MEMORANDUM
RM-3797-PR
AUGUST 1963

SOVIET CYBERNETICS TECHNOLOGY: II GENERAL CHARACTERISTICS OF SEVERAL SOVIET COMPUTERS

Edited by Willis H. Ware and Wade B. Holland

PREPARED FOR:

UNITED STATES AIR FORCE PROJECT RAND

The RAND Corporation
SANTA MONICA • CALIFORNIA

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PREFACE

This Memorandum brings together a number of translations undertaken at The RAND Corporation on the subject of Soviet computers and computing hardware. A limited amount of commentary and annotation has been included; however, since there is often a high degree of inconsistency between different articles emanating from the Soviet Union concerning the same machine, it can be treacherous to rely too much on any single source in drawing definitive conclusions. Furthermore, even though some of the included articles are fairly recent, they concern machines known to have been designed several years ago.

The value of this collection is in the inclusion of information on two little-known computers, the "Luch" (a Byelorussian machine) and the "EPOS" (a Czechoslovakian product), and some commentary on the "Ural-4," the latest known member of that series of computers. Additionally, an article on the "BESM-II" provides a good example of an article that contradicts information from other sources.

The series, Soviet Cybernetics Technology, is part of a continuing program of research in computer technology conducted by The RAND Corporation, under U.S. Air Force Project RAND. Its purpose is to keep computer specialists interested in Soviet computing technology and cybernetics informed about Soviet publications, activities, and new developments in these areas.

All translations undertaken at The RAND Corporation are registered with the Office of Technical Services, Department of Commerce, Washington 25, D.C.

SUMMARY

The translations contained in this Memorandum concern the following Soviet and Soviet bloc computers:

"Ural-2"	Soviet Union
"Ural-4"	Soviet Union
BESM-II	Soviet Union
"Razdan-2"	Armenian SSR
MN-10	Soviet Union
MN-14	Soviet Union
"Luch"	Byelorussian SSR
"EPOS"	Czechoslovakia

In Chap. 1 is presented a short translation introducing the subject of Soviet Computing technology and specifying some areas of computer application considered to be of special importance.

The "Ural" and BESM series of computers (Chaps. 2-4) are widely known and well covered in the literature. The "Ural-4" is the most recent member of that series. The BESM-II described would appear to be a modified version of that machine, since the description contained herein does not agree with the bulk of the literature concerning it.

The "Razdan-2" (Chap. 5) represents a major effort by one of the newer computing centers to pioneer new design techniques. The "Razdan" series was the first in the Soviet Union to be fully transistorized.

Two analog computers, the MN-10 and MN-14, are described in Chap. 6, followed by a brief, non-technical article (Chap. 7) on the Byelorussian "Luch" computer. The last chapter considers the "EPOS" being built in Czechoslovakia, which, although considerably behind the U.S. and the Soviet states of the art, was being designed for serial production.

FOREWORD

The translations contained in this Memorandum were completed at various times during the past 18 months and preliminary versions were circulated to a limited audience. Each has been reworked during the interim, in the hopes of improving accuracy and the general quality of the translation.

The series, Soviet Cybernetics Technology, was established in late 1961 at The RAND Corporation to provide a vehicle for distributing translations and analyses on the subject of Soviet computer technology and cybernetics. Vol. I in the series, devoted to cybernetics' applications, was released in June 1963.* Vol. III, to be released later this year, will cover programming fundamentals of the BESM, "Strela," "Ural," M-3, and "Kiev" computers.**

Interest in this subject matter at RAND was heightened by a 1959 visit to the Soviet Union of a U.S. technical delegation on electronic computers. Paul Armer and Willis H. Ware, from the Computer Sciences Department at RAND, were among the eight members of the group. An extensive trip report and analysis of the Soviet state of the art was produced upon their return.*** This report is especially

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*Ware, Willis H., and Wade B. Holland, (eds.), Soviet Cybernetics Technology: I. Soviet Cybernetics, 1959-1962, The RAND Corporation, RM-3675-PR, June 1963.

**Ware, Willis H., and Wade B. Holland, (eds.), A. S. Kozak, (trans.), Soviet Cybernetics Technology: III. Programming Elements of the BESM, Strela, Ural, M-3, and Kiev Computers, The RAND Corporation, RM-3804-PR, (to be released).

***Ware, W. H., (ed.), Soviet Computer Technology--1959, The RAND Corporation, RM-2541-PR, March 1, 1960 (hereinafter referred to by title only). Reprinted in IRE Transactions on Electronic Computers, Vol. EC-9, No. 1, March 1960.

recommended to those interested in Soviet machines, since it contains first-hand information on a number of computers, including the BESM, "Ural," "Strela," "Kiev," and others.

Other volumes in the series will be released from time to time, as new material is received and translated.

CONTENTS

FIGURES

Chapter 1

"ELECTRONIC COMPUTERS"

RAND EDITORS' INTRODUCTION

Some basic computer design principles are set forth in the book Electronic Computers,* published in 1961, the preface of which appears on the following pages. It assumes little knowledge of computer technology, but does require a background in higher mathematics. The Preface helps to convey the attitude which prevails in Soviet technical circles concerning the importance of the electronic computer.

The book is divided into ten chapters, covering the following subjects (only the Preface has been translated):

Chap. 1 Systems of Notation
2 Writing Numbers in Coded Form
3 Writing Numbers in Normalized Form and their Operations
4 Logical Bases of Computer Design
5 Designing Logical Circuits
6 A Computer's Arithmetic Unit
7 The Memory Unit
8 Programming and Machine Control
9 Input-Output Unit
10 A Short Survey of the Development of Computing Designs

Also included is a photograph of a magnetic drum memory unit (Fig. 1), probably of the type associated with the "Ural-2" computer (see Chap. 2).

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*Электронные вычислительные машины, Феликс Леонидович Фридлендер и Лев Александрович Цейтлин [Electronic Computers, Feliks Leonidovich Fridlender and Lev Aleksandrovich Tsejtlin], State "University" Publishers, Moscow, 1961, 148 pp.

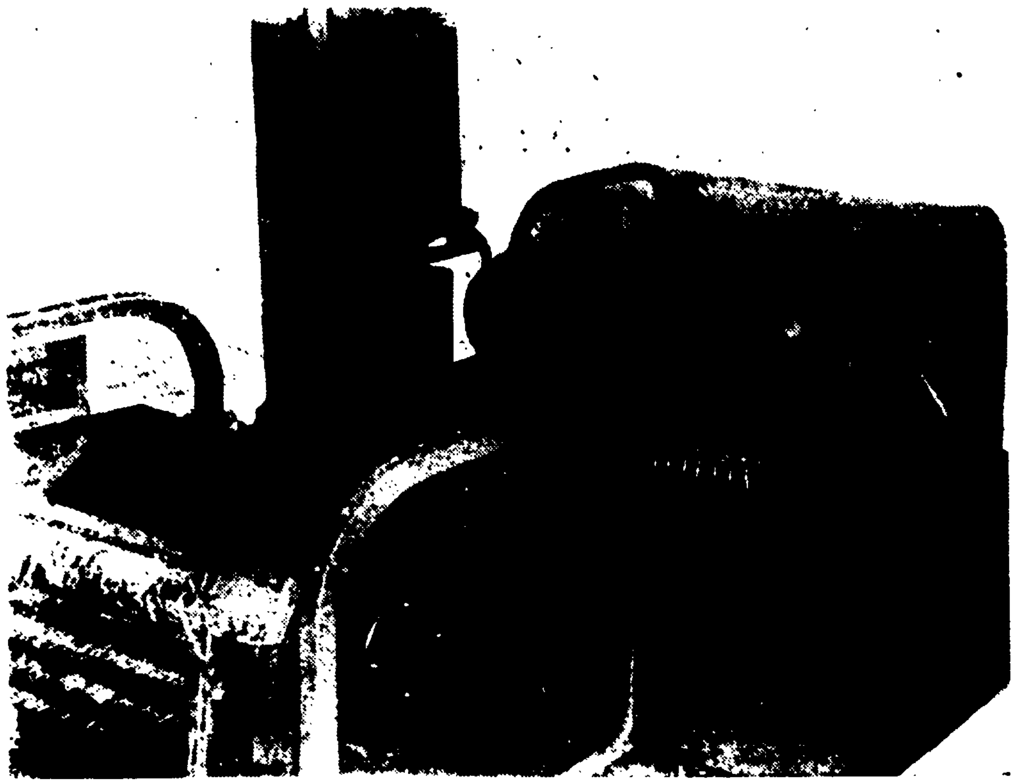

Fig. 1--Magnetic Drum Memory Unit (of the "Ural-2" Type)

Preface to "Electronic Computers"*

Our century can justly be called the century of automation. If machines invented in the 18th and 19th centuries lightened man's physical work load, the inventions of the 20th century lighten his mental load. Above all, electronic mathematics machines, which are acquiring ever greater significance, should be considered. There are many different kinds of calculations which need to be done in a short period of time; for example, the calculation of a satellite's orbit. Accomplished by hand, such calculations require many months of work.

Electronic computers permit remote control of airplanes and rockets and in a fraction of a second accept correcting instructions, which are transferred to the control mechanisms. With the enormous speeds of today's rockets and planes, rapid-action mechanisms are indispensible.

The extraordinary value of computers lies in their ability to work very fast. Contemporary computers carry out up to 50 thousand arithmetic operations per second. Machines are being designed which will accomplish, on the average, up to one million operations per second. For solving a system of 500 linear equations, such a machine needs only about ten minutes.

But speed is not the only advantage gained through the use of computers. Following given program criteria, they can select the better of several possible variants.

A mathematical computer can control metal-working machine tools, rolling mills, etc. Receiving various data from the mechanisms, it finds the best production method and itself activates control mechanisms. In doing so, the computer considers a quantity of factors that a man could

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*This material from the book Electronic Computers was translated from the Russian by Wade B. Holland.

not possibly consider in the same period of time.

Among the uses of mathematical computers is also that of translation from one language to another. Naturally, literary translation on today's computer cannot be done, but it is possible to obtain interlinear translations (of sufficiently readable quality).

Computers are being applied in such scientific fields as chemistry, biology, and medicine.

In this booklet, the authors have attempted, in a popular vein, to set forth the basic principles of electronic mathematical computer design.

Logical diagrams of the units are given without detailed technical description. At the present time, tubes have been widely replaced by transistors and ferrite elements. The use of these ferrite elements, now widely employed in the various logical operation units, is described.

The booklet is intended for those who possess a foundation in higher mathematics: university and technical school students and graduates.

The authors thank I. M. Stesin and Yu. M. Smirnov, who read the draft and offered much valuable advice and many observations.

Chapter 2

THE "URAL-2"

RAND EDITORS' INTRODUCTION

Computers in the "Ural" series are probably among the best known of the Soviet digital computers. The basic design work was done by Yu. Ya. Basilevskij at the Institute of Mechanics and Instrument Design. They are manufactured at the Penza Computer Factory, where the "Ural-2" was designed. The first "Ural" was completed in 1954, and was one of the earliest Soviet computers to be serially produced.

