to 4D, where $z = ae^{ib}$ for $a = 0(.05)1.3(.1)1.5$ and $b = 0(5°)45°$. There is also a brief introduction indicating the formulae used for the construction of the tables, and two pages of diagrams exhibiting the results.

AUTOMATIC COMPUTING MACHINERY

Edited by the Staff of the Machine Development Laboratory of the National Bureau of Standards. Correspondence regarding the Section should be directed to Dr. E. W. CANNON, 415 South Building, National Bureau of Standards, Washington 25, D. C.

TECHNICAL DEVELOPMENTS

THE CIRCLE COMPUTER

The Circle Computer is a fully automatic electronic digital computer. It has a memory of 1024 words, each consisting of forty binary digits plus two binary digits for sign. Single address instructions are used; instructions are stored in the same memory as numbers, with two instructions in each word. The memory and the operating registers appear on a magnetic drum rotating at 3540 rpm. Input and output to the computer is obtained by parallel operation of electric typewriters and punched paper tape.

In actual computation, the Circle Computer will be several hundred times as fast as a human computer using a desk calculating machine. Eight digit decimal numbers with sign can be read into or out of the Circle Computer, with the necessary conversion from or to binary, at a rate of one a second. This speed is primarily determined by the typewriter or tape handling devices. The conversion from decimal to binary or the reverse takes negligible time.

Historical. The Circle Computer was originally conceived and designed by people whose primary interest was in having such a machine for their use. Thus, the major emphasis in the design was to obtain a machine suitable for a medium size highly technical laboratory. Further, this machine had to be operable by physicists or mathematicians or engineers without an elaborate staff or specially trained computer operators. As time went on and it seemed that this goal might be obtained, it also became clear that such a machine would be of interest to many people. In order to further this aim, it was decided that it would be desirable to find an electronic equipment manufacturer to whom the construction of electronic equipment with a few thousand vacuum tubes was an old story holding few terrors. (The Circle Computer has several hundred vacuum tubes.) Such a manufacturer was found in Hogan Laboratories, Inc. Arrangements were made for Hogan Laboratories to offer Circle Computers for sale. Three such machines are now in process of manufacture.

It may be worthwhile to state again that the Circle Computer was designed from a functional standpoint by people whose main interest is in using it, whereas it is being designed from a circuit standpoint and built by people whose business it is to build electronic equipment of the same or greater complexity.

Purpose. In recent times, most calculation has been carried out on desk calculating machines, problems ranging in size from a few man minutes to several man months. The Circle Computer is intended to be used for a similar range of problems, extending perhaps to many man years on the large end. An attempt has been made to design the computer so that it may also be conveniently used for relatively short problems—in the extreme case, it is possible to code the computer to operate similarly to a desk calculator, but with almost any sort of special characteristics desired. In short, the Circle Computer is a general purpose computing machine, with no a priori limitations on the problems for which it is suitable.

Logical Design and Instruction Code. The logical design of the Circle Computer was patterned after the more successful operating large scale electronic digital computers. To indicate in a few words the type of computer being talked about we shall refer to it as an IAS (Institute for Advanced Study) type machine.

An IAS type machine may be thought of as consisting of three parts—arithmetic organ, memory, and control. The arithmetic organ is capable of the same sort of operations as an ordinary desk calculation machine. The memory is used to store both instructions and numbers. The control, in addition to including the usual arithmetic operations, must also contain such logical orders as comparison and the ability to modify its own coding. The extreme flexibility obtained by storing orders and numbers in the same memory and by being able to modify the instructions via the arithmetic organ has not been obtained in computing machines other than those following the IAS type logical design as just outlined.

Once the IAS type logical design has been selected, there remains the option of choosing single address, three address, or four address instruction code. Again our choice was for the somewhat greater flexibility inherent in single address coding, as compared with three or four address coding. This is greatly enhanced in the Circle Computer, in so far as modifications of the standard design are being considered. That is, it is easier to construct a special purpose single address order than a special purpose three address order. A few of the possible modified instructions are mentioned at the end of this paper.

Special Features. The instruction code of the Circle Computer is given in the Table accompanying this article along with average operating times. As is implied above, in the main the instructions are patterned after the IAS type machines. There are some additional instructions, however, which are desirable because of the lower speed and therefore slightly different emphasis of the Circle Computer design.

We now describe the instructions in the Table, with special emphasis on those not always present in IAS type machines. In a single address code, the instruction is stored in the memory in a position called the "floating address." The control of the machine changes the floating address by unity each time it carries out an order, so that the computer goes through its orders in sequence in the memory. This operation is modified by transfer orders, which change the floating address.

The arithmetic instructions of the Circle Computer are conventional for an IAS type machine.

The customary transfer operations, unconditional transfer and conditional transfer, are included, as is the rarer overflow transfer. Unconditional transfer means change the floating address to the address part of the instruction. Conditional transfer calls for a change in floating address only if the number in the accumulator (that register on the drum which contains the results of all arithmetic operations except division) is negative. Overflow transfer calls for a change in address if the magnitude of the number in the accumulator is too great to be handled in the Circle Computer—specifically, if the magnitude of the number in the accumulator is greater than or equal to unity, but less than two, the floating address is changed. The overflow transfer is useful in sensing the size of numbers in order to code, where necessary, floating binary point operation.

A further transfer order, as far as we know not available in any other computer, is the Function Table order. This order stores the floating address in the memory of the computer at the position called for as part of the instruction and then changes the floating address so that the control transfers to a position in the memory adjacent to that where the previous floating address was stored. The purpose of this order is to enable the utilization of subroutines in a problem by a single instruction in the main routine.

In order to call for a subroutine in coding, one must not only transfer the control to the position in the memory where the subroutine begins, but must also be sure that after the subroutine is finished, the control is returned to the next position in the main sequence. Both of these requirements are met with a single Function Table instruction. Moreover, since the floating address stored in the Function Table order is stored in the memory, there is no limitation on the number of Function Table orders that may be used, so that one can have subroutines of subroutines, and so forth. Clearly, with the Function Table order, the operator of a Circle Computer can write his own instruction code.

