuits. The latter thus are taken as the main source of operative information. The author shows that the primary element of a data display systems in the study of complex events in the logical structural image of the object. In the chapter devoted to artistic design, preliminary setting-up of a model of the data display system of complex objects is recommended, the construction of data display systems is analyzed for various objects and a general approach to the meaningful design of data display systems is proposed. However, reference [7] does not contain practical materials on data display system synthesis, and this once more confirms the heuristic character of traditional practice of data display system planning.

In references [4-7] the scientific principles of data display system synthesis are presented. The published results can logically be arranged successively, assuring in that manner the methodical base of a series of scientific-research and design work, in the final account leading to the creation of a contemporary data display system. However, in the everyday mass planning of monitoring systems such a working procedure is usually impossible due to limitedness of the planning periods, inadequacy of resources allocated for them and absence of the necessary scientific personnel. Therefore narrower practical questions of "current" data display system planning will be discussed below [8].

## The task of data display system planning

Generally, data display system synthesis must be connected with the development of monitoring and control algorithms [4-7]. However, in a considerable portion of the

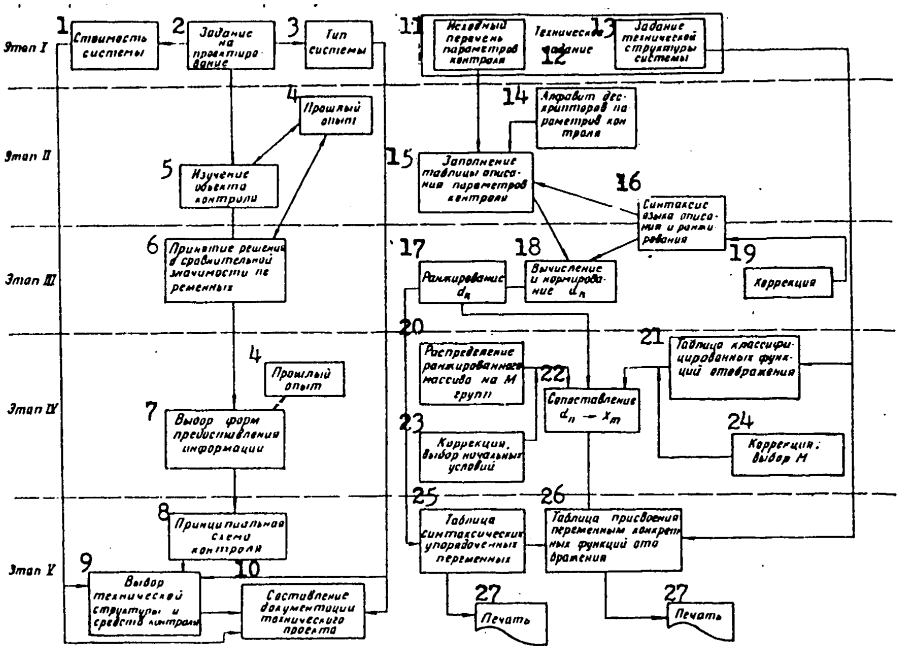

Figure 2. Block diagram of stages in data display system planning
a -- heuristic procedure b -- planning algorithm

1 -- Cost of system
2 -- Assignment for planning
3 -- Type of system
4 -- Past experience
5 -- Study of object of control
6 -- Decision making on comparative importance of variables
7 -- Selection of forms of information presentation
8 -- Control circuit diagram
9 -- Selection of technical structure and means of control
10 -- Compilation of machine plan documentation
11 -- Starting list of control paremeters
12 -- Technical task
13 -- Assignment of technical structure of system
14 -- Alphabet of descriptors of control parameters
15 -- Completion of table of control parameters description
16 -- Syntax of language of description and ranking
17 -- Ranking $d_n$
18 -- Calculation and normalizing $d_n$
19 -- Correction
20 -- Distribution of ranking of array into M groups
21 -- Table of classified transformation functions
22 -- Comparison of $d_n - x_m$
23 -- Correction. Selection of initial conditions
24 -- Correction. Selection of M
25 -- Table of syntactic ordered variables
26 -- Table of attribution of variable specific transformation functions
27 -- Printer

cases of practical ASU planning, formalizations of control are being developed (or are known) on the level of automatic control systems, and control of subsequent hierarchic levelsis proposed as non-formalized activity of personnel by means of realized data display systems and a subsystem of direct effect on an object. We will proceed from this objective situation and will henceforth consider that the data display system is being planned with unknown control algorithms.

Presented on Figure 2 is a heuristic (traditional) sequence of data display system synthesis by the planning method. Starting data for data display system planning is contained is contained in the technical task issued by the production engineers who develop the object of control. In the task a list is presented of the controllable variables and, at times, the form of information representation. The experience of production engineers and laws of the process are not discussed in the task; but are present in concentrated form as requirements for monitoring. The planners of automation accomplish the tasks in the form of a functional scheme of control. In that case the planners cannot revise the task because of their inadequate knowledge of the subject, but the form of information representation is reflected by the planners in the final account.

A poorly coordinated process of synthesis is obtained: the production engineers know the process and tasks of control of a specific object but are less competent in questions of automation; data display system planners are not sufficiently competent in the technology and tasks of control of an object but know the technology and methods of automation; knowledge of automation methods assure the possibility of planning "by analogy," on the basis of accumulated experience, but there are no formal procedures or simple criteria for national data display system construction. It is natural that with the described heuristic planning procedure the "quality" of the data display system worsens, and this leads to economic losses at the object.

Therefore the following task is urgent: that of formalizing the exchange of knowledge between production engineers and data display system planners and the stagewise synthesis of a data display system functional program. In the case of positive solution of that problem the possibilities of automation of data display system planning are opened up. Automation permits obtaining "mean" planning solutions substantially more rapidly than with the ordinary procedure. That alone, without considering possible improvement of quality of the plan, promises a saving from the automation of planning.

The starting positions and limitations for solution of the posed problem are reduced to the following:

--the task is solved with regard to the data display system synthesis for continuous chemical engineering processes;

--the construction of data display systems for ASUTP of a lower level of control is examined;

--sources of signals regarding the state of the object are assumed to be given in advance;

--the selection of specific hardware for realization of a data display system functional diagram is not included in the planning procedure being developed;

--the component and ergonomic characteristics of data display systems are disregarded.

The following hypothesis was set as the basis of formalization of the stage of "intersection" of the knowledge of production engineers and planners. The operator of a technological process and the production engineer-developer of a task estimate specific variables of a process not formally, according to certain metrics, but in accordance with an aggregate of meaningful, qualitative signs, which we will call the "technological significance." That characteristic is selective and cannot be strictly formalized, but the different variables and objects can be compared with one another and ranked according to the given characteristic, for example, by expert estimates.

The monitoring system planner forms an analogous characteristic for himself and in accordance with it determines a group of forms of information representation. We will call that group the "representation power." The representation power can be described, for example, by the number of types of industrial instruments used for monitoring and representation of each of the compared variables.

Therefore to solve the set task of planning formalization it is necessary to develop:
--methods allowed to planning organizations for ranking automatically monitored variables according to magnitude;
--classification of industrial forms of information representation, from which it is possible to simply distinguish various groups of forms of representation, unequivocally ranked by representation power.

On the basis of such developments it is possible in planning also to compile ranked "technological importance-representation power" ratios, at least for groups of variables of a specific technological process of close importance. To solve that task an algorithm has been developed, one consisting of successive procedures for obtaining formalized starting data from the production engineers and data display system planners in a regime of planner-computer interaction.

## Block diagram of the data display system planning algorithm

Presented as Figure 2b is a block diagram of the data display system algorithm. As in the heuristic procedure (see Figure 2a), in this algorithm five main stages of planning can be distinguished.

Stage I--compilation of starting data for the plan--is practically identical for both planning procedures.

Stage II--study of the object of monitoring--with the traditional method is done "by analogy," and in the proposed algorithm by obtaining from the production engineers information about the variables of the processor in descriptor form close to a natural language. The object of development is an alphabet of descriptors (signs) and special forms to be filled in by an experienced production engineer.

In Stage III the process variables are ranked in importance. A logical scheme has been developed for the programmed ranking of variables on the basis of descriptor description with use of the syntax of the ranking language (on Figure 2b, $d_n$ is the symbol of the descriptor of the n-th variable). The information logical language for description of the process variables and their ranking by importance is discussed in detail in the following section.

Stage IV corresponds to the final meaningful procedure of distribution of elements of the initial set of forms of information representation on industrial means for process variables. In the developed algorithm a table was compiled for that purpose, one classifying the representation forms; a correlation is given, according to which the total array of ranked variables is divided into groups of variables with an identical combination of forms of representation $X_m$, where m is the ordinal number of the complex of forms of representation; also compiled according to program are the ratios $d_n$ - $X_m$. The content of stage IV is described below.

Stage V--the technical execution of documentation on the functional diagram of monitoring in the proposed algorithm--includes compilation of tables of the provision of each variable with specific forms of representation and tables with decipherment of technological importance. The latter are necessary for monitoring the results of work of the program by an expert production engineer, at times the tables of importance of the variables are used to correct the entire array of starting variables of the given process. With that the automated planning process is concluded. The concluding procedures--selection of specific hardware and compilation of documentation of the technical plan--are accomplished by a traditional method.

## Information logical language of description and ranking of technological process variables

General positions. The expert ranking [9,10] of some objects, particularly of technological process variables, is a laborious procedure that requires considerable time. It is not effective enough for the evaluation of small-scale plans of new objects, and also in the absence of the necessary of expert specialists. The heuristic procedure of decision making by experts has not been discussed in the literature.

We will attempt to formulate an information logical language for expert ranking of the variables of a technological process. The purpose of the given information logical language is to give a description of the flow of signals from a specific object understandable to a wide range of specialists of various branches of knowledge and suitable for programming on a computer for the purpose of further use in logical relations of comparison and ranking.

The task of calculating subjective values (significances) has no generally accepted procedure for solution. One of the successful attempts to solve it has been described in [11], where the obtaining of a quantitative estimation of significance is based on a system of initial logical conditions and the following significant procedures: the scale of naming (methodically explains the difference of separate subjective values), the scale of order (permits successively arranging values so that they satisfy the inequalities "more or less"), the scale of intervals (permits numerically determining the difference between values), etc.

The proposed formalization of the procedure for the description and ranking of the variables of a technical process in the initial stage agrees with that approach.

The information logical language described below at times uses a methodology of construction of an information retrieval language in part of the formulation of expressions, but in the logical part differs from the information retrieval language in the method of application of the obtained expressions.

The basis of the language is an alphabet of simple concepts--or descriptors, from which a description (determination) can be made of any variable for a class of technological processes. The general requirement for the alphabet is distinguishability of adopted decisions in a general technical sense. In accordance with the principles of thesaurus construction in data processing systems [12] the concepts can be united by sex, species, etc. The total information logical language alphabet consists of three genera (groups), separated inside into species (concepts). The determination--the component descriptor--consists of three heterogeneous concepts, of one type of each sort (group).

The condition of compilation of definitions is the rule of information logical language syntax. On the basis of logical relations the conditions of comparison and ranking are given, and of course of the variables themselves--these are the following rules of information logical language syntax.

An alphabet for formal description of variables. To formalize the ranking procedure, even if narrowly, it is natural to assume that the expert production engineers have a certain meta-language of an abstract level. The elements (words) of that language must be applicable for the description and comparison of objects (concepts) of different nature. The compilation of an alphabet for universal description of instrumentally obtained variables of technological processes is based on these considerations.

Descriptors have been used which have a very broad semantic content, which permits using them to describe physically different variables of technological processes. For example, the temperature or pressure in any chemical engineering process can be represented by such a component description as "quality of the main process."

The number of primary descriptors must not be too large, as otherwise difficulties connected with remembering and ranking them arise. When the number of descriptors is too small the possibilities of determining heterogeneous elements are reduced. A compromise solution is assured by the application of component descriptors (complete definitions), consisting of several simple descriptors (in the case of the described information retrieval language, of three).

In Table 1 are 14 simple descriptors of the information retrieval language, divided into three groups. The total number of possible determinations is 4 x 5 x 5 = 100, and each group contains not more than five kinds of descriptors; this is completely acceptable for compilation of the alphabet and its use.