The following translation gives an indication of the Soviet state-of-the-art at the time the "Ural-2" was being developed, particularly with respect to the various storage units. The "Ural-2," a product of the late 1950s, has been succeeded by an improved version, the "Ural-4" (see Chap. 3).

This translation is of a specifications brochure published by the Computing Center, Academy of Sciences of the USSR, in the series, "National Economic Progress Report of the USSR."* The publication data is June 8, 1960.

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*Универсальная автоматическая цифровая вычислительная машина "Урал-2," Выставка достижений народного хозяйства СССР [The "Ural-2" General-Purpose Automatic Digital Computer, National Economic Progress Report of the USSR], Computing Center, Academy of Sciences of the USSR, Moscow, June 8, 1960, 8 pp.

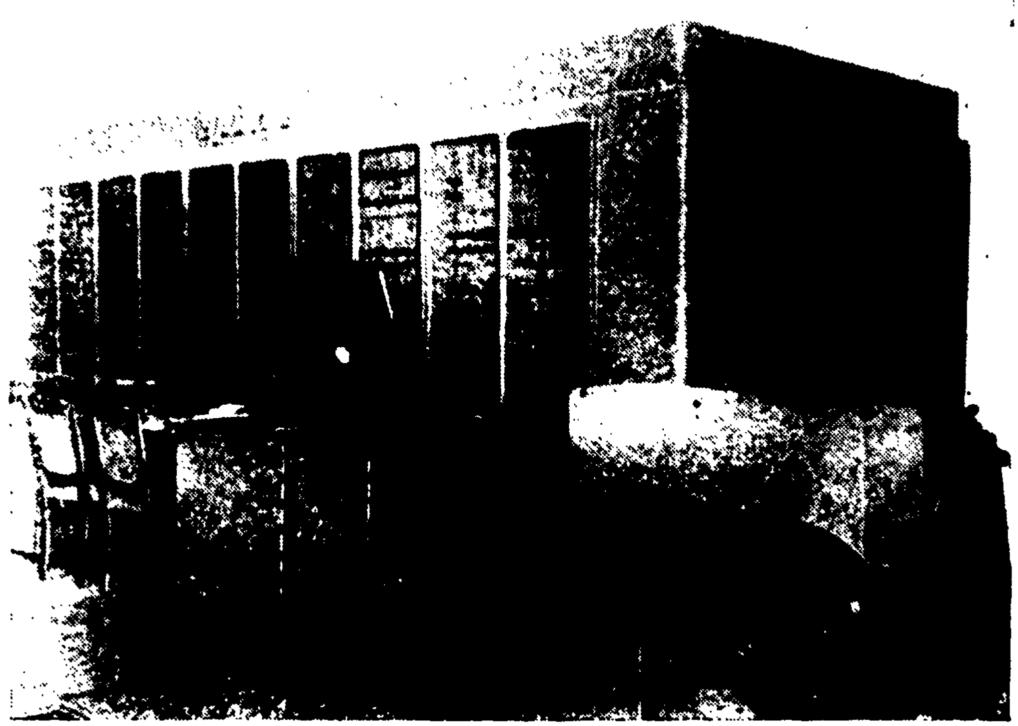

Fig. 2--The "Ural-2" Computer

The "Ural-2" General-Purpose Automatic Digital Computer*

The "Ural-2" general-purpose automatic digital computer (Figs. 2 and 3) was designed for use in scientific-research organizations, design offices, etc. It is intended for the solution of a broad class of mathematical and logical problems through automatic sequential arithmetic and logical operations, controlled by a computer program.

The "Ural-2" is a parallel-action computer with a variable cycle and an average speed of 5000-6000 operations per second. It can operate around the clock; its useful operating time is a minimum of 18 hours per day. Solution of a problem may be interrupted by shutting off the computer.

A problem given to the computer must be reduced to a definite sequence of arithmetical and logical operations; that is, a routine composed according to particular rules. The program notation should be in a standard format, checked, confirmed, and given to an operator for preparation of a perforated tape. The tapes are prepared on keying, perforating, and control-counter units.

Numbers and commands are punched on the tape (Fig. 4), occupying four lines.

In addition to the perforated tape, a magnetic tape can be prepared (if required by the routine). Its preparation consists of punching a series of zone numbers which correspond with the volume of intermediate data to be recorded onto magnetic tape.

The process of solving a problem begins when the routine and the input data are read into the ferrite storage

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*This translation from the Russian was made by A. S. Kozak and edited by Wade B. Holland.

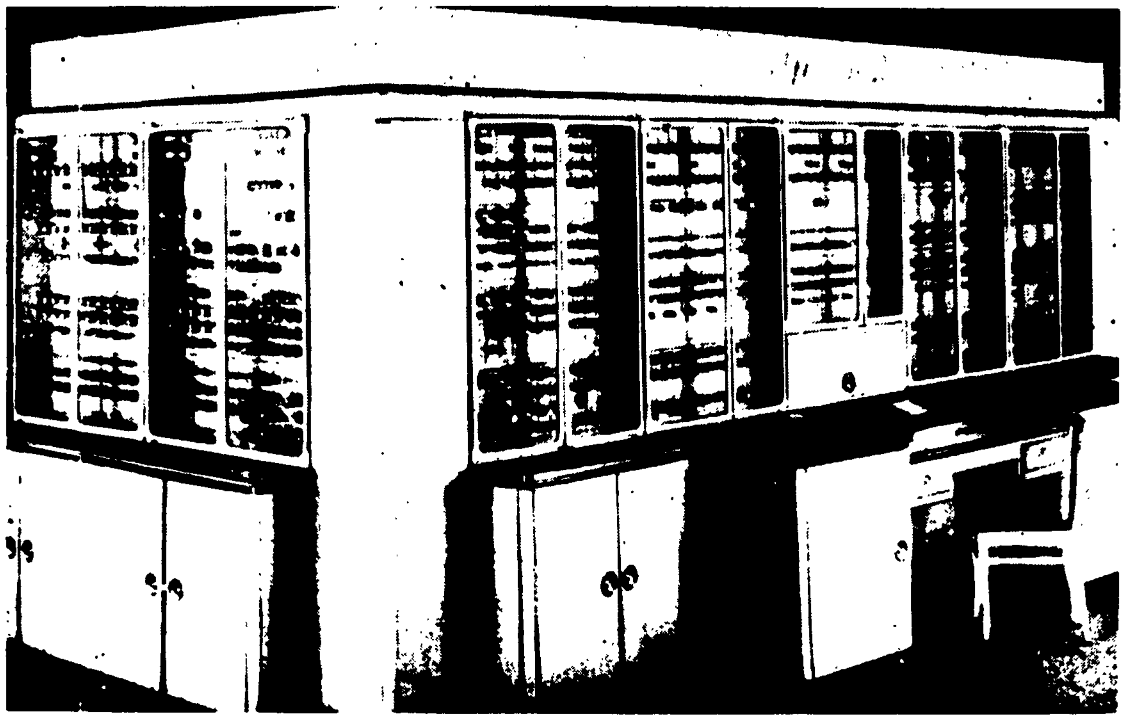


Fig. 3--The "Ural-2" Computer

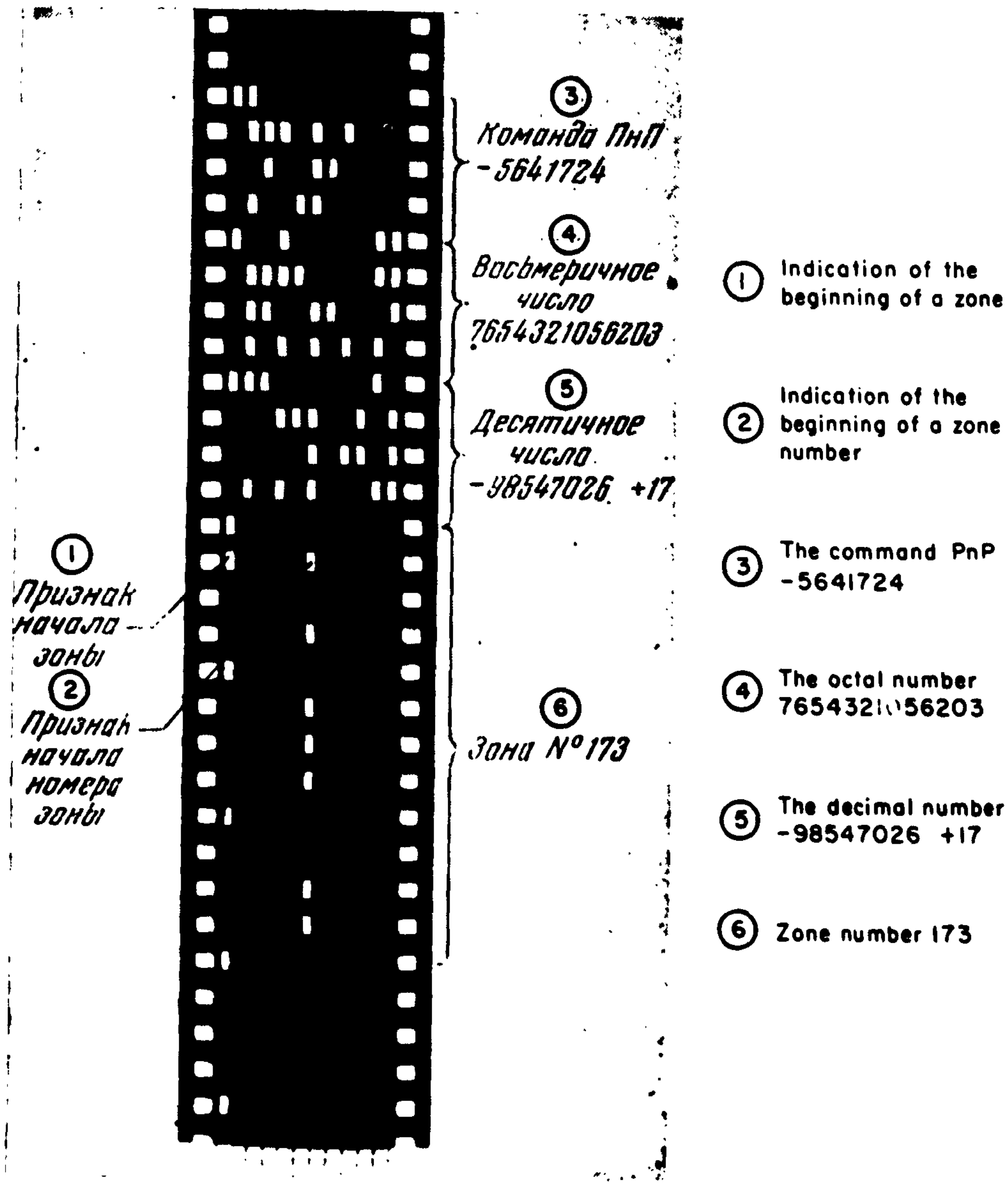


Fig. 4--An Example of Numerical Punches on Perforated Tape ("Ural-2"). Punches are Distributed over Eleven Rows.

unit. Problem solution is then completely automatic. In practice, routines require debugging, since there may have been errors in the formulation of the problem, errors in the flow chart for the routine, incorrect or unclear writing on the programming sheets, or other errors. After debugging, the routine can be output from the computer by means of an output perforating unit and corrections inserted into the original tape.