Since the Circle Computer operates in the binary number system whereas the input and output data will normally be in the decimal number system, binary-decimal and decimal-binary conversion is needed. These could, of course, be obtained as coded subroutines. However this would slow up the handling of input and output data. Therefore, special instructions are included in the Circle Computer commands to give high speed conversion. The input conversion converts eight digit decimal numbers to binary as a separate operation on the number after it has been read from the tape. The output conversion command is part of the print order and will convert the binary number in the accumulator to decimal as the number is printed. As many decimal digits as desired may be obtained. Thus, the output conversion takes no extra time; the input conversion takes 6% as much time as reading the input tape, which is negligible.

Communication. Input to the Circle Computer is by means of a six-hole punched paper tape operating in parallel with an electric typewriter. This input information is called for by the computer via the feed order. It can be accepted as numerical information in the hexadecimal system, in which case only four holes on the tape are relevant, or as alphabetical information utilizing all six holes. This information can be read into the computer at a rate of ten digits per second.

The above feed order reads information into the register of the computer, where it is available as numerical information. In addition, tape information can be used to select a floating address and transfer the control. In this manner, any one of forty-four different subroutines can be called for by tape. Furthermore, whenever the machine is idling, the same set of subroutines can be called for by depressing keys on the typewriter. It is by means of this feature that the Circle Computer could be operated as a special purpose desk computer, for example.

The output from the computer again goes to a typewriter and tape in parallel. This output may be either in converted binary or directly in groups of four binary digits (hexadecimal) or in groups of six binary digits (alphabetical). The last possibility is useful in enabling the machine to operate the typewriter—line spacing, tabulation, even typing of headings, all being obtainable by proper coding of the computer.

The above discussion was concerned primarily with communication with the computer during normal operation. To some extent one may consider the communication with the computer when hunting for errors in its instruction code as being more important. At such a time, the operator would like to see what the computer does in some detail, so that he may see where things go wrong in the coding. In order to fill this need, monitor operation is provided in the Circle Computer. When the monitor operation switch is set to monitor, every order in the computer which occurs in the left half of a word with a negative sign is automatically followed by a Function Table order to the zero position in the memory. The operator may code such a subroutine starting at this position as will cause the computer to print out that information he wishes displayed at each step being monitored.

It is our belief that the ease and flexibility of operator machine communication as indicated above makes it possible to use the Circle Computer not only for long, tedious problems, but also for many of the smaller problems which arise continuously in a technical organization.

Physical Description. The computer proper occupies about the same floor area as an office desk. The control panel and input output are connected to the computer by means of flexible cables. The computer's appearance is shown in the frontispiece.

The electronic components have been designed with an eye toward reliability and easy maintenance. It seems likely that one operator will be able to code, operate and maintain the computer. The circuits are designed to use standard computer tubes under conservative operating conditions. The speed of the electronic components is low enough so that no high currents are required of any tube. Conventional, standard (even old fashioned) tried and true circuits are used throughout.

The electronic components are divided into small logical units of a few tubes each which are attached to the machine with screw connections. We feel screw connections are more reliable than plugs. With this arrangement of small units, servicing can be accomplished by having a small stock of replacement units and tubes.

Alternatives. The discussion above has been concerned with the standard model Circle Computer, as is the Table. One Computer now under construction has a 4096 word memory, rather than the 1024 word memory of the standard model Circle Computer and is capable of operating with words of half length. Thus, this computer can be considered either a 4096 word forty binary digit (plus sign) computer or a 8192 word twenty binary digit (plus sign) computer. A complete catalog of other alternatives is impossible, but a few of the possibilities which may be of interest to some users are indicated below.

Special orders of various types can be invented almost indefinitely. A few of the more interesting of these include halving and doubling operations in which the register and accumulator are a single unit. This would be useful in rebuilding words in the machine for logical operations. Similarly the equivalent of logical multiplication is available. This order consists of replacing those digits of some word in the memory which correspond to unit digits in the register by the corresponding digits in the accumulator. Another possibility, which might be useful in conjunction with tape search, is a transfer order in which the transfer of control occurs unless the number in the accumulator is identical with that in the register.

Alternative input and output possibilities are also large in number. For example, multiple input or output tapes, with the desired one selected by coding, are immediately available. Tape searching is also a possibility. It should be pointed out that the input output speed is not computer limited but tape limited and could be upped by a factor of twenty or so without change in computer design.

Circle Computer Instructions Table

Each word is arranged as shown below:

$$\underbrace{S_1S_2}_{\substack{\text{Sign}\\\text{digits}}}\cdot A_1A_2\underbrace{A_3\cdots A_{12}}_{\substack{\text{Left}\\\text{order}\\\text{address}}}\underbrace{A_{13}\cdots A_{20}}_{\substack{\text{Left}\\\text{order}\\\text{command}}}A_{21}A_{22}\underbrace{A_{23}\cdots A_{32}}_{\substack{\text{Right}\\\text{order}\\\text{address}}}\underbrace{A_{33}\cdots A_{40}}_{\substack{\text{Right}\\\text{order}\\\text{command}}}$$

$x = (x_1, x_2, \cdots, x_{10})$ where these are stored either at $A_3 - A_{12}$ or $A_{23} - A_{32}$. The command is indicated by digits $y_1, \cdots, y_7$ where these are stored either at $A_{13} - A_{19}$ or $A_{33} - A_{39}$.

L or *R* in *LSp*, *RSp*, etc. means $y_1 = 0$ or 1. Similarly *E* or *O* in *ED*, *OD*, etc., means $y_1 = 0$ or 1. We define

$$z = 64 - 32x_6 - 16x_7 - 8x_8 - 4x_9 - 2x_{10} - y_1$$

Symbol	Average Time (milliseconds)	Operation
$x, +$	25	Clear the accumulator and add the number at memory position x into it.
$x, -$	25	Clear the accumulator and subtract the number at memory position x from it.
$x, +M$	25	Clear the accumulator and add the absolute value of the number at memory position x into it.
$x, -M$	25	Clear the accumulator and subtract the absolute value of the number at memory position x from it.
$x, h+$	25	Add the number at memory position x to the number in the accumulator. The sum appears in the accumulator.