Generic concepts in the information logical language are the structure of the technology, the semantic content of the information in the measurement channel and the method of control of the given specific variable. The division of any technological process into general-purpose parts is fairly evident; objective conversions occur in the main technology, associated technology often accompanies the main technology (for example, utilization of excessive reaction heat), auxiliary technology creates the conditions for realization of the main technology, etc. Process control signals carrying technical messages can be regarded as channels of semantic communication: danger, quality, etc; this assures their universality for various processes. The method (form) of control of a specific variable is regarded as the connection between the signal of control of the specific variable and the actuator which controls

Table 1. Form for assignment of descriptors from the alphabet of an information logical language* to variables of a technological process

| A Производство . . . . | | B Группа A | | | | C Группа B | | | | | D Группа C | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| E № п/п | F Полное наименование переменной | G Структурная часть технологии | | | | H Смысловая характеристика информации | | | | | I Форма управления | | | | | J Шифр переменной |
| | | A1 | A2 | A3 | A4 | B1 | B2 | B3 | B4 | B5 | C1 | C2 | C3 | C4 | C5 | |
| | | основная | попутная | вспомогательная | вторичная | безопасность | качество | нагрузка | режим | обеспечение | через режим | прямое | косвенное | в группе | неуправляемое | |
| | | | | | | | | | | | | | | | | |

A - Production ...
B - Group A
C - Group B
D - Group C
E - No
F - Complete name of variable
G - Structural part of technology
H - Semantic characteristic of information
I - Form of control
J - Variable number
A1 - main
A2 - associated
A3 - auxiliary
A4 - secondary
B1 - safety
B2 - quality
B3 - load
B4 - mode
B5 - security
C1 - through mode
C2 - direct
C3 - indirect
C4 - in a group
C5 - uncontrolled

*For each variable of a technological process, in each group (A, B, C) the presence of one of the characteristics is noted with a cross (each initial variable obtains a total of three marks).

that variable. That connection can be accomplished through the technological object (control through the "mode") or by simple converters (direct control): if the variable can be controlled by various actuators, it is indirect control, but if, on the contrary, a single actuator controls several variables, each of them is controlled "in a group."

A logical scheme for the ranking of component descriptors. The second part of the information logical language syntax must provide comparison and ranking according to the value of the component descriptors $d_n$.

We will adopt the following symbol designations:

$N_{in}$ -- the initial disordered array (planning list) of variables for a specific technological process;

N -- the number of variables;

$N_{alg}$ -- the ordered (through the ranking algorithm) array of variables, in which case $N_{in} = N_{alg}$;

D -- the total aggregate of simple descriptors (alphabet);

d -- the symbol of a simple descriptor $d \in D$;

$d_i$ -- the descriptor of the i-th uniform set;

a, b, c -- the ordinal numbers of the descriptors within the uniform sets.

Then the specific concepts are designaged $d_{1a}$, $d_{2b}$, $d_{3c}$, $a = \overline{1.4}$, $b = \overline{1.5}$, $c = \overline{1.5}$.

The ordinal numbers a, b and c correspond to the values of the descriptors within the i-th set. They are given a priori, on the basis of the semantic meaning of the concepts (see Table 1), which is not difficult to do when their quantity is small. In general it is useful to make such an a priori ranking in compiling an alphabet on the basis of expert estimates.

The component descriptor is determined with the formula

$$d_n = (d_{1a} \wedge d_{2b} \wedge d_{3c}).$$

For comparison of the various values of $d_n$ it is necessary to know the ratio of the values not only between elements of a uniform set ($d_{i1} > d_{i2} > d_{i3} \ldots$), but also between elements of heterogeneous sets. In the simplest case it is possible to give "overwhelming" advantage of elements of the i-th set over elements of the (i+1)-th set, and then $d_{1a} > d_{2b} > d_{3c}$ for all values of a, b and c.

For "softer" (and more real) variants of syntax of the ranking language it is possible to set also the ratios of groups A, B and C (see Table 1) of values at which descriptors from various groups alternate in value (for example, it happens that the "safety of auxiliary technology" is more significant than the "quality of the main technology."

The mutual significance of groups A, B and C is set by the planner in the process of interaction with the computer (Figure 2b, stage III, the "correction" unit), starting from an intermediate estimate of the ranking results.

## Systematization of the information representation functions

By "representation function" is understood the accepted form of representation in which messages about changes in the object are transmitted through the given monitoring channel to personnel by means of industrial hardware. We will formulate the criterion for systematization of representation functions. Data display system hardware is created for the interaction of personnel with an object in real time. It also is known [13] that the personnel in an operative monitoring mode often works under conditions of rigid time limitations. By virtue of the above, in the coupling of a data display system with man the main indicators of effectiveness are the degree of development of the complex of representation functions and time expenditures on the recognition and readout of information [14]. We will assume as a classification criterion complexity of the representation function and we will use the indicator of "readout time" as an auxiliary.

It is assumed that the form of representation also determines the possible symbolic decoding of the information cintent. This assumption is expressed in reference [15], where three forms of information representation are distinguished:

--numeration (point), corresponding to signalling;
--unidimensional (scalar), corresponding to indication;
--two-dimensional (time-scalar), corresponding to graphic registration.

Such a classification, which is completely proper for local hardware, is hard to use in digital displays. The same classification can be given a slightly different interpretation:

signalling ± x (deviation from the norm);
indication ¯x (instantaneous value);
registration x' (tendency to change).

Graphic registration of the value x(t) in implicit form also contains the representation function of mean values of the type

$$\frac{1}{\tau}\int_0^\tau x(\tau)\,d\tau.$$

Within these main forms of information representation there is an entire series of modifications which are presented in Table 2.

Table 2. Classification of information representation functions

| Type of hardware | Deviation from the norm, ± x | Quantitative value of x | Tendency to variation of x' | Integration current $\frac{1}{\tau}\int_0^\tau x(\tau)d\tau$ | Integration report $\frac{1}{T}\int_0^T x'(\tau)d\tau$ |
|---|---|---|---|---|---|
| Panel system | (1) | (5) | (13) | (14) | - |
| | (1) | (5) | (13) | (16) | - |
| | (1) | (10) | (13) | (16) | - |
| | (4) | (5) | - | - | - |
| | (4) | (6) | - | - | - |
| Centralized checking system | (1) | (5) | (13) | (15) | - |
| | (1) | (7) | - | - | - |
| | (2) | (7) | - | - | - |
| | (2) | (6) | - | - | - |
| | (4) | (6) | - | - | - |
| Computer terminals system | (3) | (8) | (12) | (21) | (18) |
| | (1) | (9) | | (19) | (20) |
| | (3) | (9) | (12) | (21) | (18) |
| | (1) | | | (17) | (20) |
| | (3) | (9) | (12) | (21) | (20) |
| | (3) | (9) | (12) | - | . |
| | (3) | (9) | - | - | - |

Key:
1 -- autonomous signalling on mnemonic circuits
2 -- complex signalling on mnemonic circuits
3 -- symbolic signalling on display
4 -- passive signalling (on indicating instrument)
5 -- autonomous scalar indications
6 -- scalar call indications
7 -- scalar group
8 -- line indications on display
9 -- digital indications on display
10 -- scalar cyclical indications (on multipoint instrument)
11 -- scalar autonomous indications (on a registering instrument)
12 -- tendency to change (indication on display
13 -- tendency to change (on graphic display
14 -- autonomous graphic registration
15 -- call graphic registration
16 -- multipoint graphic registration
17 -- call printing
18 -- report printing
19 -- periodic printing
20 -- report punched tape
21 -- mean integral on display

The modifications of functions in each column of the table are arranged in the order of increased expenditures of the time of personnel on obtaining the value of the signal. For example, it is natural that the time expenditures on estimating a deviation automatically emerging on a mnemonic circuit are smaller than the time expenditures on calling a mnemonic circuit fragment where the given signal panel is located [13,14].

Most present-day ASUTP's are planned for not a single type but for combinations of hardware [14]. This is taken into consideration in the algorithm under consideration for automating the planning of data display systems in the compilation of a working variant of a representation power table. Several alternative tables have been compiles which correspond to the adopted combined hardware structures; in that case the same four forms of representation are preserved for each variant as in Table 2, but duplication in the combinations of representation functions is reduced.

In the proposed tables the representation functions have been composed into lines at the rate of M lines for each type of system. The total of the functions in a single line corresponds to the above-introduced concept of "power of representation" ($X_m$) of information on specific signals from the object. During use of the planning algorithm (see Figure 2b) one line in the table is set in correspondence by ranked variables or groups of variables $\{d_n\}_m$, that is, all the representation functions indicated for the given line are

$$\{d_n\}_m \longrightarrow X_m.$$

The decrease in representation power proceeds from top to bottom through alternate replacement and exclusion of functions from right to left. Such a condition of change of functions corresponds to the above-adopted criterion of minimization of time expenditures on obtaining information, that is, at first even the more complex (more informative) are excluded, but then, less effective representation functions.

## Conclusion

On the basis of the described algorithm for automated planning of data display systems for ASUTP a program has been compiled for computers and methodical materials on organization of the planning process. The starting methodical document is "Instructions for the expert" for descriptor description (without making a decision on the comparison of variables in value) and variables of a technological process (completion of Table 1). In contrast with traditional expert estimates, only one expert can work in the given case. The process of data display system planning is carried out further according to "Instructions for the planner" according to a program.

Automated ranking was done for various technological processes and the results of ranking were approved by the leading production engineers. A comparison also was made of the results of ranking variables of monitoring according to the given algorithm and according to the method of expert estimates for one and the same technological process [10]. The correlation coefficient of the two ranked series is more than 0.8.

The complete procedure for data display system planning is also realized for several objects and at present is undergoing comparison with heuristic planning solutions, and also is used in planning documentation. Together with direct purpose, the developed automated planning algorithm can be used for quality control of data display system plans prepared traditionally [16].

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# A MICROPROCESSOR SYSTEM IN THE KAMAK STANDARD

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/Excerpts from article by Yu.N. Zolotukhin, Yu.M. Krendel', V.S. Yakushev and A.P. Yan, Novosibirsk/

/Excerpts/ Progress in the development of microelectronics technology has led not only to the expansion of the area of application of computer technology, but also to the possibility of constructing automation systems that are not expensive, consume an insignificant amount of power and are small in size, which -- when the possibility of providing them with sufficiently developed programming facilities is taken into consideration -- makes it possible to achieve the maximum approximation of such a system to automation projects.

In this article we describe a complex of microprocessor devices that were developed at the Institute of Automation and Electrometry of the USSR Academy of Sciences' Siberian Department. This complex is intended to be used for the creation of independent systems for the automation of scientific and technical experiments in the KAMAK standard.

The complex contains the following units: a microcomputer, a main memory with a capacity of 16 Kbyte, an operator's console and a kreyt-controller /translation unknown/. These units are connected to each other by means of plug-and-socket units and a main communication line.

The basic system is based on a general-purpose 8-bit microcomputer, for the construction of which a microprocessor set from the 6800 family (Motorola 6800, AMI 6800, Hitachi HMCS 6800, Iskra 6800) is used.

When the power is disconnected accidentally, a special POWER FAIL signal is generated, in which case the main memory module changes over to an internal regeneration mode.

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# A HIERARCHICAL TWO-PROCESSOR SYSTEM FOR COLLECTING AND PROCESSING EXPERIMENTAL DATA

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/Excerpts from article by S.P. Vikulov, A.N. Vystavkin, V.V. Romanovtsev and O.Ye. Shushpanov/

/Excerpts/ Introduction. The development of automation systems realized in the KAMAK standard is proceeding along the path of the creation of an "intellectual" terminal; in connection with this, an individual KAMAK kreyt /translation unknown/ or branch is controlled by a microprocessor that is installed in the kreyt and performs part of the central computer's functions. There exist several possibilities for linking a computer with such an "intellectual" system:

The computer is connected to the kreyt with the help of a KAMAK interface module. In this case the computer can be situated at a great distance from the KAMAK system. However, the operating speed of such a system is not very fast.

The computer is connected to the main link and the microprocessor memory's control lines through a special interface. The operating speed of such a system is very fast because of the possibility of direct access to the microprocessor's memory, but the length of such a communication link does not exceed several meters.

The computer is connected to the microprocessor through standard interfaces with the halp of standard communication links, in which simple amplifiers can be included.

In this article we discuss a laboratory experiment automation system in which a WANG-2200VP minicomputer is connected to a microcomputer in the form of a KAMAK module by a standard communication line, through parallel interfaces (third variant). In connection with this, the rate of data transmission over this line turns out to be greater than the rate on a series channel by a factor of several hundred. At the same time, when simple amplifiers and receivers are used, the length of this parallel communication link can reach several hundred meters.