The "Ural-2" is a single-address computer. A separate command is required for each operation. A command is represented in octal notation, indicating the address of the cell in the ferrite store whose contents are to be used. There are 41 basic commands.*

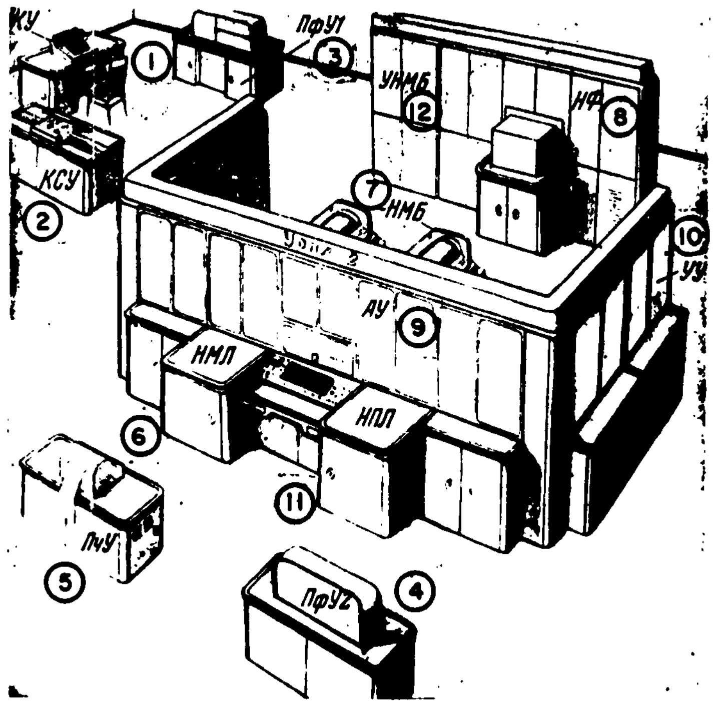
The keying unit (KU) (see Fig. 5) automatically transforms the numerical material (input data and the program routine) into binary-coded-decimal and binary-coded-octal notation, and transmits the corresponding electronic signals to an input perforating unit for perforation of a tape.

The control-counter unit (KSU) is designed to automatically verify two tapes (200 words per minute), and to reperforate tapes by means of an input perforating unit (160 words per minute).

At the input perforating unit (PfU1) it is possible to: a) punch a 35-mm film with the specified input data and program code, and b) automatically reperforate a tape which has been set up on the control-counter unit. Perforation speed is 15-20 words per minute (through the keying unit).

The output perforating unit (PfU2) outputs data recorded in the accumulator and in core storage onto a 35-mm film in accordance with the specified code.

*Editors' Note--A table of "Ural-2" instructions is given in Soviet Computer Technology--1959, pp. 166-170; in the IRE Transactions on Electronic Computers reprint, pp. 112-114.



1	Keying unit	7	Magnetic drum store
2	Control-counter unit	8	Core storage
3	Perforating input unit	9	Arithmetic unit
4	Perforating output unit	10	Control unit
5	Printing unit	11	Perforated tape store
6	Magnetic tape store	12	Magnetic drum control

Fig. 5--Basic Units of the "Ural-2"

The output perforating unit operates simultaneously with the computer. The perforating speed of data from the computer is 160 words per minute.

The printing unit (PchU) automatically converts numbers from binary-coded-decimal to decimal, and from binary-coded-octal to octal, and prints them in column-form on a paper tape at 1200 words per minute.

Numbers enter the printing unit from the arithmetic unit (AU). An interval of any width can be left between numbers by a special command. An example of decimal printing is shown in Table I. An example of octal printing is shown in Table II, and an example of commands in Table III.

Table I

EXAMPLE OF DECIMAL PRINTING

Sign	Decimal Number	Exponent
+	12345678	- 19
-	34557321	+ 11
+	41256732	+ 01
-	63216726	+ 12
+	00124632	- 02
-	44034567	+ 04
+	30536738	+ 05

Table II

EXAMPLE OF OCTAL PRINTING

01234567367532
03472105362071
04631463146311
07210275425062
11000000000000
11111111111111
12727272727272
00000000000000

Table III

EXAMPLE OF COMMAND PRINTING

02501204000000
00255364600000
10156564000000
03024240000000
11456564000000
02137210000000
02300010000000
02222411000000

Perforated Tape*

Storage on perforated tape (NPL) is designed for preserving and feeding numerical material (data and commands) to the computer in groups during the solution of a problem.

The recording of data on perforated tape can be carried out at the input units of the computer or at the output perforating unit.

The data must be transferred from the tape into core storage for use in solving a problem. The transfer can be done only in groups.

In order to obtain group input, the data is punched in separate parts of the tape (in zones). Each zone has a number which is included on the tape. There can be a total of 256 zones to a tape. Any amount of data or commands can be included, up to 2048 decimal numbers or 4096 commands. Standard 35-mm perforated opaque movie film is used. Fifty-two numbers or commands can be recorded in each meter of perforated tape. In general, only the length of the tape determines the quantity of numbers or commands which can be fed to the computer without changing the tape. A 250-meter tape (taking into account the

*Editors' Note--These subheadings are not contained in the original Russian text.

required space between zones) contains about 10,000 words or commands. If the problem permits sequential (zone after zone) input of data, then by changing the tapes the general capacity of the store can be made as high as desired. The reading speed is 150 words per second (2.8 milliseconds). Access time to an arbitrary zone for a 250-meter tape is, on the average, 40-50 seconds.

For short tapes, access time decreases correspondingly. If reading the tape during the solution of a problem occurs sequentially from one zone to the next, the time spent searching for the required zone is only a fraction of a second.

Each number on the tape is punched in 11 tracks, 4 lines (see Fig. 4).

Since multiple returns to numerical material on the tape are possible during problem solution, it is expedient to also keep on tape stored routines, individual parts of routines, and data repeatedly used during the solution of the problem.

Magnetic Tape

The magnetic tape store (NML) is designed for recording, storing, and feeding data into the computer in groups during the solution of a problem.

Recording of data on magnetic tape is carried out only from core storage (NF). For use in solving a problem, the data from the tape must be rewritten into core storage. Recording on magnetic tape and transfer from the tape into core storage can be done only in groups. The reading of a single word or command from the magnetic tape is impossible.

For group input, the data is arranged in separate parts of the tape (zones). Each zone has a number which is included on the tape. There can be 256 zones on a tape.

Any quantity of words can be carried in each zone, but not to exceed 2048 40-bit numbers or 4096 commands. A standard perforated magnetic 35-mm tape is used. In general, the number of words with which the store can operate without changing tapes depends only upon the length of the tape. A 100-meter tape (taking into account the required spaces between zones) can contain 100,000 numbers or 200,000 commands. It is possible to increase tape length to 200 meters.

Access time for a 100-meter tape is, on the average, 30-35 seconds to an arbitrarily-selected zone; recording on magnetic tape is non-return-to-zero; tape density is 10 bits per mm; recording and reading speed is 2000 numbers per second; linear tape speed is 1.5 meters per second.

Data from a perforated tape enters core storage through an output register of the arithmetic unit, whereas material from a magnetic tape enters directly. A control sum of recorded numbers (for purposes of checking) is obtained whenever numerical material from a magnetic tape is written or read into the arithmetic unit.

Magnetic Drum

The magnetic drum store (NMB) is designed for recording, storing, and feeding numerical material (data and commands) to the computer in groups for the solution of a problem.

Recording of the numerical material on a magnetic drum is carried out only from core storage. In order to use the numerical material from the NMB for the solution of a problem, it must be written into core (NF). Transfer between the magnetic drum and core storage can be done only in groups. The numerical material on a magnetic drum (up to eight drums) is arranged consecutively. For the selection of a group of addresses in the NMB (for writing or reading numbers) the first address of the group is indicated. There can be any quantity of words in a group for each block, but not to exceed 2048 40-bit numbers or 4096 commands.

Recording on a magnetic drum is non-return-to-zero; recording density is 2.4 bits per mm; clearance between the heads and surface of the magnetic drum is 20-25 microns; drum diameter is 350 mm. A drum rotates at 1500 rpm. The capacity of one drum is 8192 40-bit numbers or 16,384 commands. It is possible to have up to eight drums. The average speed of reading and writing, including the access time for the first address, is 3000 numbers per second.

The magnetic drum store is an autonomous unit with an independent system for feeding, control, and signaling.

Core (Ferrite) Storage

Core storage (NF) is designed for recording, preserving, and feeding numbers and commands for the solution of a problem. The store operates on the principle of current coincidence. Its capacity is 2048 40-bit numbers or 4096 commands (20-bit words).

One 20-bit word is stored in each cell of the NF. A 40-bit word is stored in two cells (Fig. 6). Total access time for any single 20-bit word (or command) is 15 microseconds; for a 40-bit word, 30 microseconds.

Arithmetic Unit

The arithmetic unit (AU) is designed to carry out arithmetic and logical operations on data and commands represented in binary notation. Operations on both data and commands are accomplished in the same way in binary arithmetic. [Speeds of operations are shown in Table IV.]

Arithmetic operations are carried out on words (in floating or fixed point) having 20 or 40 bits. The results

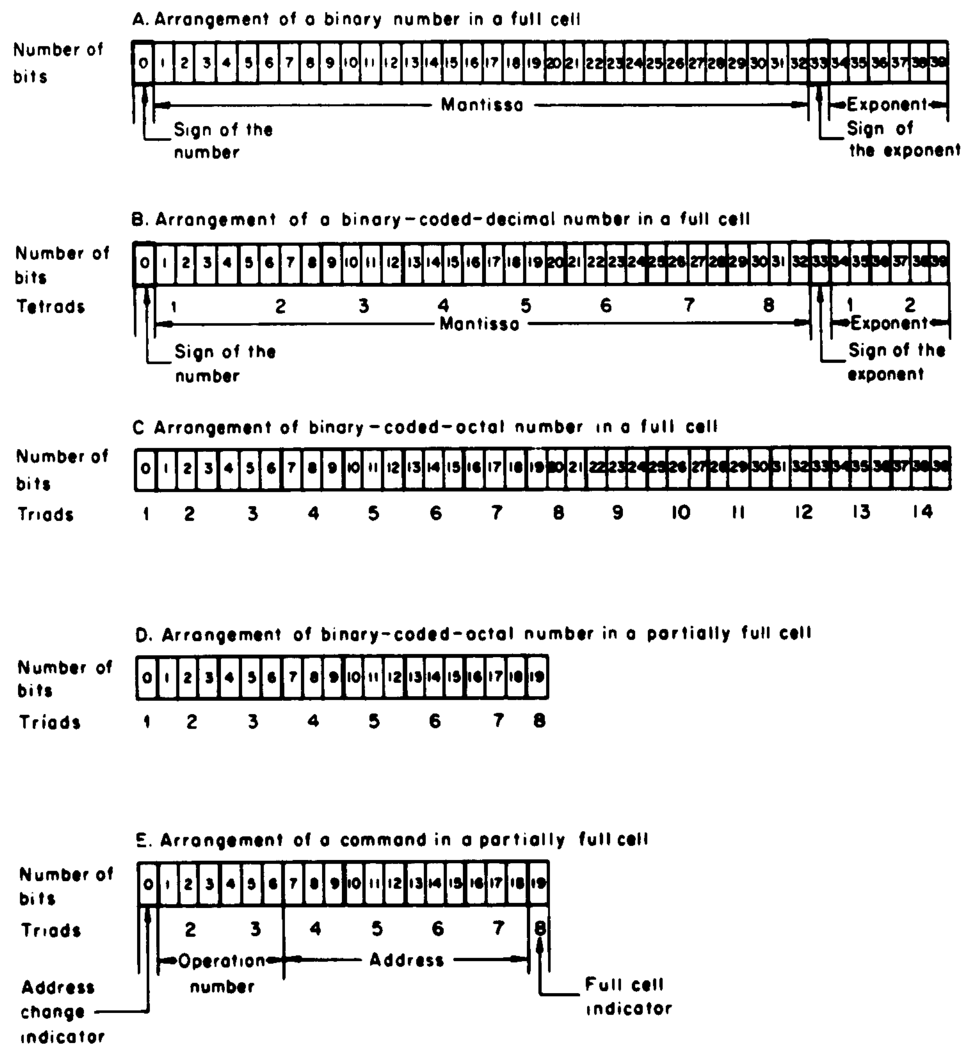


Fig. 6--Bit Patterns of the Computer ("Ural-2")