Symbol	Average Time (milliseconds)	Operation
x, $h-$	25	Subtract the number at memory position x from the number in the accumulator, leaving the result in the accumulator.
x, $h+M$	25	Add the absolute value of the number at memory position x to the number in the accumulator, leaving the result in the accumulator.
x, $h-M$	25	Subtract the absolute value of the number at memory position x from the number in the accumulator, leaving the result in the accumulator.
x, X	45	Multiply the number at memory position x by the number in the register. The more significant half of the product appears in the accumulator and the less significant half in the register.
x, XR	45	Same as x, X, except that the more significant half of the product is rounded off.
x, $\div$	45	Divide the number in the accumulator by the number at memory position x. The quotient appears in the accumulator.
x, R	25	Clear the register and put the number at memory position x into it.
OOO, DB	45	Convert the decimal number in the register into binary. The result appears in the accumulator. In this order, the address must be OOO as indicated and the number in the register must have the decimal digits in positions A_{38}–A_{40} as zero.
x, Q	25	Store the number in the register at position x in the memory.
x, S	25	Store the number in the accumulator at position x in the memory.
x, LSp	25	Replace the address digits and y_1 of the left order at the memory position x by the corresponding digits in the accumulator.
x, RSp	25	Replace the address digits and y_1 of the right order at the memory position x by the corresponding digits in the accumulator.
x, EH OH	17–35	Halve the number in the accumulator z times.
x, ED OD	17–35	Double the number in the accumulator z times.
x, EP OP	100	Clear the print register, double the number in the accumulator $2z$ times and operate the output typewriter by the contents of the print register, which contains the last six binary digits to have overflowed the accumulator.
x, EF OF	100	Set up the six binary digits contained in the print register from the next line on the input paper tape. Left shift the register $2z$ times. The six digits from the print register now occupy the six positions in the register immediately to the right of the end of the number that was previously in the register.

Symbol	Average Time (milliseconds)	Operation
x, PBD	100 per digit	Convert the number in the accumulator to decimal and print the sign and the first $z/2$ decimal digits.
x, RC	17	Transfer the control to the right hand order at memory position x.
x, LC	17	Transfer the control to the left hand order at memory position x.
x, LCc	17	If the number in the accumulator is negative (if $S_1 = 1$) carry out the operation *x, LC*. Otherwise go to the next order in sequence.
x, RCc	17	If the number in the accumulator is negative (if $S_1 = 1$) carry out the operation *x, RC*. Otherwise go to the next order in sequence.
x, Lof	17	If, for the number in the accumulator, S_1 is unequal to S_2, carry out the operation *x, LC*. Otherwise go to the next order in sequence.
x, Rof	17	If, for the number in the accumulator, S_1 is unequal to S_2, carry out the operation *x, RC*. Otherwise go to the next order in sequence.
FC	100	Read the next line on the input tape and use it to determine $x_6 - x_{10}$ and y_1. $x_1 = x_2 \cdots = x_5 = 0$. Carry out the order *x, LC* or *x, RC* with this address.
STOP		Idle the machine. The operator may push the start button, in which case the machine continues with the next order in sequence. Alternatively, the operator may push a typewriter key, in which case the machine performs the FC order, but from the information given it by the typewriter key rather than from the tape.
		The operation of the next pair of orders depends on their position $U = U_1, \cdots U_{10}, U_{11}$ in the memory.
x, LFT	25	Replace the address digits and y_1 of the left order at x by the digits indicating the order position next after U. Transfer the control to the right hand order at x.
x, RFT	25	Replace the address digits and y_1 of the right order at x by the digits indicating the order position next after U. Transfer the control to the left hand order at $x + 1$.

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Bibliography of Coding Procedure

28. Naval Proving Ground, Dahlgren, Virginia, *Mark III Notes*. The report is a preliminary version of an operator's manual for the Mark III computer. The report discusses the number system, the external tape memory, the input coding machine and the output printers of the Mark III which is a magnetic drum machine. The remaining half of the report is devoted to the coding of elementary mathematical functions such as division, reciprocal square root, exp., log, cos, and $\tan^{-1}$.

29. U.S.N. Air Missile Test Center, *RAYDAC Operations* (Program Specifications). The order code for the RAYDAC is given along with a description of the operation determined by each of these orders.

30. A. L. Leiner, *System Specifications for the DYSEAC* National Bureau of Standards, September 1952. This description of the DYSEAC gives its operating specifications and compares them with those of the SEAC. The instructions which the machine will execute are discussed and the special features of the machine are noted.

31. Joseph B. Kruskal, Jr. *A Programmer's Description of ABEL, a Magnetic Drum Relay Computer*. The George Washington University Logistics Research Project.

32. H. Uchiyamada, Digital Computer Laboratory, M.I.T. *Comprehensive service routines* (*Whirlwind*). This description of how to use the Whirlwind I input conversion programs for translating programs using floating addresses, automatic selection of input-output and interpretive subroutines, and automatic cycle control into binary machine form is intended for reference only.

33. University of Illinois, *ORDVAC Manual 1952*. Most of this well written manual is concerned with engineering details of the ORDVAC, however, the instruction code and an illustrative problem is given and there is an excellent chapter on test routines.

34. J. H. Brown (Univ. of Michigan), *Function of Preliminary MIDAC Input Translation Program*. This memo describes how an input translation program for the three-address MIDAC is expected to be used. An example is given.

Bibliography Z

1050. ASME, *Digital and Analog Computers and Computing Methods*, Symposium at the 18th Applied Mechanics Division Conference of the American Society of Mechanical Engineers held at the University of Minnesota, June 18–20, 1953. New York, 1953, 64 p.

This collection of six papers represents a wide variety of experience in the use of both analog and digital computers. There is considerable material for comparing the merits and drawbacks of the two types with their many varieties. A few problems that have been solved are described in some detail, and many more are listed in the several papers.