Structure of the System. Figure 1 is the overall block diagram of the system. It has a hierarchical structure. On the bottom level of the hierarchy there is a microcomputer with a KAMAK kreyt, which is connected to the minicomputer on the upper level through a parallel data exchange channel. Thanks to the separation of the experimental data collection and processing operations, such an organization: a) increases the system's operating speed substantially; b) makes the system easy to

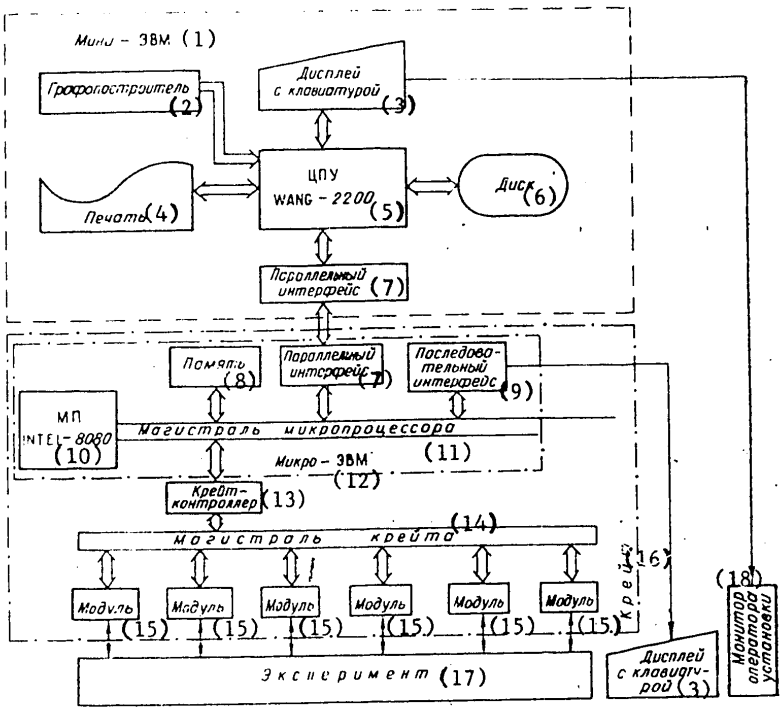

Figure 1. Block diagram of data collection and processing system.

Key:
1. Minicomputer
2. Graph plotter
3. Display with keyboard
4. Printout
5. WANG-2200 digital printer
6. Disk
7. Parallel interface
8. Memory
9. Series interface
10. INTEL-8080 microprocessor
11. Microprocessor main line
12. Microcomputer
13. Kreyt-kontroller
14. Kreyt main line
15. Module
16. Kreyt
17. Experiment
18. Unit operator monitor

enlarge and modify; c) makes it possible to connect several lower-level computers to a single upper-level one.

The KSC-3880 low-level microcomputer is based on an INTEL-8080 microprocessor, has a main memory with a 4-Kbyte capacity (that can be enlarged to 32 Kbyte) and a programmable permanent memory with a 4-Kbyte capacity (that can be enlarged to 32 Kbyte). An alphanumeric console display, which is used to start the system initially and to control the experimental installation in the dialog mode, and a KAMAK kreyt-kontroller are connected to the microcomputer. In the system, the microcomputer performs the following functions: setting the priorities of the individual modules; processing interruptions on the bottom level and the modules' LAM-inquiries in accordance with their priorities; generating the commands needed to control the KAMAK modules; preliminary processing and packing of the experimental information

Table 1.

| Command | Purpose |
|---|---|
| | Group of commands for working with texts in the working and buffer arrays |
| DELETE | Eliminate indicated part (or all) of the Assembler program |
| END | Report on available free positions (in bytes) in the array |
| INSAFTER | Rearrange indicated parts inside a single Assembler program or several Assembler programs |
| RECALL | Request indicated line of Assembler program or last directive for editing; the minicomputer's editing program is used for symbol-by-symbol editing |
| RENAME | Change or retrieve name of a variable (in the operating code) |
| RENUMBER | Renumber lines of indicated part of the Assembler program |
| SNUMBER | Shift numbering of indicated part of the Assembler program (the old numbers are increased by the given value of the shift) |
| | Group of commands for working with peripheral gear |
| LIST | Printout of Assembler program texts, translated program, reports on errors, mnemonics and basic codes of the Assembler instructions, indicators of the catalog of data disks |
| LOAD | Erasure in indicated array of part of the lines and loading, in their place, of part of the indicated file on a data disk |
| SELECT | Assignment of printing unit address for the printing of programs and translation protocols of the original modules |
| WRITE | Enter original programmed module on a data disk |
| | Group of commands for translating original programmed modules and loading process modules in the microprocessor |
| ASSEMBLE | Translation of Assembler program and entry of result onto a disk under indicated name |
| LOMIC | Load indicated translated file into the microprocessor |

Table 2.

| Command | Purpose |
|---|---|
| OSA | Single operation |
| RSA | Single read command |
| WSA | Single entry command |
| UBC | Command for entering or reading |
| RMAN | Command for reading with scanning for N |
| RMAA | Command for reading with scanning for A |
| RMAD | Command for reading with scanning for NA |
| QIF | Check state of bus Q |
| LIF | Convert to servicing of LAM-request |

into units of fixed length for subsequent forwarding to the upper-level computer, maintaining communications with the upper-level computer; maintaining the dialog between the experimenter and the system.

On the second level of the hierarchy there is a WANG-2200VP microcomputer that includes a processor, a storage unit utilizing small magnetic disks, a printing unit, a graph-plotting unit and a display unit. The computer is used to write, edit, translate and load programs for the microprocessor; maintain communications with the microcomputer; enter and store experimental information on the magnetic carrier; process incoming information in real time; perform secondary processing on and graphic representation of experimental information that has been entered.

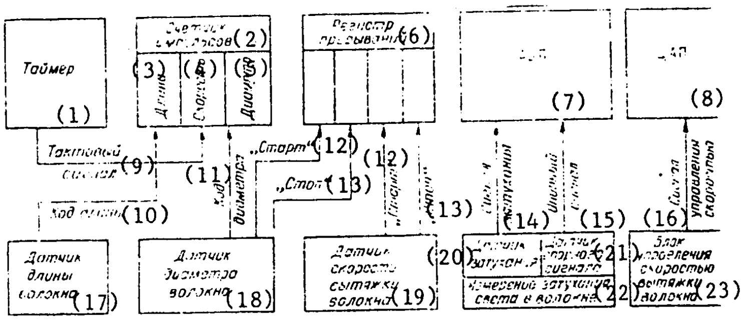

Figure 3. Block diagram of the connection of the sensors for a system for the automatic measurement of the parameters of optical fiberglass with KAMAK modules.

Key:
1. Timer
2. Pulse counter
3. Length
4. Speed
5. Diameter
6. Interrupt register
7. Analog-to-digital converter
8. Digital-to-analog converter
9. Clock signal
10. Length code
11. Diameter code
12. "Start"
13. "Stop"
14. Attenuation signal
15. Reference signal
16. Speed control signal
17. Fiber length sensor
18. Fiber diameter sensor
19. Fiber drawing rate sensor
20. Attenuation sensor
21. Reference signal sensor
22. Measurement of light attenuation in a fiber
23. Fiber drawing rate control unit

System Software. The system has the following software.

1. A complex of programs for the WANG-2200VP computer ("Systems Editor") that is used to develop programs for the microcomputer and that consists of a program for collecting and editing the original programmed modules, a translator with the Assembler INTEL-8080 language (including macroexpansions), an absolute loader for entering the process programmed modules in the microcomputer, and a printing program for the original and process modules[1]. A list of the "Systems Editor" commands is presented in Table 1.

2. A package of programs for organizing the exchange of data between the mini- and microcomputers. Data exchange can be either byte-by-byte or block-by-block, with monitoring of the transmitted information.

3. A set of macroexpansions of the Assembler INTEL-8080 language for working with KAMAK modules (Table 2) that makes it possible to execute single commands and read and enter commands in the programmed mode and the mode of direct access to the

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[1] Vikulov, S.P., Didenko, O.A., Romanovtsev, V.V., and Shushpanov, O.Ye., "Systems Software for the Development of Programs for Controlling a KAMAK Kreyt With the Help of a Microprocessor," BYUL. VNTITSENTRA. ALGORITMY I PROGRAMMY /Bulletin of the All-Union Scientific and Technical Center: Algorithms and Programs/, No 5, 1978.

microcomputer's main memory, as well as commands in the repetition and scanning modes.

4. A package of programs for the WANG-2200 computer for working with the graph plotter in the dialog mode, which is used for the representation in graphic form of data that can be given in the form of a table (a file on a disk) or a function (a program for its computation). The package makes it possible to perform, in an interactive mode, the preparation and editing of files; graph-plotting parameters; data added to a graph; data obtained as the result of the digitalization of graphs; official legends for graphs. It also makes it possible to construct graphs in accordance with the information entered in prepared files.

The system utilizes five sensors that are serviced by five KAMAK modules (Figure 3).

This installation has made it possible to detect and investigate a number of new properties of fiberglass and to produce fibers with a very low light attenuation rate (~0.8 dB/km).

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## PROBLEM-ORIENTED MEASUREMENT AND COMPUTATION COMPLEXES, BASED ON SM-3 AND SM-4 COMPUTERS AND KAMAK EQUIPMENT, FOR THE AUTOMATION OF SCIENTIFIC RESEARCH

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/Article by A.N. Vystavkin, Yu.A. Dedov, G.N. Kuklin, A.Ya. Oleynikov, Ye.V. Pankrats, S.S. Partsevskiy, L.Z. Pososhenko, A.I. Smurygov and S.N. Khrushchev, Moscow/

/Text/ 1. Introduction. The USSR Academy of Sciences and the Ministry of Instrument Making, Automation Equipment and Control Systems have planned a joint program, in accordance with which the development and industrial production of computer equipment is being carried out and systems for the automation of scientific research are being created on the basis of this equipment. A large part of this program is based on the use of SM-3 and SM-4 minicomputers and equipment for linking the computers to experimental installations and instruments that meets the international KAMAK standard. The first sets of this equipment began to be produced and delivered to scientific research organizations in 1978.

The main question in the organization of the development and production of these sets is the choice of the composition of their hardware and software on the basis of the most important requirements of researchers and with due consideration for the limitations imposed by the basic computer technology that has already been mastered, the traditions and orders of planning in industry, state standards and so on.

When formulating systems for the automation of scientific experiments on the basis of minicomputers and KAMAK equipment, two basic approaches are possible.

1. Based on an analysis of the requirements for the automation system for a given, specific experiment, we determine the system's structure and composition, including the minicomputer, the authorized peripheral equipment and KAMAK units, and the composition of the systems and applied software. After this, the necessary set of hardware and software is ordered and put into operation by the supplier or the user himself. For a number of years this has been the practice of, for example, the ("Enertek-Shlyumberzhe") company. In connection with this, standard basis software is used, while the control programs for the KAMAK equipment and the other applied programs are written by the user.

This approach involves two basic difficulties: 1) in the conditions under which we work, the completion of the hardware system is made more difficult; 2) the creation of software for the system is an extremely laborious process.

Both of these difficulties result in a considerable increase in the amount of time required to create automation systems and to the distraction of the researchers' attention from their basic scientific problems.

2. The second approach /1/ consists of using so-called basic, standard problem-oriented measurement and computation complexes (IVK). A measurement and computation complex is not simply a set of hardware and software, but is actually a complex consisting of a computer linked to KAMAK equipment, along with testing and metrological facilities. The complex's problem orientation is expressed in the composition of the set of hardware and software used in it, depending on the class of problems it is used to solve.

When specific systems are being created, the IVK's basic composition (primarily the KAMAK equipment's composition and its software) can change somewhat. The IVK can be compared figuratively to a half-finished suit that has to be fitted to the customer.

This approach is close to the one used to create process control computer complexes (UVK) for ASU's /automated control system/, and in particular for ASU TP's (technological processes).

A number of considerations have been presented in favor of the second approach /1/; the most important of these are based on the fact that this approach makes it possible to organize the industrial production of equipment with metrological certification in the structure that has been formulated, the necessary diagnostic facilities, and operational documentation. In connection with this, the centralized technical maintenance of IVK's becomes possible, as is now being done with computers.

It is assumed that on the basis of the use of problem-oriented IVK's constructed in accordance with the principles outlined above, the maximum reduction of time and expenditures for the creation of systems for the automation of scientific research will be achieved /2/.

However, we can mention here that the cost of an IVK and putting it into operation is approximately twice that of a computer and KAMAK equipment acquired by "deposition." There also exists the danger that the concept of creating and using an IVK that has been developed (to a considerable extent) by analogy with an ASU TP can prove to be not entirely justified for the construction of a system for the automation of scientific research, since the nature of scientific problems is such that they require much greater diversity in the automation systems and much more frequent readjustment of the systems. It is not without reason that KAMAK appeared precisely in problems relating to the automation of scientific experiments. In particular, the replacement of a single KAMAK module in an IVK leads to substantial changes in the IVK's documentation.

Given the conditions existing at the present time, we chose the second approach.

To answer the question of how the approach is better, we can only compare the experience gained in the use of both approaches.

In this article we explain the considerations on the basis of which the composition of the first IVK's was formulated, in addition to generalizing the experience amassed in their development.

2. Determining the Basic Trends in Problem Orientation. In determining the requirements for the first IVK's, we took into consideration foreign and Soviet experience in using minicomputers and KAMAK equipment. In connection with this we kept in mind the nature or class of the experiment and the number of experiments to be handled with the help of a single computer.