of all operations in the arithmetic unit are obtained in the number accumulator and exponent accumulator.

The number accumulator has 41 bits: one for the sign, one for overflow, and 39 for the mantissa.

The exponent accumulator has eight bits: one for the sign, one for overflow, and six data bits.

The range of number variation in the computer is $\pm 1 \cdot 10^{\pm 19}$ for floating point, and ± 1 for fixed point. The control unit (UU) is designed to automatically carry out a computer sequence of arithmetical and logical operations in correspondence with the program routine.

The power supply is three-phase, AC, 380/220 volts, 50 cycles, and 30 kw.

Table IV

COMPLETION TIME FOR SEPARATE OPERATIONS
(Microseconds)

Operations	Floating Point	Fixed Point On 32-bit Words	Fixed Point On 19-bit Words
Addition and subtraction	150*	80	80
Multiplication	490	470	330
Division	830	810	470
All remaining operations		80	
Access to core storage		160	

*Average.

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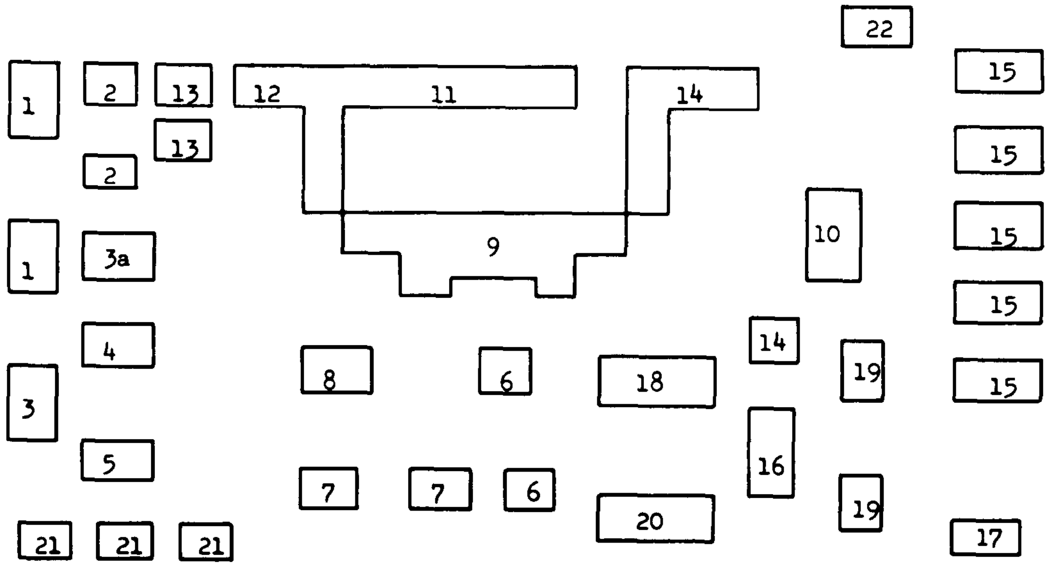
Chapter 3

THE "URAL-4"

RAND EDITORS' INTRODUCTION

The "Ural-4" is the latest known member of the "Ural" series of digital computers. Although available references do not indicate the nature of the electronic technology used in the "Ural-4," it is very likely to be the same as was used in "Ural-1." It has been established that the "Ural-2" used the same components as its predecessor, the "Ural-1." In view of the comment in the following material that the main frames of "Ural-2" and "Ural-4" are similar, the conclusion follows. Hence, "Ural-4" is well within the Soviet computer state-of-the-art, and uses well-tried and tested designs and components.

The addition of an alphanumeric printer and the presence of teletype paper tape equipment suggest that the "Ural-4" was designed specifically to be the computer component of the regional economic planning centers, which have been described in newspapers and elsewhere. The machine may well be intended for business data processing and general support of management data processing. It is not known whether the "Ural-4" is in production or not; its design completion date was scheduled for 1962.



1. 5-Hole Tape Punch
2. Card Punch
3. Alphabetic Card Punch
3a. Alphabetic Card Punch Verifier
4. Teleprinter
5. Reproducing Punch
6. Card Reader
7. Tape Reader
8. Input Control Unit
9. Arithmetic Unit with Control Console
10. Control Unit
11. Core Storage
12. Drum Memory Control Unit
13. Magnetic Drum
14. Magnetic Tape Control Unit
15. Magnetic Tape Cabinet
16. Output Control Unit
17. Tape Punch
18. Alphanumeric Character Printer
19. Card Output Punch
20. Printer Control Unit
21. Power Supply Units
22. Vacuum Tube Test Unit

Fig. 7--Distribution of "Ural-4" Components

The "Ural-4" Digital Computer*

The "Ural-4" computer is made up of the main frame and various auxiliary units. The main frame contains the control console, arithmetic unit, core storage, memory drums, and magnetic tapes. Auxiliary equipment includes the card and paper tape punching and reading equipment, teleprinter, input and output controls, and an alphanumeric printer. (See Fig. 7.)

Simultaneous operation of several input and output units is achieved through the input-output unit.** The number of such input and output modes used will depend on the particular problem.

A special magnetic tape unit differentiates the "Ural-4" from the "Ural-2." The "Ural-2" magnetic tape reader has been replaced on this later version of that machine.

Either 80- or 45-column punched cards can be used, with each row representing one decimal figure. The speed of the card reader is 300 cards per minute, and cards can be punched at a rate of 50 cards per minute.

Five-hole paper tape equipment is a new feature to the "Ural" series, permitting information to be received via teletype from any distance. The paper tape reader speed from the teletype unit is 400 alphanumeric characters per second and punching speed is 8-10 characters per second.

The printing unit is similar to that of the "Ural-2," except that the "Ural-4" has been equipped with alphanumeric capabilities. There are 63 characters, printing speed is 300 lines per minute, and there are 128 characters to a line. Printout in graph format is also possible.

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*This material was assembled from several sources, and edited by Willis H. Ware and Wade B. Holland.

**Editors' Note--Buffering of the input-output devices is implied.

The memory units consist of core storage, magnetic drums, and magnetic tape. Core storage consists of 2048 40-bit numbers, equivalent to 4096 instructions. Consequently, 20,480 decimal digits or 12,288 alphanumeric characters can be stored.* Drum capacity is 16,384 40-bit binary numbers or 32,768 commands, allowing the storage on a drum of 163,840 decimal digits or 98,304 alphanumerics. The computer can handle up to eight drums. The average drum reading or read-out time is 1000 digits per second. Special units contain the new magnetic tape storage, a unique feature of the "Ural-4."** Each of these units holds four reels of tape, with each reel having a capacity of 262,144 40-bit binary numbers, or 2,621,440 decimal digits, or 1,532,864 alphanumeric characters. Read-in and read-out speed is 2400 40-bit binary words per second.

The "Ural-4" has greater external storage capacity than the "Ural-2," and has unique instruction formats. The input-output systems have also been augmented, and the "Ural-4" is better able to handle problems in scientific and engineering fields, and in processing of statistical and planning data. It is also intended to aid in giving a deeper insight into computational problems. "Ural-1" and "Ural-2" handled only scientific and engineering problems. The "Ural-4" main frame does not differ in appearance from the earlier "1" and "2" models, but many changes have been made in its auxiliary units.

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*Editors' Note--Clearly, ten decimal digits or six alphanumeric characters are stored in a 40-bit word. Hence, a four-bit decimal code or a six-bit alphanumeric code is used.

**Editors' Note--Soviet tape units have been either low performance, as on the BESM machines (see Chap. 4), or else have used drop bins instead of reels for tape storage, as on the M-20 machine or the U.S. SEAC machine. The "Ural-4" tapes are designated as a "unique feature" because of the high flow rate and the use of reels. The "Ural-4" tape units approximate the performance of U.S. tape units which have been commercially available for several years.

In handling scientific or technical problems, "Ural-4" can carry out some 5000-6000 operations per second, and in data processing its speed is 9000-10,000 operations per second.

The "Ural-4" has both fixed and floating point capability, with input via punched cards and teletype paper tape in binary-coded decimal or binary-coded octal systems. Subroutines translate these codes into pure binary and, after computation, output is accomplished in the original systems.

Under operating conditions, program and data input is accomplished with either the card or tape reader, and output is via printer, punched cards, or punched tape. Instructions are single-address.

Power consumption is 40-60 kw, and the unit occupies 250 sq meters. The cooling system requires 11,000 cu meters of air per hour* with a capacity of 25,000 kg calories per hour.** Humidity range is 30-70% at 25°C, ± 2°.

The "Ural-4" costs approximately 850,000 rubles, as compared with the "Ural-2" cost of 450,000 rubles. Like the "Ural-2," the "Ural-4" is used 18 hours per day, with the remaining six hours being used for maintenance and servicing.

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*Editors' Note--Approximately 6500 cfm.

**Editors' Note--This corresponds to about nine tons of refrigeration. The rating of 40 kw corresponds to about eleven tons of refrigeration.

Chapter 4

THE BESM-II

RAND EDITORS' INTRODUCTION

The BESM machines are products of Sergei Lebedev's Institute of Precise Mechanics and Computing Technique, in Moscow. Lebedev was the chief designer and builder of the BESMs, the first of which was built at the Computing Center, prior to the completion of the Institute building.