"Automatic solution of mechanical problems," by E. L. Harder, of Westinghouse Electric Corporation, presents a detailed consideration of several types of problems and the advantages of different methods of solution. While analog computers are faster for those types of problems that they can readily handle, high powered digital machines are primarily designed for large problems. Pertaining to digital machines, the author states "considerable study is being devoted to making their use economical for a large volume of smaller, varied problems." Some success in this direction is indicated in the paper by S. N. ALEXANDER, National Bureau of Standards, entitled "High speed digital computers and their application to problems of applied mechanics." The NBS machine, the SEAC, does many problems, some of them of quite short duration, by "time-sharing." The changeover time "seldom exceeds ten minutes."

"Digital computer methods for solving linear algebraic equations and finding eigenvalues and eigenvectors" by D. J. WHEELER & J. P. NASH, both of the University of Illinois, will be of interest to those interested in the specific jobs that must be done in solving problems on a digital computer and the relative expense of each. Similar figures are given by Alexander and Harder in their respective papers, although the techniques of solving the problems are not gone into in as great detail. "Analog solution of beams excited by arbitrary force" by W. T. THOMSON & T. A. ROGERS, of the University of California, does a similar task for an analog computer problem, again in considerable detail.

Also included is a short, well written paper describing the essential feature of a simple differential analyser. The paper, "A synchro operated differential analyzer," by A. NORDSIECK, University of Illinois, is more than half devoted to a description of a mechanical integrator which is capable of transmitting enough torque to eliminate the torque amplifiers previously needed by such machines. Three such machines are now in use on a wide variety of problems.

C. J. SWIFT

NBSCL

1051. DAVID R. BROWN & ERNST ALBERS–SCHOENBERG, "Ferrites speed digital computers," *Electronics*, v. 26, April 1953, p. 146.

Some details of the coincident current magnetic memory scheme are described in this paper, together with nominal specifications and testing procedures for the magnetic material. The scheme itself, based on the square hysteresis phenomenon which is found in highly oriented metal magnetic materials, and also in the ferrites, involves running two currents through a number of toroids arranged in a cross matrix. Only at the one toroid through which both currents pass is there enough power to switch the core from one state to the other.

The main problem in this type of memory still seems to be in obtaining a material which has a square enough hysteresis loop. If one uses the ferrite described in this paper (General Ceramics and Steatite Corp. MF-1118) access times in the range of one to 10 microseconds are practical, but the number of words per array is limited. The article does not state how many words are possible, but later information indicates that about 1000 words per array can be achieved using ferrites in this manner. This type of memory has many desirable features (low cost and ruggedness in particular), and further work will certainly improve its characteristics.

A. W. HOLT

NBSEC

1052. R. D. ELBOURN & R. P. WITT, "Dynamic circuit techniques used in SEAC and DYSEAC," The Institute of Radio Engineers, *Transactions*, v. EC-2, 1953, p. 2–9.

It is claimed that all the high-speed arithmetic and control circuitry of an electronic digital computing machine to operate at a pulse repetition frequency of one megacycle can be built from just two types of etched-circuit plug-in packages. These packages, their circuits, components, and operating characteristics are described in this article.

J. H. WEGSTEIN

NBSCL

1053. J. H. FELKER, "Arithmetic processes for digital computers," *Electronics*, v. 26, March 1953, p. 150–155.

This article explains how numbers may be represented in various notations by using a different radix or base, and furthermore why the binary number system is a natural choice for electronic digital computers. The basic elements of binary arithmetic are explained and amply illustrated, and the method of conversion between decimal and binary notation is also covered. Common methods of error detection, and the subject of self correcting codes are discussed briefly.

SIDNEY GREENWALD

NBSEC

1054. JOINT AIEE—IRE COMPUTER CONFERENCE, *Review of Electronic Digital Computers*, 114 p. AIEE, S-44, February 1952, 28 × 21.4 cm. Price $3.50.

This Computer Conference, held in Philadelphia, Pennsylvania, December 10–12, 1951, was arranged by a joint committee of the Committee on Computing Devices of the American Institute of Electrical Engineers and the Electronic Computers Committee of the Institute of Radio Engineers, under the chairmanship of J. C. MCPHERSON, of the International Business Machines Corporation. Joining in the sponsorship of the Conference was the Association for Computing Machinery.

The keynote address was delivered by W. H. MAC WILLIAMS, of the Bell Telephone Laboratories. It was pointed out that the Conference was arranged for the purpose of (1) a review of the useful results obtained from operating high-speed digital computers and (2) a comparison of the logic of such computers. It was hoped that assessment of the adequacy of design of high-speed digital computers in operation would point out the direction desirable for future development. The following papers were presented:

The UNIVAC System, J. PRESPER ECKERT, JR., JAMES R. WEINER, H. FRAJER WELSH and HERBERT T. MITCHELL, all of the Eckert-Mauchly Computer Corp. Division of the Remington Rand Corp.

Block diagrams of the UNIVAC, the Unityper and the Uniprinter were presented and explained. There was treated, in detail, the functioning of the UNIVAC to perform the basic arithmetic and control operations. Checking circuits and engineering features of the system aimed at reliability of operation were explained. Applicability of the UNIVAC System to scientific, statistical, commercial and logistical problems was discussed. The paper ended with an evaluation of UNIVAC design with respect to reliability of operation, following comments on the performance record of the computer, both in acceptance testing and normal, productive operation.

Performance of the Census UNIVAC System, by J. L. McPherson, Bureau of the Census, and S. N. Alexander, the National Bureau of Standards.

The user's viewpoint on UNIVAC performance was given. The acceptance testing of the UNIVAC System (in this instance, a UNIVAC computer, four Uniservos, a Uniprinter and a Card-to-tape Convertor) was discussed in detail. Performance of the Computer system in the acceptance testing was outlined. A resume of operating experience on the Bureau of Census UNIVAC system was included, based on use in the Second Series Population Report problem consisting of four main parts: tallying, merging, determination of dispersion and summarizing. On a 7-day per week schedule, 24 hours a day, and during the periods from June 20 to 26, July 8 to August 4, and August 13 to October 28, 1951, the UNIVAC System was available for use 59 per cent of the time.