The most massive class of experiments consists of those performed by general-physics method, which should be distinguished from nuclear-physics methods. General-physics methods include those used in such areas as the study from space of the Earth, the solar system and outer space /_3_7; terrestrial investigations of the Sun and space near the Earth and the Sun, as well as the propagation of radio waves and laser radiation in the atmosphere; astronomy, radioastronomy and radar astronomy; plasma physics; spectroscopy and crystallography; laboratory research in solid-state physics, low-temperature physics, physical and quantum electronics, hydrodynamics, thermodynamics and so on.

The last four types of research are those that are practiced most widely. The methods that are appropriate to them are also used in much other natural-science research (chemistry, biology, geophysics and so forth). At the USSR Academy of Sciences, more than half the experiments perform use these methods. The first IVK's were oriented toward these methods. These same methods have also determined the composition of the necessary modules.

As is well known, according to the KAMAK-classification, KAMAK equipment is divided into the following groups: 1) data modules; 2) systems control; 3) testing equipment; 4) sections, power sources, components, supplementary units.

The basic difference between the composition of modules for general-physics research and those needed for nuclear-physics experiments is seen in the group of data modules. As far as the other groups -- where the modules are relatively independent of the area of research -- are concerned, from the great variety here we should choose modules with the widest area of application (the fact of the matter is that more than 3,000 types of modules have already been developed throughout the world).

The second consideration in determining the composition of an IVK is based on the fact that the requirements for the computer (primarily for operating speed and memory volume) can be differentiated for experiments that are of a single type but have different information characteristics. Besides this -- as is well known -- more than one experiment can be handled by a single minicomputer.

On the basis of these considerations, the first IVK's have been developed and are being produced with an orientation toward general-physics research and for the following purposes:
IVK-1 -- automation of relatively small experimental setups;
IVK-2 -- automation of relatively large experimental setups or two small setups;
IVK-3 -- automation of spectral (or similar) setups;
IVK-4 -- automation of several experiments on the scale of a laboratory.

3. The IVK-1 and IVK-2 Measurement and Computation Complexes. When selecting the configuration of an IVK intended for the automation of separate, comparatively small experimental installations, we should also consider the IVK's cost, with the idea that it be comparable to that of the installation and not substantially greater.

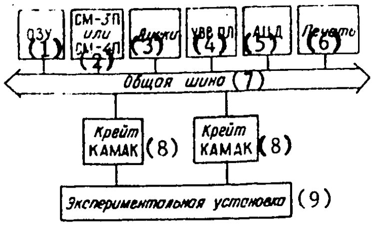

Figure 1. Generalized structural diagram of IVK-1 and IVK-2.

Key:
1. Main memory
2. SM-3P or SM-4P computer
3. Disks
4. Punched tape input-output unit
5. Alphanumeric display
6. Printer
7. Common bus
8. KAMAK kreyt /translation unknown/
9. Experimental installation

In determining the composition of the first IVK, we used the experience of a number of academic organizations, in particular the many years of experience accumulated by the USSR Academy of Sciences' IRE /Institute of Radio Engineering and Electronics/ and the IRE's SKB /Special Design Office/ in automating investigations of the properties of semiconductors on the basis of measurements of current-voltage characteristics and Hall's electromotive force /4/. These measurements are the basis of all research in the area of semiconductor physics and techniques.

An IVK-1 contains (Figure 1):
1) an SM-3 basic complex (a processor, a 28-Kword main memory (OZU), magnetic disk storage, punched tape input-output units (UVV PL), an alphanumeric display (ATsD) and an alphanumeric printing unit);
2) two kreyts that are in the same rack as the disks and are equipped with kreyt-controllers; the kreyts can be removed from the rack and placed at a distance of up to 3 m from the computer;
3) a set of modules in each of the kreyts (Kreyt No 1).

A. Input modules that are used to enter information in the computer: an analog signal commutator, an analog-to-digital converter (ATsP), an inquiry register, input registers (two), a pulse counter and a word generator.

B. Output modules that are used for information output from the computer and to control the experimental setup: output registers (two), a master clock and a digital-to-analog converter (TsAP).

C. Testing equipment to check and adjust the modules: a main line display, a manual controller, a word generator/register and an attenuator.

D. Supplementary units for expanding the system: a 24/12 V converter that is needed to power the ATsP and the TsAP; module constructs with dummy cards (so the user can create his own specific modules by the mockup method).

In order to speed up production of the IVK-1 and IVK-2, we used modules from the "Polon" company (Polish People's Republic), which were already in industrial production by the time of the beginning of IVK production. Only the kreyt-controller and the TsAP had to be developed additionally.

The IVK-2 is distinguished by the fact that it is constructed on the basis of an SM-4 computer, which has a greater computation capacity and a larger OZU volume (64 Kwords) than the SM-3 computer.

The IVK-1 and IVK-2 also contain an object simulator -- a set of cables for connecting the front panels of the modules in the kreyt in order to form closed networks in a certain manner. The simulator is used during testing of the KAMAK equipment (see Section 4.2).

4. Software. The basic software of the IVK-1 and IVK-2 includes:
PLOS SM -- a punched-tape operating system (not supplied with the IVK-2);
DOS SM -- a disk operating system;
DOS RV -- a real-time disk operating system;
a KAMAK monitor;
a test complex.

The PLOS SM is a programmed complex that is used for the preparation, debugging and implementation of the user's programs in the Assembler language and in a single-program mode. The system is distinguished by its comparatively poor capabilities, but does not require the presence of disks. Thus, the PLOS SM can be regarded as an auxiliary variant in the case of the absence of malfunctioning of the disks.

The DOS SM is a set of systems programs that is used to prepare and debug programs in the single-program dialog and package modes in the Macroassembler and FORTRAN-IV languages.

The DOS RV is a real-time control system. Because of it, several real-time problems are solved and the user's programs are developed in the background mode. The system provides for the processing of direct-access files and gives us the facilities for formulating structures with superposition (overlain structures). It contains facilities for developing and engaging programs for servicing the units for communicating with the object (see below). Thus, the DOS RV makes it possible to combine the conduct of an experiment with data processing and the preparation of new programs.

The KAMAK monitor is a set of subprograms that organizes the exchange operations between the computer and the KAMAK modules under the control of the DOS SM or DOS RV. It allows operation with the KAMAK modules in the FORTRAN-IV or IML language.

The tests are intended to check the ability to function of both the IVK as a whole and the individual modules and groups of modules.

In contrast to the other software, the KAMAK monitor and the tests were developed especially for the IVK, so we should discuss them in more detail.

4.1. Facilities for interaction with the KAMAK equipment. When the IVK was being produced, it was decided to include programmed facilities for controlling the KAMAK equipment in the standard operating systems and to standardize these facilities. This problem was solved in two stages.

In the first stage, an organizing subsystem called the KAMAK-monitor [5] and written in Assembler was created.

In the second stage, the IML language, as standardized by the ESONE Committee [6], was realized. A description of this realization is given in [7].

For the IVK-1 and IVK-2, part of this software is supplied on punched tape. It is supplied in full for the IVK-3 and IVK-4.

It should be mentioned here that the programmed facilities noted above are not an integral part of the KAMAK equipment's composition and can, therefore, be used for both IVK expansion and modification on the part of the user and for the creation of new automation systems based on the "accretion" of KAMAK modules.

4.2. Principles of the machine testing of KAMAK equipment and the possibilities for their utilization by the user. During the construction and utilization of systems for the automation of experiments, the most important requirement is to insure the operational reliability of all the elements in the system, for which monitoring and diagnostic methods for all the equipment in the system are used. Machine tests are normally used to check the standard computer equipment. During the creation of the IVK, which includes KAMAK equipment, it was natural to attempt to develop machine testing for that equipment.

The basic purpose of the tests is to check the KAMAK equipment during the process of series production of the IVK's and the setting of them into operation (that is, the development of production tests). In connection with this, one extremely important question is ascertaining the possibility of using these tests during the operating process. For most users it would obviously be more convenient to perform a periodic (such as daily) check of both the system as a whole and its separate parts.

In addition to the modules, the Western companies that developed KAMAK deliver only a printout of the completed test that indicates that the module underwent machine testing for its basic functions.

The specific nature of the testing of KAMAK equipment, which distinguishes it from the testing of standard computer units (ATsPU /alphanumeric printer/, alphanumeric display and so on) is the result of three factors.

1. In contrast to other peripheral units, KAMAK equipment is a device for computer communication with an object that is not part of the IVK, so that sufficiently complete checking of the KAMAK equipment requires additional peripheral gear (including an object simulator).

2. A degree of redundancy that makes it possible to localize the source of a malfunction is provided for in standard computer peripheral devices. In most KAMAK modules there is no such redundancy, so the thoroughness of the diagnostics is confined to the exposure of the defective module (in the sense of its correct functioning) and not to the cause of the defect. A further, more exact definition of the nature of the defect can be obtained by manual testing.

3. During the creation of specific systems, modules can be shifted to another station or even into another kreyt. Therefore, it is necessary that the testing programs be easily adaptable for a specific configuration.

The testing backup that has been developed for KAMAK equipment solves two types of problems:
1) overall checking of the functioning of the entire set of modules (a system test);
2) detailed checking of the operation of individual modules (module tests).

The testing methods used, as well as the hardware and software developed for these purposes, are described in /8/.

5. Metrological Support for an IVK. In order to insure the reliability of the results obtained with the use of an IVK, IVK metrological support is being developed at VNIIEP /All-Union Scientific Research Institute of Electrical Measuring Instruments/. For analog modules (relay multiplexors, analog-to-digital and digital-to-analog converters), the individual metrological characteristics are determined in the automatic mode. The following characteristics are determined for these modules: magnitude of the systematic component of the error, mean-square value of the error's random component, variation in the output signal, permissible value of the error.

In order to determine the metrological characteristics, an F7046 programmable source of calibrated voltages, controlled by a special KAMAK module, is used. The determination of the metrological characteristics is based on statistical methods (multiple measurements) and the conduct of these tests with the help of the computer in the complex, which accelerates the metrological checking considerably. Such a check is performed for each IVK exemplar at the plant. When the necessary hardware is present, the user can also conduct checks when necessary. Metrological checking programs are applied in the form of punched tape and contain the modules' program drivers and processing programs. The complexity of the utilization of these programs is the same as in the case of tests related to the necessity of changing the addressing.

6. The IVK-3 Measurement and Computation Complex. One of the largest classes of experiments requiring automation is spectral (or similar[1]) investigations having a common techniques for conducting experiments and processing data. The characteristic features of spectral experiments are small magnitudes of the signals being measured; the necessity of controlling the position of the spectral element or some other parameter that changes the state of the experimental setup; the necessity of graphic representation of the information.

On the basis of experience amassed in the automation of spectral research /9/, requirements were developed for the IVK-3, which is oriented toward that and similar types of research. Into the modules of the KAMAK Kreyt No 2, which is part of the IVK-3, it was decided to introduce modules developed at the USSR Academy of Sciences' IRE's SKB: a 14-bit analog-to-digital converter, a timer-synchronizer, two modules for controlling the stepping motor, a relay output register, two binary-decimal counters with a display; in addition, the IVK also contains an F-30 digital voltmeter, with a sensitivity of 1 µV, with a corresponding control modulus and a two-coordinate N306K graph plotter.

The IVK-3's software also includes a package of applied programs for spectral analysis.

7. The IVK-4 Measurement and Computation Complex. In order to support the creation of an automated laboratory in which several different experiments of the general-physics type could be conducted simultaneously, the IVK-4 complex was developed. It is constructed on the basis of an SM-4 computer and has additional disks, a general-purpose, programmable controller for switching on various devices, a bus switch for the possibility of coupling with analogous complexes, a N710 roll-type graph

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[1] We have in mind the measurement of one or several values as a function of another (current, magnetic field, angle of rotation and so on).

plotter, a programmable timer, a general-purpose, color-coded, variable-sign, graphic measuring indicator, and an additional standard rack and program-controlled calibrator, which are needed for metrological checking. The complex includes KAMAK kreyts Nos 1 and 2 and one kreyt with a kreyt-controller and mockup modules (Kreyt No 3).

8. Prospects for the Near Future. For the near future we are planning the organization of the production of IVK-5 measurement and computation complexes oriented on research in the fields of nuclear and high-energy physics, as well as the IVK-6, which will contain -- in addition to the units already mentioned -- an "Elektronika-60" microcomputer, which is program-compatible with the SM-3 and SM-4 minicomputers and will make it possible to construct distributed systems for controlling experiments and processing measurement data for a broad class of investigations in many areas.

Another thing that is being planned is the production of basic complexes containing an "Elektronika-60" microcomputer and one or two KAMAK kreyts for autonomous (including portable) systems that will be used to automate experiments of low and moderate complexity.

At the present time, the Council on the Automation of Scientific Research of the USSR Academy of Sciences' Presidium is studying the experience gained in the use of the first IVK's for the purpose of defining more precisely the principles of their construction, the organization of the production and the acquisition of KAMAK modules and other devices that supplement IVK's to the necessary composition of scientific research automation systems, and the unification of the efforts of individual collectives for the creation of a common fund of programming (primarily applied) support for scientific research automation systems on the basis of the use of measurement and computation complexes.