BESM-II's predecessor, BESM-I, is said to approximate the IBM 701, and was a fast, reliable machine for its period. It was completed in 1952. It is a binary machine, with a word length of 39 bits, accomplishing 8000-10,000 operations per second. It carries 1023 words in its electrostatic primary storage, with storage access time of 6 μs. It's auxiliary storage is on a magnetic drum (5120 words) and magnetic tape (120,000 words). The core storage is reputed to be quite reliable. The BESM-I is best known for its work in language translation, especially English-to-Russian.

BESM-II contains the same logic and circuits as the I model, although there have been some modifications. The fundamental technologies of the two machines are equivalent, but a number of refinements have been incorporated into the later version. Work on BESM-II apparently began almost immediately upon the introduction of BESM-I, but proceeded rather slowly. It was completed in early 1959. It differs from the I model in the use of semi-conductor diodes and in a greater memory capacity, both primary and auxiliary.

The following material is a translation from the Russian of an article which appeared in a Hungarian journal.* The article was submitted in December 1959, and the journal published in early 1960.

It should be noted that information on the BESM machines from different sources is quite often contradictory, especially with regard to the instruction system. It was the impression of a U.S. technical delegation on electronic computers which visited the Soviet Union in 1959 that the command structure on the BESM-II was equivalent to that of the BESM-I.** This is borne out by other publications which independently present nearly equivalent instruction systems for the two versions of the machine.*** The present article is difficult to evaluate, because the instruction system it gives is substantially different from that given elsewhere. The machine herein described may be a locally modified version.

The BESM-II is a redesign of the BESM-I, apparently carried out to make it suitable for serial production.

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*"Краткое описание машины "БЭСМ"-11 (основные параметры)," Л. А. Зак, Т. И. Мильченко, и В. П. Смирягин ["A Brief Description of the BESM-II (Fundamental Parameters)," L. A. Zak, T. I. Mil'chenko, and V. P. Smiryagin], A Matematikai Kutató Intézet Közleményei, Vol. 5, No. 1/2, 1960, pp. 171-178. (Editors' Note--At the time BESM-I was being converted into BESM-II, Smiryagin was a chief engineer at the Computing Center in Moscow.)

**Soviet Computer Technology--1959, p. 63.

***For example, the following two publications contain instruction formats for the BESM: Soviet Cybernetics Technology: III. Programming Elements of the BESM, Strela, Ural, M-3, and Kiev Computers, Edited by Willis H. Ware and Wade B. Holland, The RAND Corporation, RM-3804-PR (to be released); and Zapominayushchie ustrojstva BESM-2 [BESM-2 Memory Units], N. I. Merkulov, A. A. Pavlikov, and A. S. Fedorov, Fizmatgiz, Moscow, 1962.

A Brief Description of the "BESM-II" (Fundamental Parameters)*

Abstract**

"The authors describe the new soviet digital computer BESM-II, built under the direction of Academician S. A. Lebedev.

"The BESM-II is a stored-program, universal three-adress digital computer, with a word-length of 39 binary digits. It has a floating-point parallel arithmetic unit. The high-speed working memory is made of ferrit-cores and has a capacity of 2048 words. The medium-speed memory consists of two magnetic drums, with a total capacity of 12,288 words, which are backed up by four magnetic tape-units, with a total capacity of about 160,000 words. The input is from perforated tapes with a speed of 15-20 words per seconds; the output is a line-printer with a speed of 15 eight-decimal numbers per second. The average speed of the machine proper is about 8000 three-adress operations per second. The tube complement is about 3500, the power-consumption about 50 kW.

"The authors are giving also the block-diagram and a photograph of the machine as well, as the detailed order-code."

General Characteristics of the BESM-II

The BESM-II high-speed electronic computer is intended for the solution of a wide range of mathematical problems. The BESM is internally programmed and automatically solves problems reduced to a specified sequence of arithmetic and logical operations.

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*This article was translated from the Russian by A. S. Kozak and edited by Willis H. Ware and Wade B. Holland.

**Editors' Note--The abstract appears in the original text in English; it is reproduced here exactly as written.

Stored program control provides for automatic variation in the flow of a program as a function of the results of computation at a prior stage. Program modification and repeated cycling of a modified program can be carried out.

With the BESM arithmetical and logical operations on data and instructions can be carried out, and group transfers between storage units can be made. Furthermore, provision is made for automatic introduction into the programs of elementary mathematical functions by means of library routines contained on a drum.

All these features create a broad logical capability for solving various mathematical problems and make this computer general-purpose.

The BESM was built by a group of engineers and technicians under the direction of Academician S. A. Lebedev, chief designer.

Basic Characteristics

The BESM-II is a stored-program, general-purpose, three-address digital computer, with a word length of 39 binary digits. It has a floating point, parallel arithmetic unit.

The output decimal numbers contain eight places; basic clock frequency is 400 kc; average operational speed is 8000 operations per second.

The computer is composed of three main units of modular construction. It has a ferrite core, high-speed memory with a capacity of 2048 39-bit words.

Memory capacity on its two magnetic drums is 12,288 words. The capacity of four magnetic tape units is about 160,000 words. Input to the computer is via perforated tape with a speed of 15-20 numbers per second; output is to a high-speed printer with a speed of 15 numbers per second.

The BESM-II contains 3500 electronic tubes and requires about 50 kw of power.

Figure 8 shows a block diagram of the BESM-II.

Figure 9 is a [photograph of a prototype of the BESM-II computer*].

The BESM-II consists of the following functional units:

Arithmetic unit (AU)
Control unit (UU)
Magnetic high-speed memory (MOZU)
Magnetic auxiliary memory (MZU)
Input and output units.

Briefly, the use and characteristics of the individual units of the computer are as follows:

I. AU [Arithmetic Unit]

The AU carries out operations with 39-place binary numbers represented in a floating point system.

Distribution of the bits:

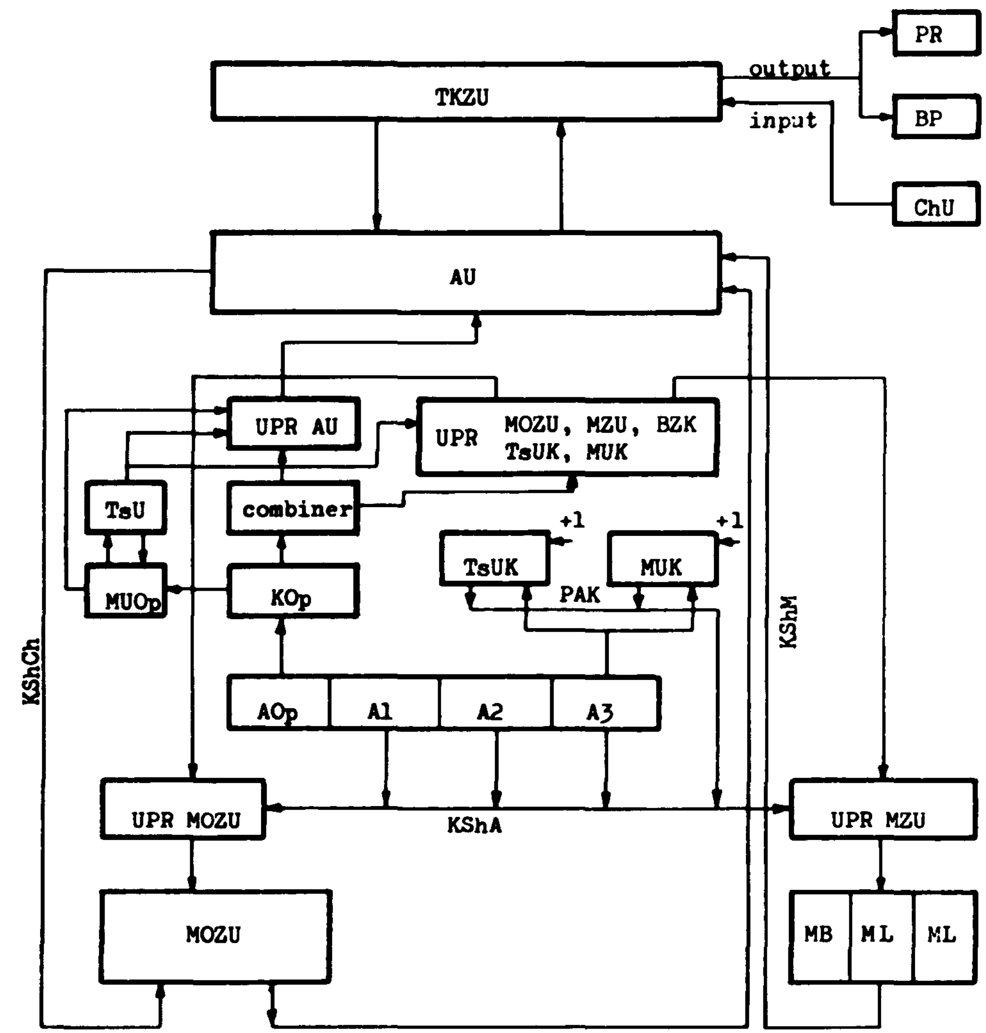
1-32	digital part--mantissa**
33	sign of the [mantissa]**
34-38	exponent
39	sign of the exponent.

A negative exponent is represented in complement form; but the mantissa of negative numbers is always in sign-magnitude. The 39th bit indicates whether normalization is necessary or not.

The AU is made up of static trigger cells and is parallel.

*Editors' Note--A photograph of the console carried in the original text was not of adequate quality for reproduction. The photograph used here is from Obshchee opisanie BESM i metodika vypolneniya operatsij, S. A. Lebedev, and V. A. Mel'nikov, Fizmatgiz, Moscow, 1959, p. 19.

**Editors' Note--The authors refer to the "digital part" and the "sign of the number," apparently meaning the mantissa and its sign.



LEGEND

A1	Op Code First Address
A2	Op Code Second Address
A3	Op Code Third Address
AOp	Op Code Number
AU	Arithmetic Unit
BP	High-Speed Printer
ChU	Reader
KOp	Commutator Operation
KShA	Address Code Bus
KShCh	Data Code Bus
KShM	Auxiliary Storage Units' Code Bus
MB	Magnetic Drum
ML	Magnetic Tape Units
MOZU	Magnetic Core Storage
MUK	Local Control of Commands
MUOp	Local Op Control
MZU	Auxiliary Magnetic Storage Units
PAK	Transfer of Command Address
PR	Reproducing Perforator
TKZU	Memory Unit Control Trigger
TsU	Central Control Block
TsUK	Central Control of Commands
UPR AU	Arithmetic Unit Control
UPR BZK	Commands' Storage Block Control
UPR MOZU	Core Storage Control
UPR MUK	Control of Central Command Control Block
UPR MZU	Auxiliary Storage Units' Control
UPR TsUK	Control of Local Command Control Block
UU	Control Unit

Fig. 8--Block Diagram of the BESM-II

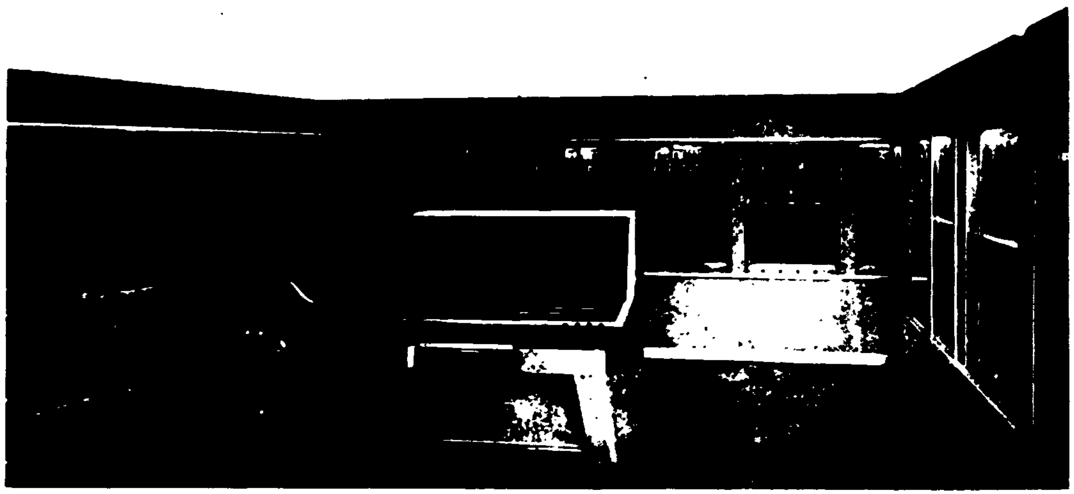


Рис. 1. «Быстродействующая электронная счетная машина» БЭСМ.