This level of performance was said to indicate that the Bureau of Census UNIVAC System would accomplish work planned for it at about one half the cost of doing it with any other tool available.

The Burroughs Laboratory Computer, by G. G. Hoberg, of the Burroughs Adding Machine Company.

This computer is a magnetic-drum, electronic machine, incorporating static magnetic registers. Designed and constructed in 9 months time, and checked out within 48 hours after the mounting and inter-connection of its units, the computer utilizes, wherever feasible, the Burroughs unit-packaged electronic pulse circuits. The computer is not a neatly-packaged commercial machine, however, but rather a laboratory device used in the research and development program of the Burroughs Adding Machine Company. It was described and evaluated by Mr. Hoberg on the basis of its performance in the latter role.

IBM Card-Programmed Calculator, by J. W. Sheldon and Liston Tatum, IBM.

This paper was concerned primarily with the programming and over-all operation features of the IBM Card-Programmed Electronic Calculator. The built-in operations were discussed, with use of a control panel layout, a block diagram giving the interconnection of the units of the calculator and a slide of a typical instruction card. The general-purpose nature of the calculator was stressed. An impressive list of applications of the device, classified as to mathematical structure, together with an indication of the fields in which the problems originated, was given as a demonstration of the utility of the Card-Programmed Calculator as a design and research tool.

The ORDVAC, by R. E. Meagher & J. P. Nash, University of Illinois, with introductory remarks by H. H. Goldstine, IAS.

The ORDVAC is a general-purpose computer built by the University of Illinois for the Ballistic Research Laboratories, Aberdeen, Md.

Dr. Goldstine's introduction was particularly relevant in view of the fact that the ORDVAC design, in many respects, follows closely the IAS Computer-Project design of a single-address, asynchronous machine with direct-coupled circuits. The introduction was brief, consisting of a few words on the history of automatic computation and a brief classification of the type of machine represented by the ORDVAC according to number representation (binary), mode of operation (parallel) and kind of storage (Williams' tubes).

The ORDVAC paper, supplemented by slides of computer views and circuit elements, was a description and objective evaluation of design features of the device under the headings: Arithmetic Unit, Input-Output, Memory, Control and Power Supplies. Included also was a description of the operation of the ORDVAC on test routines; at the time of the Conference the ORDVAC had not been used on mathematical problems.

Design Features of the ERA 1101 Computer, by F. C. MULLANEY, Engineering Research Associates Division of Remington Rand, Inc.

This computer, a single-address, binary-system, parallel machine using magnetic-drum storage, was described functionally by use of a block diagram of its principal elements and view of various parts. Sections of the paper on testing and maintenance and the operational record of the computer indicate, first, points of the circuit design thought to contribute to reliability and, second, a rather phenomenal, substantiating operational history.

The Operation and Logic of the Mark III Electronic Calculator in view of Operating Experience was presented by GLEN E. PORTE, United States Naval Proving Ground, Dahlgren, Va.

Considerable difficulty has been experienced in placing this, one of the more complicated magnetic-drum computers, in operation. The arithmetic unit is electronic, serial, employing the coded decimal system. Of the 4,350 internal storage capacity, 200 general registers and 150 constant registers contribute fast storage (one machine cycle); the remaining 4000 registers provide slow storage (access time of several machine cycles). There is a sequence magnetic drum, in addition to eight number storage drums. Included in the system are, also, eight magnetic tape read-record units and five separate printer units. A useful auxiliary is the "coding unit" which records an instruction sequence on magnetic tape, with the use of suitable checking features. The sequence is transferred thence to the sequence drum before the beginning of computation.

Specific causes of Mark III malfunctioning were listed in the paper, and remedies taken, or planned, were given. The logical design was evaluated, the conclusion being that, with the exception of a few points, the computer is a well-balanced machine including several outstanding features which should be perpetuated in future machines.

The University of Manchester Computing Machine, by F. C. WILLIAMS & T. KILBURN, University of Manchester, Manchester, England.

This paper was the first of two on the computer which is the culmination of a research project initiated at the Telecommunications-Research Establishment at the end of the war, and which was actively supported by the TRE after its move to the University of Manchester in January, 1947. The design of the present machine, developed in close cooperation, in detail, with Messrs. Ferranti Limited, followed the construction of three prototype computers. The unique and interesting use of storage lines on cathode-ray tubes as control and arithmetic-unit registers is explained in the paper, and the general features of the computer are given. The cathode-ray storage consists of 10,240 binary digits, on eight cathode-ray tubes, scanned serially. Magnetic storage of 150,000 binary digits is servo-synchronized with the master oscillator. Multiplication of two 40-digit numbers requires 2.16 milliseconds; the remaining operations are faster, requiring 1.2 ms. Division is not a built-in function. The input photoelectric tape reader reads 200 5-digit characters a second. Ten characters a second is the output speed of mechanical tape punching and/or teleprinting.

The Design, Construction, and Performance of a Large-Scale, General-Purpose Computer, by B. W. Pollard, of Ferranti Limited.

Here were presented the engineering techniques used and performance of the computer constructed by Ferranti, Ltd., and installed at the University of Manchester. Perhaps the most interesting sections are those concerning the Williams Storage system, which uses a mixture of "defocus-focus" and the "dot-dash" systems, and the magnetic-drum storage system, in which the method of synchronism of drum with the basic clock wave form generator, to positional accuracy of 1/100 degree, is described. Typical examples of industrial computations on the computer, as well as selected standard subroutines were listed. It was mentioned that out of a total of 834 hours logged on the computer since its dedication, there was 74 hours fault time, giving approximately a 90 per cent availability.

The Whirlwind I Computer, by R. R. Everett, Digital Computer Laboratory, Massachusetts Institute of Technology.

Again, we have the first of two papers on a computer, the first one being a description of computer characteristics and the second one being more concerned with engineering aspects of the design.