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# ELECTRONIC KAMAK MODULES FOR PRECISION LASER MEASURING AND CONTROL SYSTEMS

Novosibirsk AVTOMETRIYA in Russian No 3, May-Jun 80 manuscript received 3 Aug 79 pp 33-40

/Article by A.M. Shcherbachenko and Yu.I. Yurlov, Novosibirsk/

/Text/ The laser interferometer is one of the promising precision sensors that are used to convert different physical parameters into signals that are proportional to a phase or frequency shift in electric, alternating-current signals. The use of laser interferometers as primary converters opens the possibility, in principle, of achieving greater levels of accuracy in the measurement of the latter than does the use of converters of another type.

Both in the Soviet Union and abroad, the first laser interferometers were used in instruments for measuring such parameters as displacement, velocity, vibration, gravitational acceleration and the refractive index of transparent materials. Each of them contained a frequency-stabilized laser, an optical unit (the interferometer) and electronic equipment that implemented the operations of counting the number of interference bands, converting them into a given code, and computing, registering and displaying the measurement results.

The expansion of the circle of problems solvable with the help of independent devices, the presence in them of monotypical functional assemblies, and the possibility of the joint utilization of laser interferometers and modern computer technology facilities required the application of new principles for the construction of the electronic part of such devices so as to insure the possibility of creating systems for the solution of variegated measurement and control problems from a set of general-purpose electronic units.

Such an approach was realized at the Institute of Automation and Electrometry of the USSR Academy of Sciences' Siberian Department, where the KAMAK standard was used as the basis for the development of a set of functional units for precision measuring and control systems that was used, in particular, for the creation of the "Zenit" automatic photogrammetric device, a hologram memory and a laser photographic plotting device for the synthesis of optical elements with axial symmetry /1,2/, as well as a number of program-controlled systems for the measurement of different physical parameters in which laser interferometers were used as the primary converters /3,4/.

This set of units is represented schematically in Figure 1. It is subdivided into specialized electronic modules that are intended for direct operation with signals from laser interferometers or other laser devices and general-purpose modules.

The specialized modules are the adapter, the reversible counter, the number-pulse multiplier, the reversible pulse-count divider and the modules for controlling the electric motor and the laser modulator.

The set of general-purpose modules includes a digital display, a main line indicator, pulse counters, digital-to-analog and analog-to-digital converters, code converters, an OZU /main memory/ module, interfaces for digital measuring instruments and controllers for the computer.

Below we discuss the requirements for the specialized functional units and list the specifications of the modules that have developed. We also present examples of the use of these modules in systems controlled by computers of different types, including a T3-16M EKVM /electronic keyboard computer/, for which we developed a controller for its communication with the KAMAK kreyt /5/.

Among the specialized modules, only the adapter modules must be different for interferometers constructed on the basis of a single- or double-frequency laser. However, regardless of the type of laser interferometer, the adapter's output signals must be signals that define the direction of displacement of the prism and pulsed signals, the frequency of which is proportional to the prims's rate of motion, while the recurrence interval determines the discreteness of the displacement of the laser interferometer's movable reflector, which is a multiple of the laser's wavelength. The adapter module must also contain a command decoder (Dsh) and a service register (SR) for the registration and screening of inquiries arising as the result of malfunction of the laser's frequency stabilization system or a reduction in the amplitude of the interferometer's output signal below the threshold that insures reliable operation of the module's shaping amplifiers. The structure of the other modules remains constant and does not depend on the type of laser interferometer.

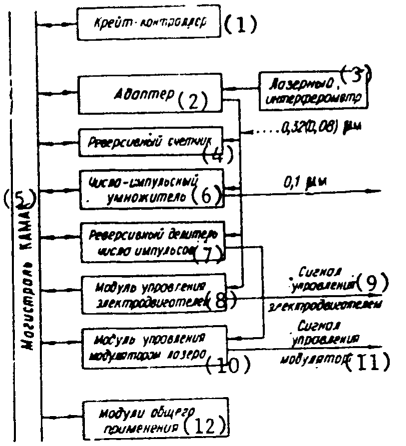

Figure 1. Structural diagram of KAMAK laser measuring and control systems.

Key:
1. Kreyt-controller /translation unknown/
2. Adapter
3. Laser interferometer
4. Reversible counter
5. KAMAK main line
6. Number-pulse multiplier
7. Reversible pulse-count multiplier
8. Electric motor control module
9. Electric motor control signal
10. Laser modulator control module
11. Modulator control signal
12. General-purpose modules

The reversible counter module is used to count the number of pulses in the addition and subtraction mode. This module -- as is the case with the module discussed in /6/ -- contains a command decoder, a reversible counter (RS), a circuit for controlling its operating mode, a data register (RD) and a display circuit. Presetting of the counter's digits is accomplished by means of the KAMAK main line, through which the counter's contents, as displayed on the front panel with the help of light diodes, can be read. The module has been developed in two versions: the first uses a binary reversible counter and the second a binary-decimal one. The light pulses' maximum frequency is 5 MHz.

The number-pulse multiplier multiplies a sequence of pulses by a constant factor that is a multiple of the laser's wavelength and is expressed in units of length of the chosen measurement system. The module contains a command decoder, a multiplication factor data register (RD) and a digital integrator with sequential carry.

The principle of this multiplier's construction is discussed in detail in /7/. Pulses from the adapter enter the module's input. The input pulses' discreteness is $\lambda/8$, where $\lambda$ = the laser's wavelength. The discreteness of the module's output pulses is 0.1 $\mu$m. It provides for the multiplication by a constant factor, on a real time scale, of a sequence of pulses in the 0-1 MHz frequency band.

The reversible pulse-count divider forms pulses with a given discreteness interval. The module contains a command decoder, a data register for the division factor, a reversible counter and a coincidence circuit. The discreteness of the pulses at the coincidence circuit's output can change over a range of $(2^0-2^{16})0.1$ $\mu$m. The division factor is entered in the register through the KAMAK main line. The maximum frequency of the pulses is 5 MHz.

The electric motor control module is intended for use in the tracking systems of precision installations, the dynamics of which are described by a second-order differential equation. The demands made on the control systems of these installations are quite rigorous and contradictory. On the one hand, they must provide a rapid shifting of the controlled objects -- carriages that can weight up to tens of kilograms -- from one position to another at a speed of 1 m/s over a period of time that is close to optimal; on the other hand, in connection with this the positioning error must not exceed tenths of a micron. In order to solve this problem, two-mode control is realized in the module: quasioptimal control is used to shift the object rapidly into some comparatively small zone, while proportional control is used for precise positioning in a small zone /8/.

During the development of the module, the basic attention was devoted to the creation of digital regulators with relay control and PID regulators. The module contains a command decoder, a service register, a reversible counter with a data register, a digital-to-analog converter (TsAP), a quasioptimal and PID regulators, a precise control zone decoder, a light diode display and a keyboard register for controlling the module in the "off line" mode.

The first-stage digital regulator realizes control that is close to optimal and is turned on when the magnitude of the misalignment exceeds the dimensions of the zone of comparatively small coordinate misalignment. The entire range of changes of positions within which the high-speed stage operates is divided into several zones, in each of which linear transformation of the misalignment error into a pulse recurrence frequency is carried out. The formation of the quasioptimal regulator's control signal's sign is accomplished by a logic unit, according to the signals of the misalignment error's sign, the controlled object's direction of motion, and the difference in frequencies, which are proportional to the object's actual velocity and the misalignment error.

The second control stage utilizes a PID regulator, the special feature of which is that all the components of the regulating action are represented as pulse recurrence frequencies, it being the case that the P and I components are preliminarily converted into digital form by digital integrators. The absence of analog integrating devices and the simplicity of the multidigital code-to-frequency converters simplified the PID regulator's structure substantially and improved its operational reliability.

The module that has been developed provides for control of the displacement of the carriages of precision devices under conditions of precise positioning and movement at a given rate. As far as the equipment is converned, movement at a constant rate is realized by both the quasioptimal and proportional regulators, with blocking of the pulses entering the RS's input during the period of movement at a constant rate; this is necessary because in this mode the RS is used as a rate and displacement code register. If the code for the rate of movement is greater than the code of the number corresponding to the value of the proportional control zone, the quasioptimal regulator operates, but when this condition is not fulfilled, the PID regulator does.

The programmed mode of mechanical displacement is realized with the help of signals from the digital-to-analog converter, constrol over which is exercised by the computer, which -- on the basis of the reversible counter's readings -- computes the control signal's value in accordance with the chosen algorithm.

When the electric motor control module is in operation, the carriage's rate of displacement is sometimes quite high. A malfunction in the system leads to a situation where the carriage can reach its extreme position at a high speed, which causes deformation or destruction of the mechanical assemblies of precision installations. In order to prevent such accidents, in the module there is a provision for the transmission of signals blocking control by the quasioptimal and PID regulators. In connection with this, a shielding signal is formed that slows down the electric motor. When shielding is triggered, the control module displays inquiry 1, by reacting to which the computer addresses the module's service register and, according to the state of the status triggers' signals, determines which of the extreme positions (reference points) is occupied by the carriage.

A second inquiry is formulated if the carriage reaches the required position with the given accuracy. The module's coordinate resolution in the positioning mode is 0.32 $\mu$m in the measurement range $\pm 0.32(2^0-2^{23})$ $\mu$m. The range of regulation with respect to velocity changes within limits of 10 $\mu$m/s to 0.5 m/s.

The module that has been developed can also be used to control the rate of rotation of motors containing a frequency sensor of the number of revolutions.

The laser modulator control module forms a direct-current control signal in the 0-2.048 V range, with a minimum discreteness of 4 mV. It contains a command decoder, a control register (RU), a pulse counter, gates and a digital-to-analog converter. The level of the digital-to-analog converter's output signal is given by a code register by the pulse counter. The control code is entered in the counter through the main line or from a pulse generator connected to the counter's counting input. Such modes are intended for use when the module is used in photographic plotting devices controlled by computers with different operating speeds. When the control code from the pulse generator is entered in the counter, the output voltage changes linearly. Entering the code in the counter through the main line makes is possible to establish a control signal level that changes according to a given law. The control code's maximum frequency must not exceed 100 kHz.

The service part of each of the modules that has been developed contains only a command decorder or a command decoder together with a service register. The decoder decodes the NAF commands used in the module. The service register contains two control triggers and two inquiry triggers that can appear in modules for various reasons, as well as two inquiry mask triggers and status triggers. Information is entered in the service register, from the main line, over the following entry buses: W2, W3 -- control triggers; W5-W7 -- status triggers; W9, W10 -- inquiry triggers; W13, W14 -- inquiry mask. The R buses with the appropriate numbers are used to read the service register.

The KAMAK commands used in the modules that have been developed are listed in the table on the next page.

Figure 2 /not shown/ is a picture of the KAMAK rack with a kreyt containing the special electronic modules and the general-purpose modules, the "Elektronika T3-16M" EKVM and a number of peripheral units. The modules shown in the picture are used in a precision, multigradation laser photographic plotter, the "Zenit-2" precision automatic photogrammetric unit, and the GZU-2 holographic memory, which are controlled by the T3-16M and the YeS-1010 and M-400 computers, respectively. Tests of the modules in these systems demonstrated their high accuracy and operational reliability.

Figure 3a /not shown/ depicts a photomask produced by the "Zenit-2" automatic photogrammetric unit. The recording of the photomask involved the use of the following modules: adapter, reversible counter, electric motor control (one each for the X and Y coordinates), number-pulse multiplier, reversible pulse-count divider and laser modulator control.

The mask's points are plotted in lines parallel to the X-axis, with the carriage holding the photographic carrier moving at a constant speed along both sides of the X-axis. In order to do this, the electric motor control module is set for the X coordinate in the mode of carriage movement at a constant speed, while for the Y coordinate it is set in the positioning mode. The sign of the code entered in the electric motor control module's reversible counter determines the carriage's direction of motion, while the magnitude of the code determines the speed. The mask's spacing with respect to the X coordinate is given by a code enter in the controllable number-pulse multiplier's data register.