Fig. 9--The BESM-II Computer

In connection with the floating point system, the AU consists of two parts--the AUCh [mantissa] and the AUP [exponent].*

The AUCh [mantissa part] has two registers and one accumulator (each register shifts and has complementing inputs to the triggers). The second register and accumulator have an end-around left and right shift. The AUP [exponent part] has a similar unit, but the shift is only on the first register.

The AU connects to the supplementary control register, TKZU, into which the result of each operation is put (in parallel with transfer into MOZU [magnetic core storage]).

II. UU [Control Unit]

The UU provides a specific sequence of impulses and potentials, which guarantee the completion of the elementary actions (the transfer of a number, addition, shift, etc.) for each operation.

The instruction system is three-address, and the instruction format is:

Bits	1 - 11	Third address, A_3
Bits	12 - 22	Second address, A_2
Bits	23 - 33	First address, A_1
Bits	34 - 38	Operation Code, AOP
Bit	39	As a rule, this is the bit which indicates necessity for normalizing the result.

Except in some special cases, a command is carried out in one cycle. Thus, for addition, the first operand from

*Editors' Note--Literally, "arithmetic unit--number" and "arithmetic unit--exponent"; the dichotomy of the AU is of a mantissa part (sign-magnitude arithmetic) and an exponent part (complement arithmetic).

cell A_1 and the second operand from cell A_2 are read from MOZU [memory]; the result of the operation goes into cell A_3. Finally, according to the address in the instruction counter, the next instruction is read and goes to the instruction register. Certain instructions are carried out with fewer references to MOZU [memory].

III. MOZU [Magnetic Core Store]

The MOZU stores 2047 39-bit binary numbers; further, in the "zeroth" cell is stored an "empty" number.

Cycle time is 10 μs. The average frequency of consultations with the MOZU [core store] during operation of the computer is about 40,000 per second.

IV. MZU [Auxiliary Storage]

The MZU [auxiliary storage] consists of two independent units:

MB--magnetic drums
ML--magnetic tape units.

1. The MB [drum unit] consists of two magnetic drums with a capacity of 6144 words each. With one pair of instructions (Ma and Mb), it is possible to transfer to or from MOZU [core storage] up to 2048 numbers. Furthermore, the drums contain fixed subroutines and checks for computer accuracy. Access time is 40 ms (750 revolutions per minute). The reading rate is 800 numbers per second.

2. Four magnetic tapes provide storage of 25-40 thousand words each. Since the tape reels can be changed as required, storage capacity on tape is practically unlimited. The reading rate is 200 words per second.

V. UVV [I/O Units]

One input unit handles input from perforated single-track paper tape, at a rate of about 15 words per second.

The perforator punches the numbers into either a base-16 or a binary-coded decimal system. The output unit is a digital printing device with a speed of about 15 12-bit words per second. Base-16 numbers can be printed.

Interaction of the Individual Units of the BESM-II

I. The input device is a perforated tape unit, which operates much the same as a tape recorder (with respect to the control circuitry); input is accomplished by the two commands, Ma and Mb.

The code, "perforated tape," and the initial location in the memory is contained in the first command [Ma]. The quantity of input data is recorded in the second command (Mb). This input information is entered serially into one of the shift registers of the AU, and the assembled word is transferred to the MOZU in parallel.

II. After all the data has been entered into the MOZU (or the MOZU is full), it can be transferred to MZU [auxiliary storage]--either drum or tape; the information is not erased in the MOZU. The parallel-serial change in representation is achieved by the same shift register of the AU, but in reverse sequence: information is transferred in parallel from the MOZU to the register, and then is serially shifted into the MZU [auxiliary store]. During operation, information is transmitted from the MZU to core memory--the same as with input from perforated tape.

III. Data is directly available only from the MOZU. When it is necessary to use the additional console key-operated registers, command No. 12, PCh $A_1A_2A_3$, is used, where A_1 is "empty" and in A_2 is carried the number of the register (1 or 2) whose contents are transferred, according to address A_3, to MOZU.

IV. Output of the result is printed by the command PCh A_1 and A_3. A_1 is the address of the cell in the MOZU where the result is stored (there is a sign "1" and ten bits in A_2), and A_3 is the cell to which the result can be transferred simultaneously with the printing. The result remains in A_1.

Table V

INSTRUCTION SYSTEM FOR THE BESM-II

Number	Operation Code	Desig-nation	Description	Opns/sec (in 1000's) Min.	Opns/sec (in 1000's) Max.
1.	00 (40)		Transfer of the contents of A_1 into cell A_3 or the clearing of A_3.	--	15
2.	01	+	Addition of the contents of A_1 with A_2. The result appears in A_3.	4.4	15
3.	02	-	Subtraction of the contents of A_2 from A_1. The result appears in A_3.	4.4	15
4.	03	X	Multiplication of the contents of A_1 by A_2. The result appears in A_3.	--	4.2
5.	04	:	Division of the contents of A_1 by A_2. The result appears in A_3.	--	4.2
6.	05	+P	Addition of the exponent of A_1 with the exponent of A_2. The mantissa of the result is from A_1.	7	15
7.	06	-P	Subtraction of the exponent of A_2 from A_1. The mantissa of the result is from A_1.	7	15
8.	07	(PP)	The exponent A_1 is complemented and appears in A_3 as a normalized number.	7	15
9.	10	Xa	Multiplication of A_1 by A_2 without rounding. The high-order bits appear in A_3.	--	4.2
10.	11	Xb	Storing of the low-order bits (of the result of Xa).	--	15
11.	12	:a	Division with a remainder; the quotient enters A_3 without rounding.	--	4.2
12.	13	:b	The mantissa of the result is the remainder from the division of :a (the sign is from A_1).	--	15
13.	14	E	A whole number in A_1 goes into A_3 and the unnormalized fractional part into A_2.	4.4	15
14.	15	PCh+	Transfer of a number from A_1 into A_3 with the sign of the number from A_2.	7	15
15.	16	U	A logical digit-by-digit (formulating type) addition of A_1 and A_2 into A_3.		
16.	17	L	A logical digit-by-digit multiplication of the contents of A_1 by A_2; the result appears in A_3.	--	15
17.	20	$\dot{E}$	A modulo 2 addition (addition without carry).		
18.	21	(TsS)	Cyclical accumulation with end-around carry into the least significant column.	--	15
19.	22	SK	Fixed point addition of instructions; the exponent of A_1 goes into A_3.	--	15

Table V--Continued

Number	Operation Code	Designation	Description	Opns/sec (in 1000's) Min.	Max.
20.	23	-			
21.	24	-			
22.	25	IP	Change the exponent of A_1 by a value from A_2. The result also appears in A_3.	7	15
23.	26	Full shift	Change the contents of A_1 by a value from A_2; the result appears in A_3.	6.5	15
24.	66	Incomplete shift	The mantissa of A_1 is shifted by a value from A_2; the exponent of the result is zero.	7	15
25.	27	Console	Input of parameters from 1st or 2nd console registers (and of certain other data) (A_2) into cell A_3.		
26. 27.	30* 31	Ma } Mb }	Transfer to MZU [auxiliary storage unit].	--	15
28.	32	Print	One number from A_1 is printed; it alone appears in A_3.		
29.	33	stop	Unconditional stop.	--	--
30.	34	ITsUK	Change the instruction number in the TsUK [local command control block] and transfer to the TsUK with return.	--	15
31.	73	Stop usl.	Machine halt when a toggle switch is off, conditional stop.	--	--
32.	35	=	If $(A_1) = (A_2)$, control transfers to A_3, otherwise, control transfers to the next [command].	--	15
33.	75	≠	Transfer to the command in A_3 if $(A_1) \neq (A_2)$ (and to the following [command] if $(A_1) = (A_2)$).	--	15
34.	36	<	Transfer to the command of A_3, if $(A_1) < (A_2)$ (otherwise, to the next [command]).	--	15
35.	76	|<|	Transfer to the command of A_3 if $\|A_1\| < \|A_2\|$ (otherwise, to the [illegible] [command]).	--	15
36.	37	PTsUK	Transfer control to the TsUK [local command control block] [illegible] increment the TsUK counter by ..	--	15
37.	77	IMUK	Transfer control to the MUK [local command control block] according to the 3rd address.	--	15
38.	74	ITsUK	Transfer to A_3 & clear the address of A_2.	--	15

*Ma -- A_1 specifies drum, magnetic tape, perforated tape, printout, or reading; A_2 specifies the first address of the group on the drum or the number of the zone on the tape; A_3 specifies the first address of the group in the MOZU [core store].

Mb -- A_2 indicates the last address of a group of numbers on the MB [drum] or the quantity of words on the ML [tape]; A_3 indicates the number of the cell to which the check sum must be sent.

Chapter 5

THE "RAZDAN-2"

RAND EDITORS' INTRODUCTION

The "Razdan-2" digital computer is a product of the Armenian SSR Academy of Sciences; the name is taken from the Razdan River, which flows through the Armenian capital of Yerevan. The "Razdan" computer series was the first in the Soviet Union to be fully transistorized.

The present translation is from a specifications brochure published in the series "National Economic Progress Report of the USSR."* The source of the brochure is probably the Academy of Sciences of the USSR. The publication date is October 30, 1961.

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*Универсальная цифровая вычислительная машина "Раздан-2," Выставка достижений народного хозяйства СССР [The Razdan-2 General-Purpose Digital Computer, National Economic Progress Report of the USSR], Moscow, October 30, 1961, 3 pp.