The WWI, sponsored by MIT, ONR and the USAF, is a 16 binary-digit, electrostatic-storage, parallel computer, performing 20,000 single-address operations a second. Addition takes 3 microseconds complete with carry, and multiplication requires 16 μs on the average, including sign determination. The extremely high speed of operation is a reflection of the intended applications in control and simulation problems on the computer design.

System layout and a functional description of arithmetic, control and storage units were given. There was included, in addition, a statement of the opinion of the WWI designers on what kind of checking features could profitably be included in computer design.

The manner of operating the computer, during the interval March 14, 1951, to November 22, 1951, was described. A partial list of actual problems carried out by the Digital Computer Laboratory was given.

Evaluation of the Engineering Aspects of Whirlwind I, by Norman H. Taylor, Digital Computer Laboratory, MIT.

In this paper, details of gate and trigger circuitry used in WWI were given. Also, control circuitry was described, and details of construction of the MIT electrostatic storage tube were presented. There was included an analysis of the WWI performance record, with particular attention to the causes of vacuum tube and crystal diode failures, and the utility of marginal checking in facilitating useful operation of the computer. The paper ended with a listing of good, adequate and doubtful points of the Whirlwind system.

The EDSAC Computer, by M. V. Wilkes, University of Cambridge.

This paper described the EDSAC, which was developed at the University of Cambridge, and has been in operation there since the summer of 1949. The computer is a binary, serial machine with ultrasonic storage. It has a precision of 16 binary digits, storage capacity of 1024 words, and uses a single-address order code. A 5-hole teleprinter tape, read by a photoelectric tape reader, provides the input, and a similar tape, or direct printing on a teleprinter, is the form of the output. In addition to a description of the computer system the paper includes discussion of interesting engineering features and an analysis of component failures.

The National Bureau of Standards Eastern Automatic Computer, by S. N. Alexander, National Bureau of Standards.

This paper, the first of two on the SEAC, is an account of the history of the development of the SEAC, constructed at NBS with the support of the USAF, including a narrative of the growth of its specifications as the work progressed and discussion of its operating record. Some prominent deviations from normal engineering techniques that contributed to the SEAC design are listed. A rather impressive list of problems that have been solved on the SEAC is included.

Engineering Experience on the SEAC, by Ralph J. Slutz, NBS.

The use of the SEAC in evaluating components under operating conditions and in testing out new auxiliary equipment in order to obtain design experience for further development is described in this paper. As an example of the former use, the 6AN5 tube, on which relatively little experience was available when the SEAC was designed, but which had been developed partly to meet computer requirements, was made the major vacuum tube in the computer. Moreover the tube was not derated, but under certain combinations of circumstances element dissipations could reach those specified by the manufacturer. The experience with the 6AN5's, for approximately 12,000 hours of computer operation, is carefully analyzed, the conclusion reached being that this tube is very satisfactory for computer use.

The characteristics of the germanium diodes used in the SEAC are discussed also. Test specifications for both the 6AN5 tubes and the diodes are given. Preventive maintenance for the computer is described, and component reliability is discussed.

Computing Machines in Aircraft Engineering, by Charles R. Strang, Douglas Aircraft Company.

The scale of present-day aircraft engineering and manufacturing was painted vividly by Mr. Strang. To give one of his illustrations, the engineering man hours devoted to the DC-6 plane, up to the first flight, totals about 1,295,000 hours, and up to the time of the talk, totaled about 3,275,000 hours. The DC-6 was a development of the DC-4 on which 3,850,000 man hours of engineering work was required. Thus a grand total of about 7,120,000 man hours was required for the development of a specific type of airplane.

The extensive use of computing equipment by the Douglas Aircraft Company was discussed. By the end of 1952 it was expected that, among the three Douglas Company plants in the Los Angeles area, the computing equipment in use would comprise: 2 IBM Defense Calculators (now called the IBM 701 Calculator), 5 Card Programmed Calculators, 1 electrical analogue computer (Constructed by the William Miller Company), 1 REAC (Reeves Instrument Company), and numerous IBM 604 electronic calculators and associated equipment. The engineering method, as applied to aircraft design, was described and comparison was made of the utility of digital and analogue computational devices. Typical design problems were discussed in some detail. Some machine design objectives were suggested, as being desirable from the user's standpoint.

A review of the Bell Laboratories' Digital Computer Developments, by E. G. ANDREWS, BTL.

With the "complex number computer" as the pioneer and with Model VI as its latest achievement BTL relay computer development has spanned the pre-electronic large-scale digital computer era. The different models are described briefly, from the functional viewpoint. They are all electro-mechanical computers using telephone system relays and teletype transmitting and recording devices as their principal apparatus elements.

The succession of BTL developments had its origin in 1938 in the mind of GEORGE R. STIBITZ, then with the Bell Laboratories as a research mathematician, with the design of Model I, the Complex Number Computer. The engineering and manufacturing of the Model I were supervised by SAMUEL B. WILLIAMS, a telephone systems design engineer. These two men played an important role in the creation of several of the succeeding BTL relay computers.

An interesting historical account was given of the publicizing of the Complex Number Computer, which multiplied and divided complex numbers and accumulated results algebraically if desired, before the Mathematical Society at Dartmouth in the fall of 1940. The computer in New York was controlled by a keyboard in the University, at Hanover, N. H. Test problems were placed on the keyboard; the computer in New York made the computation and controlled the printing of the answer on a typewriter at Hanover. This feat of remote control operation was not duplicated until 10 years later.

Of the BTL computers Models V and VI represent a highly satisfactory state of the development of electromagnetic computers; evaluated according to the following figures of merit, proposed and discussed by the speaker: dependability, ease of maintenance, ease of operation, ease of programming and machine accuracy.

The Transistor as a Digital Computer Component, by J. H. FELKER, BTL.

The natural application of transistors is to provide the gain required for communications between crystal diode circuits performing all the logic functions of the computer. In such applications the life of the transistor would appear to be equal to or better than that of the best vacuum tubes that have been made for digital computer use.