When the carriage with the photographic carrier is moving along a line parallel to the X-axis, with given length increments formulated by the number-pulse multiplier and the controllable pulse-count divider, there is pulsed engagement of the laser, the intensity of which is determined by the computer. After the line is exposed in one direction, the carriage moves parallel to the Y-axis through the spacing determined by the code entered in the reversible Y counter of the electric motor control modulus and begins to plot the masks's elements whil the carriage moves in the opposite direction. After the original coordinate on the X-axis is reached, a new line is moved to, and the sign of the direction of motion changes, the entire mask production cycle is repeated.

| Name of Module | Commands | Buses Used | Content of Commands |
|---|---|---|---|
| Adapter | A(9)F(19) | W9, W10 = 1<br>W13, W14 = 1 | Selective setting of SR:<br>setting of inquiries 1,2,<br>setting of mask of inquiries 1,2 |
| | A(9)F(23) | W9, W10 = 1<br>W13, W14 = 1 | Selective suppression of SR:<br>suppression of inquiries 1,2,<br>suppression of mask of inquiries 1,2 |
| | A(9)F(1) | -- | Reading (SR):<br>R9, R10 -- inquiries 1,2,<br>R13, R14 -- masks of inquiries 1,2 |
| | A(0)F(8) | -- | Reading of inquiry from bus Q |
| Number-pulse multiplier | A(0)F(16) | W1-W24 | Entry in RD |
| Reversible counter | A(0)F(9) | -- | Suppression of RS |
| | A(0)F(16) | W1-W24 | Entry in RS according to S1, in RD according to S2 |
| | A(0)F(0) | -- | Reading of RS |
| Reversible divider | A(0)F(16) | W1-W16 | Entry in RD |
| Electric motor control module | A(0)F(9) | -- | Suppression of RS |
| | A(0)F(16) | W1-W24 | Entry in RS |
| | A(0)F(0) | -- | Reading of RS |
| | A(1)F(25) | -- | Start |
| | A(1)F(24) | -- | Stop |
| | A(2)F(16) | W1-W10 | Entry in TsAP RD |
| | A(9)F(19) | W2 = 1<br>W3 = 1<br>W9, W10 = 1<br>W13, W14 = 1 | Selective setting of SR:<br>autonomous control,<br>constant speed,<br>setting of inquiries 1,2,<br>setting of mask of inquiries 1,2 |
| | A(9)F(23) | W2 = 1<br>W3 = 1<br>W9, W10 = 1<br>W13, W14 = 1 | Selective suppression of SR:<br>control from computer,<br>positioning,<br>suppression of inquiries 1,2,<br>suppression of masks of inquiries 1,2 |
| | A(9)F(1) | -- | Reading of SR:<br>R2 -- COMPUTER/AUTO,<br>R3 -- positioning/constant speed,<br>R5 -- ON/OFF,<br>R6, R7 -- datum points 1,2,<br>R9, R10 -- inquiries 1,2,<br>R13, R14 -- masks of inquiries 1,2 |
| | A(0)F(8) | -- | Reading of inquiry from bus Q |
| Laser modulator control module | A(0)F(16) | W1-W10 | Entry in TsAP counter |
| | A(1)F(16) | W1 | Entry in RU |

The photomask -- a fragment of which is shown in Figure 3a -- contains 100 x 100 elements. The diameter of each of the elements is 100 μm. The grid spacing with respect to the X,Y coordinates is 130 μm. The maximum absolute error in the plotting of each of the elements does not exceed 0.5 μm with respect to both coordinates.

Thanks to the fact that the plotting of the mask of elements takes place without stopping during the time of exposure, the total production time for such a mask does not exceed 10 min.

Figure 3b depicts test tracks on vitreous chalcogenidic film that were obtained with a laser photographic plotter controlled by a T3-16M EKVM. The recording of the test tracks is analogous to that of the photomasks's elements, the only difference being that on any of the lines (which are concentric circles), there is a linear change in the control code every time the laser is engaged. The line width is 10 μm, and the absolute error in the drawing of any of the lines does not exceed 0.32 μm.

These examples show that the modules that have been developed can be used extensively in automated measuring systems, in installations for the synthesis of elements of the motion picture type, in the production of the phototemplates of integrated circuits, and in the monitoring and measuring units used in the production of computer memories on magnetic disks with capacities of more than 100 Mbytes.

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# AN AUTOMATED COMPLEX FOR PROCESSING IMAGES

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/Article by L.V. Buryy, Yu.N. Zolotukhin, V.A. Ivanov, V.S. Kirichuk, V.P. Koronkevich, Yu.Ye. Nesterikhin, A.K. Potashnikov, B.M. Pushnoy, G.P. Cheydo, A.M. Shcherbachenko. N.S. Yakovenko and A.P. Yan, Novosibirsk/

/Text/ This article gives a brief description of an installation for the processing of aerospace information -- a high-resolution automated complex for processing images recorded on a transparent carrier -- that has been realized at the Institute of Automation and Electrometry of the USSR Academy of Sciences' Siberian Department. The work discussed here was done within the framework of the Siberian Department's general program for the creation of the "Sibir'" Central Computer Complex Network.

Principles of construction of the complex:
utilization of a hierarchical, multicomputer complex with specialization of the computers in it;
extensive use of KAMAK equipment, both for equipment control and to provide communication between the components of the complex;
utilization of a complete functional set of devices for the input and output of information and the registration and visualization of images (developed at the Institute).

Purpose of the complex:
automatic entry in a computer of the optical density and coordinates of an image recorded on a photographic carrier;
processing of images in dialog and automatic modes;
registration of the original information and the results of processing on display screens and photographic and paper carriers;
creation of a data bank on magnetic disks and in a holographic memory.

Functional Diagram of the Complex. The first stage of the complex has now been completed (Figure 1). Communication between objects in the complex is provided by a standardized main-line information exchange system (UMSO) that is realized in the KAMAK standard. This structure makes it easy to reorganize the complex, replace peripheral gear, and enlarge its functional capabilities without rearranging the existing basic software. KAMAK equipment is used not only for the realization of the communication facilities, but also to control the information input-output devices.

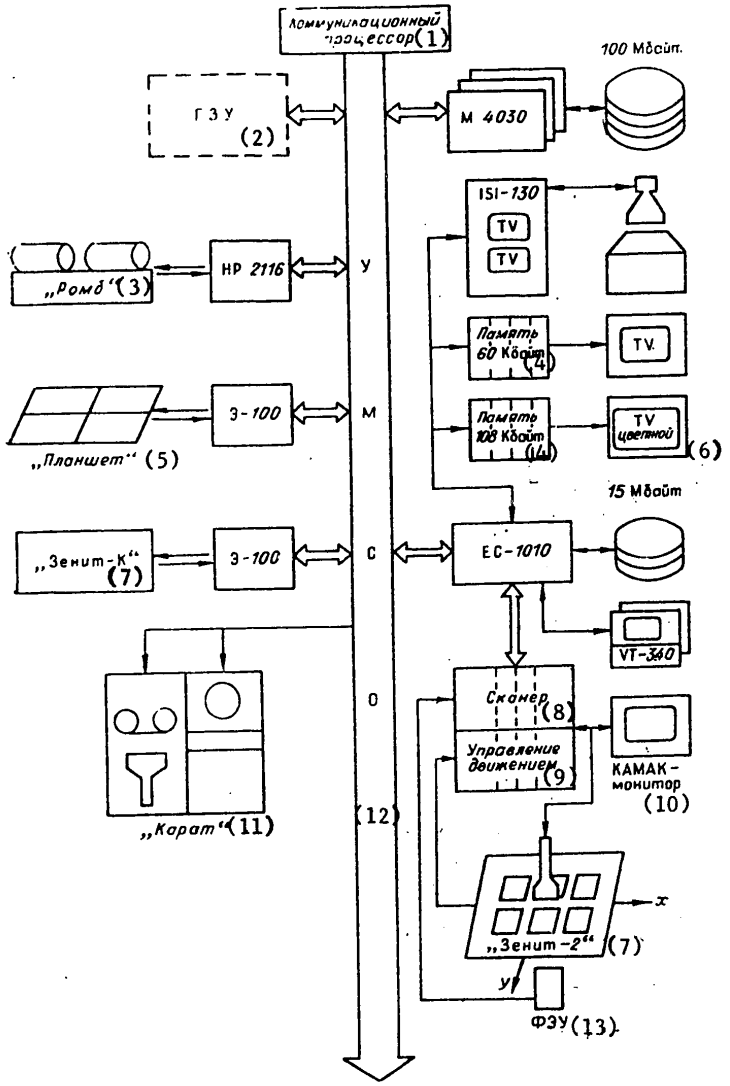

Figure 1.

Key:
1. Communication processor
2. Hologram memory device
3. "Rhombus"
4. ...-Kbyte memory
5. "Plotting Board"
6. Color television
7. "Zenit-."
8. Scanner
9. Movement control
10. KAMAK monitor
11. "Carat"
12. UMSO
13. Photomultiplier

Computer equipment for the complex. Specialization of the computers in the complex made it possible to create program-independent systems software for each of them and made it possible to use them in an independent mode.

The complex contains:
a YeS-1010 computer for realizing the dispatcher functions, control the "Zenit-2" unit, performing primary processing and realizing the adaptive information-reading algorithms;
an "Elektronika-100I" computer for controlling the "Plotting Board" graph plotter and encoder;
an NR2116 computer for controlling the "Rhombus" optical information input-output unit and performing primary information processing;
an "Elektronika-100I" computer for controlling the "Zenit-K" unit and performing primary processing of the information obtained from it;
a complex of three M4030 computers with disk storage having a capacity of 100 Mbyte, for the purposes of prcessing information and creating data banks for the results of the processing.

Image input devices. A "Zenit-2" automatic photogrammetric unit for reading images with 6-μm resolution on a 420 x 420 mm field /1-4/.

A "Zenit-K" automatic photogrammetric unit for the input of microimages with 2-μm resolution on a 1 x 1 mm field /5/.

A "Rhombus" unit for image input and output with 25-, 50- and 100-μm resolution on a 130 x 180 mm field /6/.

Dialog and visualization devices. A KAMAK monitor for visualization of the scanning field with the capability of changing the image's scale.

A halftone display for output of halftone images and processing results on a television monitor screen.

A color display for output of colored images on a television monitor screen.

Recording devices. A "Carat" unit for recording archive-type graphic material -- including material for the holographic memory device (GZU) -- on movie film and a video monitoring screen /7/.

A "Plotting Board" unit for the output of graphic material on a paper carrier /8/.

The presence of a complete functional set of input-output, recording and visualization devices makes it possible to carry out a full processing cycle with this complex, from information input to the obtaining of the needed graphic material and the entry of the obtained results in the data banks.

Specifications of the Equipment in the Complex. "Zenit-2." In this complex, the basic tool for reading images is the "Zenit-2" automatic photogrammetric unit. It utilizes a combination of an electronic scanning unit with an opticomechanical movement system /9/.

The presence of a program-controlled grating (on command from the computer, the light spot can be placed on any of 4,096 x 4,096 points on the cathode-ray tube's screen) and the use in the tracking drive of a movable carriage with a photographic carrier having precision laser displacement measurement devices fundamentally distinguishes this automatic unit from the scanning systems that are widely used. This principle makes it possible to regard an image as an external computer memory with a capacity of $10^{11}$ bytes.

The "Zenit-2" automatic unit's specifications are: maximum image size -- 420 x 420 mm; accuracy of positioning of scanning spot -- 2 $\mu$m; scanning spot diameter -- 6 $\mu$m; range of measurement of optical density -- 0-2; time of measurement of optical density at a single point -- 10 $\mu$s; number of registerable levels of optical density -- 256; signal-to-noise ratio -- 50.

It became possible to achieve such parameters with the help of digital correction methods, which are used to reduce the effect of nonlinearity of the beam deflection system and the optical density reading channel, eliminate vin'yetirovaniye /translation unknown/ of the object glass, and equalize the coordinates of the mechanical movement system. Correction of all these systematic errors is performed by a separate unit that is realized in the KAMAK standard.

Program control of the scanning system makes it possible to use processing algorithms that operate with only that information that is essential at the given stage of the work; that is, to avoid total input of the image information into the computer. In connection with this, there is a significant reduction in both the volume of computer memory that is used and the time required to process the information.

The presence of this capability is especially important for problems involving the searching of areas with given features, processing astronomical negatives, and working with several photographs of the same object (stereopairs, MKF-6 photographs and so on).

"Zenit-K." The "Zenit-K" automatic photogrammetric unit differs from the "Zenit-2" by the absence of precision mechanics and the presence of replaceable optics. The purpose of this unit is to analyze and process objects with dimensions that do not not exceed those of the scanning grating. The replaceable optics make it possible to vary the field's size from 40 to 1 mm, while the scanning spot's diameter can be changed from 40 to 2 $\mu$m. This unit's good resolution makes it possible to analyze micro-objects down to several microns in size.

"Rhombus." This unit is used in the complex both to solve problems requiring continuous reading of images and to produce images and processing results on a photographic carrier.

Image-depiction and dialog facilities. At the present time, most practical image-processing problems are not subject to full automation (neither the memory nor the operating speed of modern computers is adequate). The natural outcome of this is the creation of a dialog processing system. The human participation consists of target designation, making decisions about the direction of further processing, and assisting in controlling the complex in a complicated situation. Therefore, the complex under discussion is equipped with visualization devices of different types that enable the operator to follow the course of the processing and intervene in it on an operational basis.