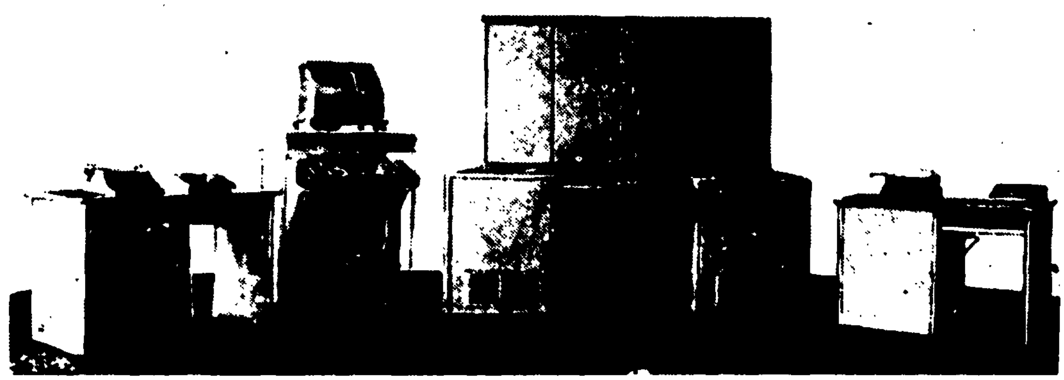

Fig. 10--The "Razdan-2" Computer

The "Razdan-2" General-Purpose Digital Computer*

The "Razdan-2" general-purpose digital computer is intended for the solution of scientific and engineering problems in computing centers, scientific research organizations, industrial and university laboratories and design centers. The machine is based on semi-conductors and ferrites.

Basic Technical Data

The average computing speed is 5000 operations per second. Instructions are two-address and the number form is floating point binary. The mantissa contains 29 bits, the sign of the mantissa two bits, the exponent five bits, the sign of the exponent two bits. An instruction contains 36 bits. The range of numbers (decimal) with which the machine operates, is from $\pm 10^{9}$ to $\pm 10^{-18}$. Internal storage is in ferrite cores, with a capacity of 2048 numbers or instructions. Access time is 25 microsec. The magnetic tape external memory unit has a capacity of 120,000 numbers or commands. There are 128 zones.

Output of results is accomplished by a wheel printer, whose speed is 20 numbers per second. Numbers are converted into decimal, but instructions are printed in octal. Input of numbers and instructions on paper tape is automatic from a photo-reading unit. Input speed for numbers is 35 numbers per second or manually from the control console. Preparation of data is accomplished with the aid of a perforating unit. Perforation is accomplished by printing of the code for visual execution of control. For reproduction of perforated tape there is a reperforator.

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*This material was translated from the Russian by Wade B. Holland.

Specifications

2100 x 1800 x 1000 mm; 1200 x 900 x 900 mm.*

Power

Three-phase, AC, 220 volts, 50 cycles. Power consumption is less than 3 kw. The useful work day is at least 22 hours. It is intended for non-mobile installation.

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*Editors' Note--Roughly 83" x 71" x 40" and 47" x 35" x 35".

Chapter 6

THE MN-10 AND MN-14

RAND EDITORS' INTRODUCTION

The MN-10 and MN-14 computers are the only analog machines covered in this Memorandum. Little is known about them; the MN-10 is a small table model unit, while the MN-14 is classed as a medium-sized unit.

The information on the two machines is taken from specifications brochures in the series, "National Economic Progress Report of the USSR,"* published by the Academy of Sciences.

The exact nature of the cathode ray tube plotter used in conjunction with both machines is not clear. There is also some question regarding the use of "stepped curves" on the MN-14 for approximating variable coefficients. It would appear that the curves are plotted only with horizontal and vertical lines, which intersect the curve in a predetermined fashion, unlike U.S. machines, which simulate curves with short straight lines. It is also implied that the MN-14 is to be supplied with a ventilating unit, rather than an air-conditioning or refrigeration unit. As the ventilation unit is not a standard component, it is perhaps assumed that the computer would be installed only in a properly air-conditioned facility.

***Малогабаритная нелинейная аналоговая математическая машина МН-10 на полупроводниках*, Выставка достижений народного хозяйства СССР [*The MN-10 Small Transistorized Nonlinear Mathematical Analog Computer*, National Economic Progress Report of the USSR], Moscow, February 28, 1962, 3 pp.

Электронная нелинейная аналоговая математическая машина МН-14, Выставка достижений народного хозяйства СССР [*The MN-14 Nonlinear Mathematical Electronic Analog Computer*, National Economic Progress Report of the USSR], Moscow, February 27, 1962, 3 pp.

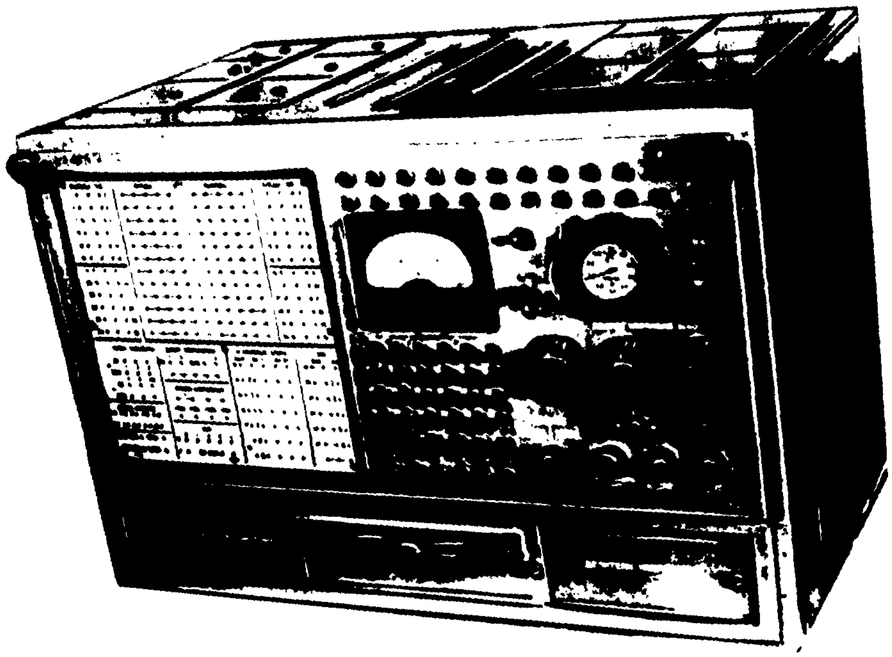

Fig. 11a--The MN-10 Analog Computer

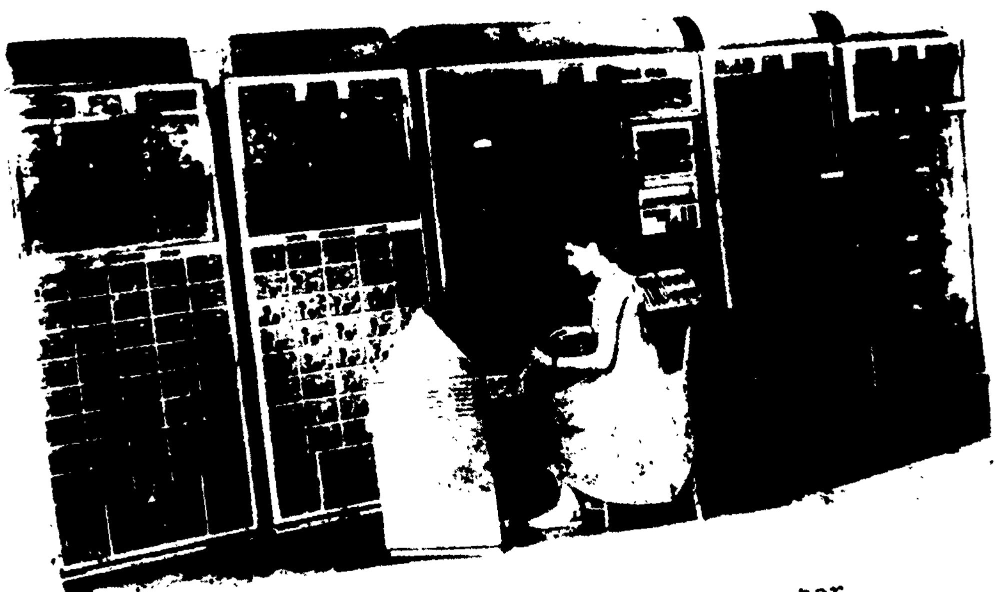

Fig. 11b--The MN-14 Analog Computer

The MN-10 Small Transistorized Nonlinear Mathematical Analog Computer*

The MN-10 mathematical analog computer is intended for the study and solution of problems described by ordinary nonlinear, differential equations of the type

$$\frac{dx_i}{dt} = F_i(x_1, x_2, \ldots, x_6, t),$$

where $i = 1, 2, \ldots, 6$.

The computer is intended primarily for research into various physical systems through the use of an electrical modeling method (in particular, real-time research with actual automatic control devices [incorporated in the model]). On it can be solved differential equations, consisting of up to six nonlinear functionally dependent equations of one variable or the product of two variables. (The dependent variables in each equation can be in any combination, in quantities up to six.)

There are 25 small, operational DC amplifiers in the computer which accomplish integration, differentiation, summation, and multiplication by constant coefficients. Also, six diode units are used in the system for reproducing typical nonlinear functions such as the hysteresis loop, dry friction inertia, dead zones, and limiting functions. There are also four diode function generators for a function of a single-variable and four diode function generators for functions of two variables. Input of the problem to be solved is via a standard input unit.

Two or more MN-10 computers may be connected in parallel for solving more complicated problems.

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*The two items in this chapter were translated from the Russian by Wade B. Holland.

Solution of the problem can be observed on an I-5 or I-4 cathode ray tube plotter. The plotter is not included as a standard component.

The computer receives power from the ESB-10M unit, which is built-in. It requires 130 watts on a single-phase, 220-volt, 50-cycle system.

Both the machine's operational unit and its power source use only semi-conductor diodes and transistors.

The computer occupies an area on a table-top of 0.3 sq meters.

In all, the computer weighs about 45 kg.*

The MN-14 Nonlinear Mathematical Electronic Analog Computer

The MN-14 nonlinear mathematical electronic analog computer is a medium-sized computer intended for simulating complex dynamic systems which may be described by ordinary nonlinear differential equations of up to 20 variables with large numbers of nonlinear dependencies.

The MN-14 computer is of modular construction, composed of the following sections: a central, a linear, and two nonlinear sections; either an electronic time-sharing or a potentiometric servomechanism [multiplier] section; and a console display plotter, the power supply, and a panel for checking the functional units.

The main element in the operational portion of the system is the U-1 DC amplifier with automatic "zero-drift" compensation.

The following functional units are included in the computer:

1. 10 double units of integrating amplifiers, permitting 20 integrations simultaneously.

*Editors' Note--99 lb.