Circuit details and characteristics of a high-speed regenerative amplifier using transistors, and appearing to be especially suitable for use in serial digital computers, were given. Uses of the amplifier were suggested and building blocks proposed for a transistor ditigal computer.

Digital Computers—Present and Future Trends, by JAY W. FORRESTER, Digital Computer Laboratory, MIT.

The paper summarized the present status of digital computer development, enumerated the better features of the machines described at the

Conference, and indicated trends to be expected in the future. Evaluation criteria were proposed for storage performance, design efficiency and reliability. The utility of marginal testing was stressed, in pointing out design weakness in a new machine and in assuring operating away from the failure threshold of components.

In the discussion of future trends, it was pointed out that, although the transistor looks promising, it should not be considered a panacea. In fact, the transistor is not so interesting for its small size and power consumption as for the unproven possibility that it can be made to operate in greater freedom from intermittent change in performance than the vacuum tube.

In connection with the Williams tube memory, it was stated that computer design groups had probably been overoptimistic in planning to use in parallel machines, at high access rates, the tube which was designed by F. C. Williams for use in connection with serial scanning techniques. It was suggested that the electrostatic tube, regardless of type, is but a transient on the stage, to be replaced in the next few years by developments in solid state physics. It was predicted, however, that the great steps in the near future would lie in the direction of simplification of computer circuitry without the loss of performance.

Without exception, the talks at the conference were supplemented by remarks from the floor. In many cases, the speakers were led into interesting discussion by questions from the audience. Also, during the course of the sessions there were informal meetings of representatives of some of the various computer groups at the conference to discuss problems arising in programming. The conference apparently was well timed, with an agenda stimulating the interest of all participants.

E. W. C.

1055. L. B. Lueck & W. W. Wetzel, "Performance of high output magnetic tape," *Electronics*, v. 26, March 1953, p. 131–133.

Recent advances in the formulation of magnetic materials have produced an increase of more than two to one in magnetic remanence of the oxide used for magnetic recording tape. This results in a signal output of about twice that of standard tapes. The gain is achieved with no increase in noise level, thereby giving an improvement in signal-to-noise ratio. This gain can be used to reduce necessary tape speed or decrease recording track width.

James L. Pike

NBSEC

1056. Office of Naval Research, *Digital Computer Newsletter*, v. 5, July 1953, 11 p.

The contents are as follows:

1. UNIVAC
2. Moore School Automatic Computer (MSAC)
3. The SWAC
4. Burroughs Laboratory Computer
5. Consolidated Electronic Digital Computer, Model 30-201

6. Monrobot Electronic Calculator
7. The Oak Ridge Automatic Computer (ORACLE)
8. The NAREC
9. The ELECOM Computers
   ELECOM 100
   ELECOM 120
   ELECOM 200
10. University of Illinois Computer (ILLIAC)
11. Air Force Missile Test Center Computer (FLAC)
12. Naval Proving Ground Calculators
13. The Institute for Advanced Study Computer
14. The Logistic Computer
15. ABERDEEN PROVING GROUND COMPUTERS
    The ORDVAC
    The EDVAC
    The ENIAC
16. Whirlwind I
17. ERA 1103
18. Hughes Airborne Computer
19. Elliott-N.R.D.C. Computer 401 Mk 1
20. NICHOLAS

Data Processing and Conversion Equipment

1. Solid Acoustic Delay Line Memory Unit—Model 3C1-384
2. Contact Telereader
3. Character Display Signal Generator

List of Computing Services
Computer Courses

1. Remington Rand Inc. (UNIVAC Training Courses)

Notices

1. Computer Symposium
2. Joint Computer Conference
3. DCN News Item

1057. WILLIAM ORCHARD-HAYS, *The Duplex System for IBM's Model II CPC, A Fast Four Address, Double Operation, Floating-Decimal Set-Up.* Project RAND Research Memorandum 1044, The RAND Corporation, February 23, 1953, 42 p., 21.65 × 28 cm. Available without charge to libraries and research institutions.

The author described a floating decimal computing system for the Model II CPC which incorporates many desirable features. It is a four-address system with three inputs, two operations and one result per card—most pairs of operations being done in one machine cycle, i.e., while maintaining the maximum speed of 150 cards per minute. Numbers are represented by a combination of eight decimal digits and sign plus two digits for the exponent representing the scale factor.

In addition to the basic arithmetic operations, two (sometimes three) of which can be done in one card cycle, one can compute square root, log (base 10), antilog(base 10) and cosine (radians). Log and antilog are each two card operations. The negative balance test is used as a master control to switch to an alternate control field. Ten conditions such as attempting to take the square root or log of a negative number or committing certain errors in coding will cause the machine to stop.

Complete wiring diagrams of 418 and 605 boards together with detailed explanations of both are included.

R. K. ANDERSON

NBSCL

1058. N. ROCHESTER, "Symbolic programming," The Institute of Radio Engineers, *Trans.*, v. EC-2, 1953, p. 10–15.

Symbolic programming is described as a process in which instead of writing a true computer code the programmer replaces true addresses by symbolic addresses such as 1.1, 1.2, 1.10, 1.10.3 and writes out the operation in lieu of the true characters which the computer uses. With this method of programming the IBM 701 system, one instruction is punched on each card and the computer calls in the symblic code, processes it, and punches out a true machine code ready for use. Several advantages are claimed over conventional programming. For example, instructions can be added to a program by merely inserting cards, and subroutines or library programs can be included in a program by just placing their cards with the input deck.

J. H. WEGSTEIN

NBSCL

1059. C. R. STRANG, "Computing machines in aircraft engineering," *Electrical Engineering*, v. 73, Jan. 1953, p. 43–48.

This informative article points out the many and complicated problems which a modern aircraft laboratory must solve before undertaking to build an acceptable airplane model. A number of such problems are presented accompanied by their mathematical formulas or schematic diagrams. Even a cursory glance at this formidable array makes the reader appreciate the necessity for the elaborate computing equipment, listed by the author, at present in use by the Douglas Aircraft Company. This includes electronic computers, both analogue and digital.