The complex includes the following equipment:
a halftone KAMAK monitor that is used to survey the scanning field, look for desired areas, and trace (manually) the boundaries of formations (number of scanning elements -- 256 x 256, retransmission frequency -- 16 Hz);
a halftone television monitor that is used to display halftone images and processing results on the screens of series-produced black-and-white television sets and that has an independent memory for storing and retransmitting a halftone image (number of scanning elements -- 256 x 384, number of brightness levels -- 32, recording speed -- 300,000 points/s, retransmission frequency -- 50 Hz);
a color television monitor that is used to display color images and processing results on the screens of series-produced color television sets (number of scanning elements -- 256 x 384, number of brightness levels for each color -- 8, recording speed -- 300,000 points/s, retransmission frequency -- 50 Hz).

The presence of a color television monitor in the complex enlarges the information possibilities of a representation substantially. On the color monitor's screen it is possible to visualize images synthesized in a computer and, by selecting the coloration, to distinguish poorly contrasting details, superimpose several black-and-white images and so on.

The inclusion of television monitors in the complex has also resulted in a significant acceleration in the debugging of processing programs, since it makes it possible to observe the course of program implementation on the monitors' screens.

The investigator needs the results of the processing not only in the form of digital information, but also (as a rule) in the form of graphic material and images (contours of objects, graphs of different distributions, the image immediately after the completion of processing and so forth). Therefore, image-recording devices are included in the complex: a "Carat" photographic plotter and a "Plotting Board" photographic plotter and encoder. The purpose of these devices is a rapid printout of graphic information on photographic and paper carriers.

Software for the Complex. At the present time we have completed the development of a set of systems programs, the basic purposes of which are to provide interaction among the complex's users and a dialog processing mode, as well as to create comfortable (from the user's viewpoint) conditions for working on image input and processing.

The complex's systems software makes it possible to realize exchanges between the complex's devices; read information from sections of an image with a given orientation, size and magnification; produce graphic information with the "Carat," "Plotting Board" and "Rhombus" devices; represent a fragment of a scanning field on the KAMAK monitor, change its scale and move along the scanning field; produce images and processing results on the halftone and color monitors, with the capability of carrying out given amplitudinal converstions of the signal; carry out target designation of areas and manual tracing of boundaries; enter the coordinates of fragment boundaries and necessary points in the computer's memory and store this information and processing results on external carriers.

Functions of the complex's special software: track an object's boundaries relative to density, textural features and a change in the mathematical description; search for objects differing in density from the background; determine the geometric and photometric characteristics of separable or indicated areas and objects; realize amplitudinal conversions of original fragments of an image (filtration, calculation of averages, gradients, Laplacian operators, running dispersions and so on); determine textural features of an image on the basis of a matrix of estimates of transient probabilities; classify objects and areas.

On the basis of the special software that has been developed, at the present time we are creating image-processing programs that are oriented toward the solution of the following problems:

1. Analysis of an image of micro-objects. Micro-objects (5-6 μm and larger in size) are searched for and the boundaries and parameters characterizing the object's geometry and the distribution of its optical density are determined. The values of these parameters are transmitted to the M4030 computer, where object classification takes place /10,11/.

2. Processing of astronomical negatives. Here the problem consists of searching for star and quasar images, determining their position (1-μm accuracy on a 300 x 300 mm field is required) and dimensions accurately /12/, and identifying stars automatically /13/.

3. Processing photographs taken in space with the MKF-6 camera. In order to work with space photographs, we have developed a cassette (for the "Zenit-2" automatic unit) that makes it possible to arrange six spectral photographs in a mutually parallel position, thereby eliminating the turning operation from the fragment superimposition programs. The mean-square error in the correlation of the photographs is 1-1.5 μm in a 420 x 420 mm field. The time required to correlate the photographs according to nine reference crosses is less than 3 min, while insuring mutual parallelness takes 2 min; that is, the total time required to correlate six photographs is 25-30 min.

The use of the complex also makes it possible to solve such space photograph processing problems as obtaining synthesized color images of a site, searching for and analyzing homogeneous areas, conducting a textural analysis of separable or indicated areas for the purpose of classifying them /14/, and searching for and tracing the boundaries of formations and objects.

Conclusion. The automated complex that we have been discussing makes it possible to read and process information quite rapidly, as well as to represent the results of the processing operationally and in a convenient form. The use of modern input-output devices and the software that was developed made it possible to create, on the basis of the "Zenit-2" automatic unit, a highly accurate and productive system for processing images that has no analogs in Soviet practice.

Further development of the complex is oriented on a substantial increase in its operating speed and improvement of the ease with which the operator works with it (improvement of the quality and resolution of the terminal units and the introduction of spcial parallel-action processors).

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## A DIGITAL SYSTEM FOR STORING AND PROCESSING TELEVISION PICTURES FOR ASTROPHYSICAL RESEARCH

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/Article by Yu.Yu. Balega, A.N. Kasperovich, Yu.A. Popov, N.N. Somov and A.F. Fomenko, Nizhniy Arkhyz-Novosibirsk/

/Text/ Introduction. In astronomy, the use of television systems to record low-brightness images has a number of advantages over photographic methods. They are realized in full measure with the help of digital data collection systems that have a high operating speed and a sufficiently large memory. The input speed and memory of modern computers are inadequate for real-time operations with a television picture. In order to solve several practical problems of astrophysics, it has been possible to circumvent these difficulties by creating specialized high-speed systems /1,2/.

The Special Astrophysical Observatory of the USSR Academy of Sciences, together with the Institute of Automation and Electrometry of the Academy's Siberian Branch, has developed a high-speed automated system for storing and processing television pictures with frame formats of 256 x 256 and 128 x 512 elements. The system is capable of recording television pictures with a frame frequency of 60 or 30 Hz from the screen of an image converter tube (EOP) used as a preliminary brightness amplifier both in the analog signal mode and in the individual photon counting mode, in addition to performing arithmetic and logic operations with these pictures.

Block Diagram of the System and Organization of Storage. Figure 1 is a block diagram of the image storage and analysis system. After an image's brightness is amplified by the EOP, it is scanned by a high-sensitivity television tube. From the tube, the video signal enters the input of a 5-bit analog-to-digital converter (ATsP) or the input of a device for the synchronous determination of the centers of flashes (when the photons are being counted). After being converted to digital form, the image is enter in a high-speed storage system (BSN). In the system's memory, which has a capacity of 64K 12-bit words, the image is stored either by the addition of frames or by the addition of units with respect to addresses found by the device for determining the centers of the photon flashes. Through a digital-to-analog converter (TsAP), the memory's contents enter a monitor. In order to transmit control commands and exchange information, the system is connected to an "Elektronika-100I" computer by a standard, programmable communication channel. There is also a channel for direct processor access to the BSN's memory that makes

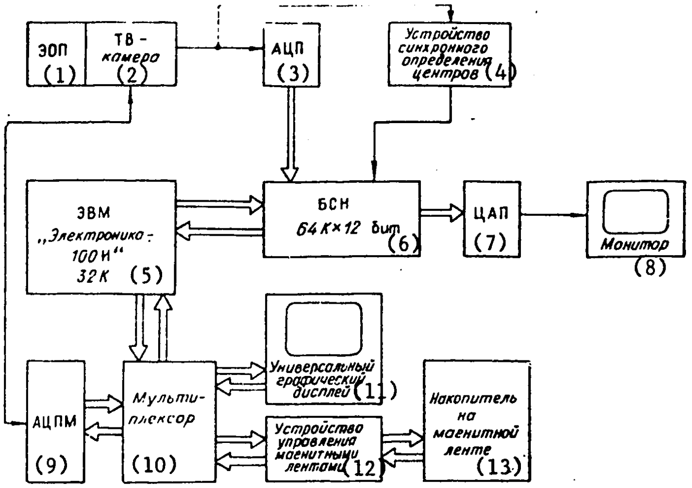

Figure 1.

Key:
1. EOP
2. Television camera
3. ATsP
4. Unit for synchronous determination of centers
5. 32K "Elektronika-100I" computer
6. BSN (64K x 12 bits)
7. TsAP
8. Monitor
9. ATsPM
10. Multiplexor
11. General-purpose graphic display
12. Magnetic tape control unit
13. Magnetic tape storage

it possible to process pictures without entering them in the computer. In the real time mode, when the system's memory is engaged in storing or reproducing data the computer's processor can work with the external memory only during inversion of the frame-scanning process.

A graphic display (for an experimenter-system dialog), a multichannel analog-to-digital converter (ATsPM) (used to collect data from the system's control points) and a magnetic tape storage unit (used as an external memory) are connected to the computer through a multiplexor. For feedback with the experimenter, there are two kursory /translation unknown/ that are illuminated on the monitor's screen in the form of blinking points. The kursory are controlled by a program and their contents and coordinates are shown on the display.

The basic components of the BSN (Figure 2) are eight external MOZU (magnetic core storage) units, an "Elektronika-100I" computer, a synchronization and control unit, an arithmetic-logic unit (ALU), multiplexors A and B, and a unit for communication with the computer. For operation in real time on a frequency of 4.5 MHz, the MOZU units operate in the conveyor mode, which is realized with the help of a 16-bit address counter: through the address multiplexor and the decoder, the three low-order bits start the MOZU units in sequence, the next 12 bits determine the cell's address, and the highest-order bit is used to select one or two memory arrays that are in all the MOZU units. As a result, access to each unit is realized in 1.7 μs, while sequential entry and reading of information is done with an interval of 220

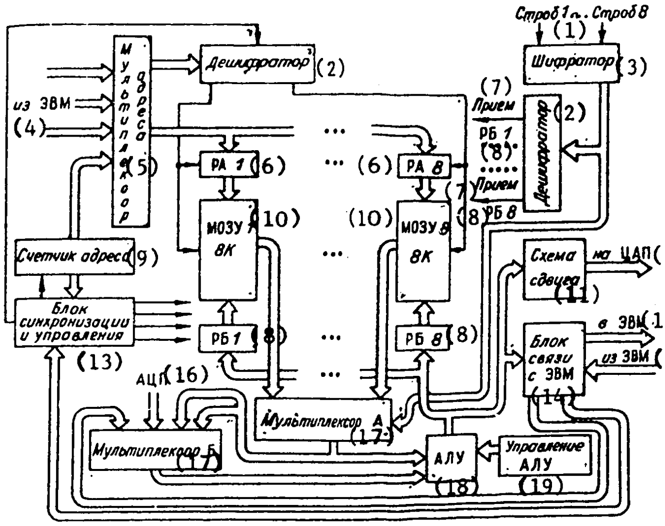

Figure 2.

Key:
1. Gate 1. . .Gate 8
2. Decoder
3. Encoder
4. From computer
5. Address multiplexor
6. RA .
7. Reception
8. RB .
9. Address counter
10. MOZU . (8K)
11. Shift circuit
12. To TsAP
13. Synchronization and control unit
14. Unit for communication with computer
15. To computer
16. ATsP
17. Multiplexor .
18. ALU
19. ALU control

ns. The units' output buses are connected through the multiplexor to the ALU, which sums a single "Center of Photon Flash" signal or the ATsP's output code with the contents of the BSN memory cell. The synchronization unit controls the BSN's operation and formulates the line and frame synchronizing impulses for the standard television equipment that is connected to the system. The frame change frequency can be 60 or 30 Hz for 256 x 256 or 128 x 512 scanning elements per frame.

Analog Storage. In the analog recording mode, a code passes from the ATsP through multiplexor B into the ALU and, after summation, is fed into the buffer register (RB) bus. Through the shift circuit and the TsAP, the ALU's output modulates the brightness of the monitor's beam, which is synchronized with the memory.

One effective method of increasing the signal-to-noise ratio during the observation of weak objects is to have the system's memory integrate an image that was preliminarily stored in the television tube's target. In the system there are provisions for the setting of a storage time corresponding to the duration of 1-$16^6$ frames. In connection with this the control unit forms a signal that locks the tube during the exposure time. When a 5-bit ATsP is used and when the video signal in the BSN is at its maximum amplitude, at least 128 frames can be added without overfilling the memory cells. As an illustration of the effect of analog storage we can use the image of the globular cluster M5 (Figure 3 /not shown/), which was obtained in the BSN during a laboratory simulation of this operating mode.

Panoramic Counting of Photons. A broad circle of astrophysical problems is related to the registration of very weak light flows, in connection with which it is necessary to preserve the linearity and spatial resolution of the image that is obtained. The use of an EOP with high amplification makes it possible to obtain sufficiently intensive light flashes on the output screen, even from single photoelectrons.

The dimensions of the radiating element of the EOP's target exceed those of the counting tube's resolution element, and although a separate photoelectron even should be registered by only a single memory element, for registration in the BSN a group of cells corresponds to the event, which leads to a loss of spatial resolution. In order to improve the resolution, the system utilizes a device for the operational determination of the centers of photon flashes /3/ that is a specialized processor operating according to a rigidly assigned program and working with the current video signal and the contents of the auxiliary operational memories at a speed that corresponds to television scanning. The coordinates of the centers of the photon flashes, as determined by the processor, indicate the addresses of memory cells, the contents of which are increased by one. The procedure for determining the photon flashes' centers makes it possible to improve the system's resolution by a factor of 2-3 for operation in real time and in the photon storage mode.