2. 15 double units of summing amplifiers, permitting 30 addition operations simultaneously. Each unit can operate in two modes: first, with five inputs [to each single unit]; or second, with ten inputs [to each double unit].
3. 10 double units of amplifiers for changing sign, permitting 20 inverting operations simultaneously.
4. 10 auxiliary amplifiers with a set of resistors, capacitors, and diode units which permit a number of linear, nonlinear, and logical operations to be completed.
5. 3 constant delay units, permitting the simultaneous generation of 3 functions with delayed argument, $Y = x(t-\gamma)$, where γ is a constant delay of 10, 50, or 100 microseconds.
6. 6 double units of variable coefficients, permitting the simultaneous approximation of 12 variable coefficient functions by stepped curves.
7. 120 voltage dividers, which permit setting constant coefficients from 0 to 1.
8. 50 multiplication units, arranged so as to permit one of the following operations:
   a) multiplication of two variables according to the formula:

$$Y = - \frac{sx_1x_2}{100}$$

   b) division of two variables according to the formula:

$$Y = - 10\,\frac{x_1}{x_2}$$

c) extraction of the roots of a quadratic according to the formula:

$$Y = -10\sqrt{x_1}$$

9. 20 units of universal nonlinear elements, permitting generation of nonlinear functions of one variable $Y = f(x)$.
10. 4 units of special nonlinear elements, which allow generation of such nonlinear functions as restriction of coordinates, dead zones, and hysteresis loop.
11. 6 trigonometric function units.
12. 12 electronic time-shared servomechanisms, intended for multiplication and addition operations according to the formula:

$$Y = -\frac{x_o \cdot x_i}{x_o},$$

where $i = 1,2,\ldots,5$.

The time-shared servomechanisms yield greater precision in multiplication.

If the user wishes, instead of the time-shared servomechanisms, a section with 12 potentiometric systems may be installed.

With the aid of the potentiometric servomechanisms unit, it is possible to carry out multiplication of a function of one variable (X_o) by six others (X_1 to X_6) or a function of two variables (X_o) by two other variables X_7; X_8.

The computer contains about 360 amplifiers.

A large portion of the nonlinear units and the power source are constructed of semi-conductor elements.

Integration time ranges from 1 sec to 10,000 sec.

The MN-14 computer is distinguished by its well-developed, flexible system of control, which provides for automatic data input and output. The computer has a removable input plug board, and an electronic digital voltmeter.

Display of a solution may be accomplished with a cathode ray tube plotter, which has a four-input electronic commutator; or with external printing devices; or with a two-coordinate plotting board.

For normal operation, the computer must be supplied with a ventilation system of approximately 5000 cu meters per hour.

The printers, the two-coordinate plotting board, and the ventilation unit are not included as standard components.

Power requirements are: three-phase, 220/127 v., 50 cycle, 15 kw.

The machine requires an area of approximately 40 sq meters.

Chapter 7

<u>THE "LUCH"</u>

<u>RAND EDITORS' INTRODUCTION</u>

The "Luch" computer was designed in the late 1950s at the Byelorussian Academy of Sciences' Institute of Physics and Mathematics, under the direction of Ivan Vasilevich Lebedev. The "Luch" project was undertaken in preparation for the Seven-Year Plan of 1959-1965. The word "luch" means "ray" or "beam."

The article on the following pages is taken from <u>Ogonek</u>, a popular magazine.* It's description of the "Luch" is non-technical, with very little information on the specifics of its design or operational characteristics. It does, though, indicate some of the uses for which the "Luch" is intended and the article, in general, is a good example of the increasing volume of popular-consumption material appearing in the Soviet press on various facets of cybernetics and computer technology.

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*Морозов, С., "Разведчики индустрии," <u>Огонек</u> [Morozov, S., "Reconnoitering Industry," <u>Ogonek</u>], No. 52, December 21, 1959, p. 10.

Reconnoitering Industry*

A Thinking Machine

"This is where she was born--she will live and work elsewhere, in a more spacious setting," says the smiling manager of the laboratory, Ivan Vasilevich Lebedev, as he conducts us through rooms resembling a miniature factory.

The machine, which the scientist seems to regard as a living person, presents itself as a multitude of radio components spread out on tables, with metal control panels and numerous bales of wire. We are shown the keyboard, much the same as a typewriter, long paper tapes with rows of holes (a conventional numeric code), and tiny rings of magnetic ferrite material, which will serve as memory elements.

All of this makes up the eyes and ears, nerves and brain matter of a future artificially-built organism which is being created, much like the conception of a person.

When you listen to the explanation of I. V. Lebedev and his assistant, it seems now and then that they are reading a fantasy novel. It is difficult to imagine a brain able to execute 4000 arithmetic operations in a second; yet the "Luch" electronic computer, being constructed here at the Institute of Physics and Mathematics at the Byelorussian Academy of Sciences, will be such an "ingenious Hercules."

From the point of view of speed or, as they say here, "rapidity of action," it will surpass the existing "Ural" electronic computer by a factor of approximately 80.**

In this world of astronomical figures and cosmic speeds, its basic unit of time is a measurement equal to eight-millionths of a second. Two such time units are

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*This article was translated from the Russian by Wade B. Holland.

**Editors' Note--This implies a speed of 8000 operations per second.

required by the "Luch" to add two numbers [= 16 μs]; a multiplication operation requires 40-80 [330-640 μs] such units.

"Recall the common office calculator," says I. V. Lebedev. "Electronic computers work essentially on the same principle, only here instead of beads, impulses of electrical current are moved. Whereas only several beads can be moved on an abacus in a second, this computer, in the same amount of time, transmits hundreds of thousands of impulses. Its calculating speed is commensurate."

Ivan Vasilevich relates how three years ago [i.e., 1955] a group of young White Russian scientists began to design the "Luch" computer, and about how it is now being successfully assembled and, in the first year of the Seven-Year Plan [i.e., 1959], will be operational.

"In what ways does the "Luch" differ from similar existing computers?" "Both in speed of operation and ease of construction," Lebedev answers. "The extraction of the root of a quadratic, for example, which requires several dozen operations on other computers, is performed by the "Luch" in a single operation. A significant point is that economically feasible electronic tubes were devised in the construction design phase of the development of the "Luch." The basic design principle is in the use of semi-conductor components."

"What will be the effect of the "Luch" when it is in actual operation?" "After we finish the basic computer, we will be devising electronic controlling mechanisms," says Lebedev. "Unlike common, rigid, automatic machines which repeat one and the same operation, it will be flexible, capable of interpreting a changing situation and adjusting to it; it will transmit signals in accordance with its operational program. Such automatic machines are especially needed in the chemical industry, where, frequently, unified control of hundreds of secondary regulators--pressure, temperature, composition of gases at many points in a factory--is needed. Readings from measuring instruments will be fed into the computer where they will be compared with given values. If, for instance, pressure is less than specified, the computer will emit a control signal which will trigger a compressor to raise the pressure. We hope that electronic control computers, with our yellow trademark, will appear in chemical factories all over the country during the Seven-Year Plan."

Chapter 8

THE "EPOS"

RAND EDITORS' INTRODUCTION

The "EPOS" digital computer is of Czech design, a product of the Mathematical Machines Research Institute, in Prague. It is quite obviously well behind the U.S. state of the art, as indicated by the lack of an arithmetic unit, the characteristics of auxiliary components, speeds, and the statement that the use of transistors will be a new feature on the next version of the machine.

Though the current "EPOS" is apparently a pilot model, which will be improved upon in succeeding versions, it is scheduled for serial production.

The first article appeared in a Czech publication* while the second article is a compendium assembled from several sources by the editors.

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*Svobodne Slovo, April 8, 1962.

"EPOS" Digital Computer in Testing Stage*

At the Mathematical Machines Research Institute, in Prague, work is progressing toward the completion of the "EPOS" digital computer. The "EPOS" is a medium-sized electronic computer. In literature, the Czech word epos describes an epic poem; in a metaphorical sense, it denotes "a great achievement," which this computer represents.

Nearly all digital computers consist of input, output, memory, arithmetic, and control units. In the main frame of the "EPOS," the arithmetic unit is missing, but is partially replaced by the control unit. The main frame can be regarded as a complete digital computer and is presently being debugged. The "EPOS" is modular and can be expanded by the addition of auxiliary units.

The present initial version has the following equipment:

1) Input via punched cards at a speed of 14 cards per second.
2) Electric typewriter for input and output; paper tape can be punched simultaneously.
3) Line printer with a speed of four 120-bit lines per second.
4) Magnetic drum memory and tape units with a capacity of 10,000 read and write characters.

The "EPOS," a decimal computer, can transfer alphabetic characters as well as order them alphabetically. Via the control unit, errors can be detected and corrected. The calculation speed is 18,000 operations per second. The "EPOS" has time-sharing, which permits five programs to be processed simultaneously, since the peripheral equipment is independent.

Tubes and diodes are of Czech manufacture, and the

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*This article has been translated from the Czechoslovakian.

computer was designed by Dr. A. Svoboda and his assistant engineer, J. Oblonsky.

The machines will be built in series by the VE Company ARITMA.

The next version of the "EPOS" will have transistors.

The "EPOS" Data Processing Computer with Built-in Time-Sharing*

The "EPOS" data processing computer, which features time-sharing, was completed in late 1959. It is a medium-sized computer intended for use in automation of management data processing, scientific-technical calculations, and control of technological processes.

It is a decimal, series-parallel, modular machine, capable of processing both numerical and alphabetic data.

Central Unit

The "EPOS" central unit is made up of the control, central memory, sequencer, and console units. It has no arithmetic unit, but the control section contains logic for shifting, some decisions, addition, and subtraction on 12-digit decimal numbers in fixed point. Its average speed is 17,000 operations per second. Subroutines are used for multiplication and division. Together with the input and output equipment, the central unit can be considered a general-purpose computer.

The internal memory has nickel delay lines for five words, and a core storage of 1024 words; words are of 12 decimal digits. Access time for both the nickel delay lines and the core storage memory is 13 microseconds.

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*This material, mainly translated from the Czech, has been assembled from several sources by the editors.

Instructions contain one full address for communication with the core memory and three addresses ... for communication with the nickel delay lines.

Expansion of the Central Unit

The central unit can be expanded in the following way:

1) The capacity of the nickel delay lines can be increased to nine words.
2) An arithmetic unit can be added which executes basic operations with fixed or floating decimal points. It could also carry out operations which the central unit is not able to handle.
3) Drum storage of 5000-50,000 words can be added.
4) Up to ten tape units can be connected.
5) For input and output the following can be connected:
   a) electric typewriter I/O unit;
   b) up to ten card readers;
   c) up to ten punches;
   d) up to ten printers;
   e) punched-tape equipment and high-speed printers are also planned.

The arithmetic is series-parallel and has the unusual feature that all operations are derived from multiplication.

The "EPOS" computer has two types of time-sharing, internal and external. The external time-sharing permits the sequencer to organize simultaneous processing of five programs. The internal time-sharing permits the concurrent execution of some instructions in any specific programs while multiplication and division operations are being executed.

Speeds of Operations (μs)

	Fixed	Floating	With Internal Time-Sharing Fixed	With Internal Time-Sharing Floating
+	52	130	-	-
-	208	234	65	104
x	1196	1209	52	91

The "EPOS" features automatic error correction in the transmission of words between the memory unit and the processing units. A special logic permits detection and correction of errors in the main arithmetic circuits.

The computer has 2400 tubes, 15,200 germanium diodes, 2500 resistors, and 6800 capacitors.