The author concludes the article by pointing out some features which he would like computers to possess. It is not clear to the reviewer in what way the UNIVAC, or the SEAC, or the RAYDAC—to mention only three of the existing high-speed computers—fail to measure up to his specifications.

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NEWS

The American Society of Mechanical Engineers.—The eighteenth National Applied Mechanics Division Conference of the Society was held on June 18–20, 1953, at The University of Minnesota, Minneapolis, Minnesota. Included in the Conference was a Symposium on Digital and Analog Computers and Computing Methods. The program for the Symposium was as follows:

Friday, June 19, 1953, 9:30 a.m.

Symposium I	J. ORMONDROYD, Univ. of Michigan, *Chairman*
	S. LEVY, NBS, Washington, D. C., *Vice Chairman*
Analog solution of beams excited by arbitrary force	W. T. THOMSON & T. A. ROGERS, Univ. of California, Los Angeles
A synchro-operated differential analyzer	A. NORDSIECK, Control Systems Laboratory, Univ. of Illinois
New analog computers and their application to aircraft design problems	G. D. MCCANN & C. H. WILTS, California Institute of Technology, Pasadena

Panel discussion on applications of analog computing equipment.

Friday, June 19, 1953, 1:30 p.m.

Symposium II	L. E. GOODMAN, Univ. of Illinois, *Chairman*
	J. L. BOGDANOFF, Purdue Univ., *Vice Chairman*
Digital computer methods for solving linear algebraic equations and finding eigenvalues and eigenvectors	D. J. WHELLER & J. P. NASH, Univ. of Illinois
High speed digital computers and their application to problems of applied mechanics	S. N. ALEXANDER, NBS, Washington, D. C.
Automatic solution of mechanical problems	E. L. HARDER, Westinghouse Electric Corp.

Panel discussion on applications of digital computers.

The banquet at 7:00 p.m. on Friday featured as speaker Dr. MINA REES, Office of Naval Research, Washington, D. C.; the subject of Dr. Rees' talk was "Future field of application of high-speed computers."

Massachusetts Institute of Technology.—A Special Summer Program on "Digital Computers and Their Applications" was offered at M.I.T. during the Summer Session of 1953, from August 24 through September 4. The course stressed general precepts for coding of problems and attempted to reveal the advantages, difficulties, potentialities, and limitations of current electronic digital computers. In this connection, students were allowed to make use of the M.I.T. Whirlwind computer, in particular, and their experience gained on this computer was directed to all high-speed computers in general. The instruction was slanted to the selection of suitable computation methods and to ways of reducing programming time, computing time, and mistake-location time associated with coding. The program was under the direction of CHARLES W. ADAMS. The instructors were composed of staff members of the Digital Computation Laboratory, and the lecturers included M. V. WILKES, Director, University Mathematical Laboratory, Cambridge, England, and JAY W. FORRESTER, Director, M.I.T., Digital Computation Laboratory.

The University of Michigan.—From Monday, August 10, through Friday, August 21, 1953, the Willow Run Research Center of the Engineering Research Institute of the University presented a special two-week program on Digital Computers. The course was designed to emphasize the present and future applications of machines now in operation with special attention to business and industrial applications, scientific computations, digital simulation, and process control. The MIDAC (Michigan Digital Automatic Computer) was made available to the enrollees for training purposes, and the techniques and methods used on this machine were made applicable to a much wider range of computers. Special attention was given to the methods of programming of problems for machine solution originating at the various digital computer establishments throughout the world.

The instruction included discussions of number systems, machine instruction methods, computational modes, subroutines and the subroutine concept, translation processes, general aids to programming, storage devices, input-output equipment, computer operation procedures, and computer reliability. The special program was under the direction of JOHN W. CARR. The instructional staff was composed of members of the Digital Computation Group. Special lecturers were N. R. SCOTT, builder and designer of the University of Michigan magnetic drum computer, and W. F. BAUER, Willow Run Research Center, mathematician and analyst, and specialist in digital simulation.

Wayne University Computation Laboratory.—A special summer course in computer applications and components was offered by Wayne University from August 10 to August 21, 1953, in an endeavor to meet partially the immediate need for trained personnel in the field of automatic computing machinery. The course was held to train people to prepare and program problems for automatic computers, to adapt electronic techniques to the problems in business and industry, and to apply new design ideas for more effective equipment. This course is a part of a comprehensive educational program in this field instituted by the University in cooperation with local industry.

Applicants could register for any one of three different groups, namely; business applications, engineering applications, and computer components. In the first group, three daily lectures were given on programming, selected accounting applications, and production scheduling. Actual sample payroll or inventory problems were coded and run on the computers. The members of the second group joined the lecturers on coding and programming in the first group in addition to hearing separate lectures on engineering applications. Members of the group on computer components attended lectures on magnetic drum and other memory systems, ferro-electric and ferro-magnetic materials, and transistors. This special course offered as lecturers and discussion leaders many prominent leaders in the field of computers and their applications. Two new computers were available to students in order that they might code problems in their own field of interest, and with the assistance of the laboratory staff that they might run them on the machines. One was a large scale digital computer with a 5000-word magnetic drum memory, built by the Burroughs Corporation, and the other was a digital differential analyzer type of machine furnished by the Bendix Aviation Corporation.

OTHER AIDS TO COMPUTATION

BIBILOGRAPHY Z

1060. P. B. AITKEN, "Ruler for drawing radio activity decay curves," *Nucleonics*, v. 10, no. 6, 1952, p. 64.

The curvature of the edge of this ruler is varied by driving a wedge into a slot.

1061. ANON., "A high speed crystal clutch," Franklin Inst., *Jn.*, v. 252, 1951, p. 427–428.

A note on certain results of the National Bureau of Standards program for the development of fast acting clutches suitable for use in high speed computers.

1062. VALENTINE APPEL, "Companion nomographs for testing the significance of the difference between uncorrelated percentages," *Psychometrika*, v. 17, 1953, p. 325–330.