A fragment of a television frame with a digital image of Galaxy NGC5248, which was obtained by projection from a poorly illuminated photographic negative (the average value of the flow in the area of the image is 50 photoelectrons per channel per hour) is shown in Figure 4a /not shown/. The resolution is limited by the dimensions of the electron cell (50 $\mu$m), which corresponds approximately to 20 $mm^{-1}$, a figure that is close to the resolution of the EOP that has been used. Part of the spots in the image are the tracks of bright flashes from the preceding frame; their existence is explained by the time lag of the television tube's target. As is the case with intensive ion flashes, most of them are discriminated by the processor. Figure 5b shows the result of the summing together of 20 frames recorded in the determination-of-the-centers-of-photon-flashes mode. Figure 4c illustrates the result of a 30-minute accumulation in this mode. It should be mentioned that these frames were obtained under conditions of severe "noisiness" in the image caused by thermoelectronic emissions from the EOP's photocathode (internal noise in the system), since the recording took place at room temperature. Despite this, the spiral arms of the Galaxy arising from individual photons can be traced even for an accumulation time of 0.3 s. The vertical bands in the photograph are explained by sighting lines appearing in the video channel when the system is operating.

As preliminary research has shown, the system's linearity when it is operating in the photon-accumulation mode is quite high: the dynamic range is 1-$10^4$ photons per channel per hour, which corresponds to typical weak flows in astronomical investigations.

Conclusion. One important feature of the system that has been developed is the possibility of direct processing of images in a computer for the purpose of improving or analyzing them. The following types of processing are provided for in the system: restoration and digital filtration, visual analysis and mathematical processing itself. Restoration is primarily understood to mean the elimination of instrument distortions on the basis of Fourier and autocorrelation analyses, allowing for the nonuniformity of the receiver's sensitivity, eliminating permanent defects related to flaws in the television tube's target and so on. The system makes it possible to obtain, during the storage process, cross-sections of images in arbitrary directions and to determine (with the help of kursory) intensities at any points in an image. Graphic and literal information can be displayed on the monitor's screen, in parallel with the data that are being accumulated.

This system is intended for use in astrophysical research as a panoramic photon counter, so that maximally weak objects can be studied, as well as for the panoramic storage of images with increased brightness. There have also been discussions concerning the possibility of using the system for interferometric work (in combination with a special processor) and for high-speed microdensitometry of astronomical photographs.

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## A PACKAGE OF PROGRAMS FOR CALCULATING THE CHARACTERISTICS OF INTENSIVE BEAMS OF RELATIVISTIC CHARGED PARTICLES

Novosibirsk AVTOMETRIYA in Russian No 3, May-Jun 80 manuscript received 13 Jul 79 pp 92, 98

/Excerpts from article by V.T. Astrelin and V.Ya. Ivanov, Novosibirsk/

/Excerpts/ Introduction. The development of electronic-optical systems with highly accurate relativistic beams is made substantially easier when numerical methods are used to calculate the electrical fields and solve the problem of the distribution of the beams of charged particles while allowing for the external and intrinsic electrical and magnetic fields. Questions relating to the numerical modeling of beams have been discussed in a number of works. The most nearly complete bibliography is given in /1/.

The programs described below are intended to be used for the solution of standard problems in two-dimensional axially symmetric or plane-parallel cases. The algorithms for calculating the characteristics of electrostatic fields are based on the method of integral equations from the theory of potential, using the splaynovaya /translation unknown/ approximation of the density of surface charges. Relativistic equations in the pulse form are solved with due consideration for all the components of a beam's external and intrinsic fields.

The package of programs under discussion is a component part of the TOPAZ machine planning automation system, which is now being developed at the Computer Center of the USSR Academy of Sciences' Siberian Department. The programmed modules that make up this package make it possible to solve the following types of problems:
calculating the electrostatic potentials and fields of a system of electrodes with given potentials in the presence of interfaces with various dielectric mediums and conditions for the symmetry and periodicity of the solution;
calculating the fields of a system of electrodes with given potentials or full charges on them ((Roben's) problem);
calculating the trajectories of particles of different types in external electrical and magnetic fields with different particle emission laws, as well as the particles' angular and energy distributions;
calculating the self-congruent fields and trajectories of intensive beams of charged particles, with due consideration for their space charge and all the components of the particles' intrinsic magnetic field in the relativistic case.

The component parts of the package are a translator with the program-oriented SYeZAM language for describing the input data, algorithmic modules for calculating the electrostatic fields and trajectory analysis, and a system for the graphic processing of the output information. The package has documentation in the INFORMATOR form -- directions for the use of the system that are stored in the computer's external memory.

All of the modules that realize numerical algorithms are written in FORTRAN, while the translators from problem-oriented input languages are written in ALGOL-GDR, which has an apparatus for working with line and bit values. An insignificant part of the modules are written in the MADLYeN assembly language in order to insure maximum operacing speed. The total volume of the package is about 3,700 punched cards. The basic software for photographic plotters -- the SMOG system -- is used in the library programs. It should be mentioned that the package has undergone many years of careful checking, both on methodological problems (which make it possible to evaluate the algorithms' accuracy and operating speed) and for calculations in quite complex and variegated practical problems of the electrostatistics and electron optics of intensive electron-ion relativistic beams /6-8/.

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# PUBLICATIONS

## ABSTRACTS FROM THE JOURNAL 'AUTOMETRY'

Novosibirsk AVTOMETRIYA in Russian No 3, May-Jun 80 pp 127-130

UDC 539.107.5

### SOME CRITERIA FOR SELECTING THE COMPUTER IN AUTOMATED HIGH-ENERGY PHYSICS SYSTEMS

/Abstract of article by I.F. Kolpakov/

/Text/ The author discusses some criteria for selecting the program sources in the automated systems of spectrometers with wire chambers (SPK) that are used in high-energy physics. SPK's receive information from m classes of events with intensity n during an accelerator pulse with duration $t_i$ during a working session $T_p$. The author gives expressions for the exchange channels' capacity $C_0$, and the buffer ($S_b$) and mass ($S_m$) memory volumes. He compares large and small computer, micro-computers and intelligent controllers in a kreyt /translation unknown/ according to the following characteristics: capacity of the exchange channels $C_0$, number of peripheral gear addresses M, cost of connecting peripheral gear, buffer and mass memory volumes, configuration cost $E_k$ and mean time between failures. The results of the comparison are presented in the form of histograms and graphs that make it possible to select a program source on the basis of proposed criteria. Figures 5, references 14.

UDC 529.107.5

### CRITERIA FOR SELECTING STANDARD INTERFACES

/Abstract of article by I.F. Kolpakov/

/Text/ The author suggests the following criteria for comparing exchange devices: capacity in the block transmission mode, capacity according to number of information sources and receivers and program sources, relative cost (site cost), extent and mean time between failures. He determines the cases where it is necessary to use a standard interface as an exchange device and, using the suggested criteria, compares the standard interfaces of compact systems: a kreyt /translation unknown/, a branch, a multicontroller KAMAK kreyt, a byte main line and extended systems (a sequential KAMAK main line and communication interfaces, as well as the high-speed main line that is being developed). The results of the comparison are presented in the form of histograms and graphs that define the limits of utilization of standard interfaces. The author shows that the use of standard interfaces for medium-sized and large systems yields a substantial gain in comparison with the direct utilization of computer exchange channels. Figures 7, references 18.

UDC 519.219:519.22:519.223:519.226:519.254:528.7

### SEGMENTATION OF IMAGES

/Abstract of article by V.A. Ivanov, V.S. Kirichuk and G.I. Peretyagin/

/Text/ The authors discuss one of the basic problems of the segmentation of images: the discrimination of fragments with statistically equivalent properties. Here the key is the selection of the model of the image's texture. With this end in view, the authors describe images as random Markov fields (MSP), the basis of which is the relationship of each component of the field to its neighbors. They prove that the set of sufficient statistics for an MSP consists of the neighborhood's frequency $n_k$ (k, = i, m) and the k-th and -th levels of the optical density on a digitalized image. Checking the uniformity of the textures of two fragments comes down to checking a multiple hypothesis on the equality of the probabilities ($P_k^1$ and $P_k^2$ ) of the neighborhood of the k-th and -th levels that correspond to the fragments being compared. The authors find the asymptotic, uniformly most powerful, invariant criterion for testing this homogeneity hypothesis. They also present experimental results. Figures 3, references 11.

UDC 681.3:681.7.014

### CORRELATION WITH A STANDARD -- AN EFFECTIVE METHOD FOR DETECTING THE ANISOTROPIC PROPERTIES OF IMAGES

/Abstract of article by M.S. Alyavdin, S.L. Gorelik, B.M. Kats, Ye.G. Mikhelevich, V.S. Noshchenko and A.I. Ofin/

/Text/ On the basis of a determination of the spatial heterogenity of textures as statistically significant variations in characteristics measured in different areas of an image, the authors propose a method for deriving indicators characterizing the anisotropic properties of textures. The indicators are obtained by analyzing the original image's correlation function with an anisotropic standard. As an example, the authors discuss the case of correlation with a straight line. The mutual correlation function is calculated on the basis of the method of nonpoint representations. The authors propose methods for the programming and equipment realizations of the method and discuss the results of experimental studies of the anisotropic properties of textures, using images of cloud fields as an example. Figures 7, references 7.

UDC 681.142.6:621.397

### A DISPLAY-TYPE PROCESSOR FOR AUTOMATED IMAGE PROCESSING SYSTEMS

/Abstract of article by I.M. Bokshteyn and L.P. Yaroslavskiy/

/Text/ The authors discuss the structure of a device for the dynamic visualization and specialized processing of images: a display-type processor that is defined by the set of functions it performs. They present data on the structure of the display processor's units -- memory and arithmetic and control units -- as well as the facilities needed to conduct a dialog. They also describe the prototype of this display-type processor, which was built at the USSR Academy of Sciences' Institute of Information Transmission Problems. Figures 3, references 9.

UDC 681.2.082

ALGORITHMS FOR SEARCHING FOR POINT LIGHT OBJECTS AT THE OPTIMUM SPEED

/Abstract of article by V.M. Yefimov, A.A. Nesterov and A.L. Reznik/

/Text/ The authors discuss optimum (from the viewpoint of operating speed) algorithms for detecting an unknown Poisson source. They present different algorithms for both single-stage and multistep optimum searching that were obtained as the result of the solution of the corresponding extreme problems. References 2.

UDC 65.012.122

ON THE SOFTWARE FOR SYSTEMS FOR THE AUTOMATIC DESIGNING OF ELECTRONIC OPTICAL SYSTEMS

/Abstract of article by V.P. Il'in/

/Text/ The author discusses the methodological principles of the development of software for systems for the automatic designing of electronic optical systems. He describes the mathematical formulation of the problems related to calculations for an extensive class of electronic instruments. He also gives a review and a comparative analysis of the numerical methods for solving them. The author also describes problems encountered in the technology of the development and functioning of a package of design programs. Figures 1, references 25.

UDC 621.384:681.7.069.32

A PROBLEM-ORIENTED LANGUAGE FOR DESCRIBING DATA FOR THE EXTREME PROBLEMS OF ELECTRONIC OPTICS

/Abstract of an article by V.Ya. Ivanov/

/Text/ The author describes the formulation of goals for the optimization of the characteristics of image-forming electronic optical systems, a problem-oriented input language for the description of the data, and a translator, all of which are components of the information support for the TOPAZ automated design system. The use of specialized software makes it possible to increase the flexibility of the control over the computation process, the clearness and compactness of the representation of input data with a complex structure, and the reliability and operational nature of the human-computer dialog during the automated designing of an extensive class of electronic instruments. The author also presents examples of the use of the basic constructions of the EZOP language. Figures 1, references 2.

UDC 681.327.12

A GENERAL-PURPOSE, AUTOMATED SUBSYSTEM FOR ENCODING COMPLEX FORMS OF GRAPHIC DATA BASED ON A PROGRAMMABLE COORDINATE MEASURING DEVICE OF THE PLOTTING BOARD TYPE

UDC 681.327.12

# A GENERAL-PURPOSE, AUTOMATED SUBSYSTEM FOR ENCODING COMPLEX FORMS OF GRAPHIC DATA BASED ON A PROGRAMMABLE COORDINATE MEASURING DEVICE OF THE PLOTTING BOARD TYPE

/Abstract of article by G.P. Aparin and V.N. Samuilova/

/Text/ The authors propose and discuss a class of structural realizations of ergaticheskiy /translation unknown/ subsystems for encoding complex forms of graphic data in the form of drawings, maps, diagrams and other line figures with accompanying symbol information. These realizations are simultaneously effective as far as the criteria of ergonomichnost' /translation unknown/, flexibility, productivity, realiability and cost are concerned, and are based on a single programmable and functionally rearrangeable (in the time-sharing mode) multifunctional coordinate measuring device of the plotting board type that operates on-line with a computer. Figures 1, references 8.

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