The Human Relations of Computers and Automation
... Fletcher Pratt

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SECOND EDITION OF THE
GLOSSARY

In this issue, we print in full a glossary of terms in the field of computers and automation. This is the second edition of the glossary published by COMPUTERS AND AUTOMATION. The first edition, now superseded, was published in three issues in 1953. This second edition is indebted to many sources, particularly to previously published glossaries, including one published in 1950 by the Institute of Radio Engineers, and one, dealing with digital computer programming terminology, by the Association for Computing Machinery in June, 1954, and to the following persons who have made contributions in one way or another: Grace M. Hopper, Alston S. Householder, D. R. Clutterham, James A. Pederson.

As usual, in the definitions printed in this glossary, we have tried to report meanings as used, rather than meanings which "should" be used.

Comments and criticisms of the definitions are invited, and will be appreciated, and probably will be published.

PUBLISHER OF "COMPUTERS AND AUTOMATION"

Beginning with the next issue, the publisher of COMPUTERS AND AUTOMATION will be Berkeley Enterprises, Inc.; we are incorporating. The members of Edmund C. Berkeley and Associates will become members of Berkeley Enterprises. A majority of the stock of Berkeley Enterprises will be owned by Edmund C. Berkeley, who will be president of the corporation. The organization Edmund C. Berkeley and Associates will continue to exist for some purposes (particularly the courses by mail) but a great part of its operations will be transferred to Berkeley Enterprises.

We hope that among other things this step will make it possible for us to publish a larger, more useful, and better magazine.

GREETINGS

To all our readers, advertisers, and friends, we wish Christmas Greetings and a Very Happy New Year — from the staff of COMPUTERS AND AUTOMATION.

To those who enjoy puzzles, and particularly to computers, we express an additional greeting, appearing at the top of the next column.

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The Human Relations of Computers and Automation

Fletcher Pratt, New York
Author of 'Ordeal by Fire' and 30 other books

As automatic computers extend their operations into new fields of business and industry and the process of automation reaches new heights, there becomes visible an area of problems which as yet have received consideration chiefly by avoidance. This is the field of their human relations, particularly their labor relations, and the social changes that may be expected to follow from the new processes.

Technological Unemployment

Even the technological unemployment problem has been shuddered at rather than considered. A refinery in Canada is in an area which has no labor supply, and to which labor stoutly refuses to move because of the lack of creature comforts. This was anticipated by the builders of the refinery, and they very sensibly chose to make the operation as nearly fully automatic as possible, with a resultant saving of about 30% in the operating force needed. The plant is a success -- but the operating firm refuses to allow its name to be mentioned, presumably on the theory that it will have bad labor relations elsewhere as a result.

Similarly, many firms buying Univac time from Remington-Rand insist that their use of the computers be kept a secret. But it is difficult to see how the use of computers which only furnish data unobtainable by any other process, could be viewed by any reasonable person as threatening anyone's employment.

Reasonableness of Management and Labor

The answer probably is that management in such cases has a suspicion that labor will not be very reasonable in the face of innovations; and the suspicion is likely to be justified. The new photographic composing machines, made by manufacturers headed by Photon, largely have the simple 42-key typewriter keyboard and can be operated by any competent stenographer. The typographers promptly claimed jurisdiction over persons operating the new machines, which is within the normal pattern of labor relations. But they have also produced a mechanical monster called the Brewer keyboard to be attached to the photo machine. The typographers consider this easier than spending two or three weeks to learn the simpler keyboard.

Neither labor nor management is squarely facing problems which can be solved only by the cooperation of both. Primarily this is a case of the narrow view. Of course, some kind of technological unemployment results from any new process: the invention of the automobile sensibly reduced the demand for blacksmiths, and that of the linotype for men who could set type by hand. But there is a difference. In the cases of automobile and linotype, the advance of the new devices was gradual and the bodies of labor affected were not the highly organized and vocal pressure groups of today.

Periodic Reeducation

The problem is likely to grow more acute with the advance of automation into new fields. Does it mean some kind of reorganization of industrial structure? It would be almost idle to predict, for the problem has not yet been submitted to enough study. It is possible that the solution will require going back to the level of the secondary schools and altering education. As now organized these schools tend to turn out specialists or at least people who will specialize at the next educative stage. Yet the demand of both automatic computers and an economy based on automation is for an immensely increased adaptability on the part of the individual. He must be willing not merely to accept periodic reeducation, but to regard it as a normal part of existence.

The Prospective Advance of Computing

The technological unemployment question is however only a single aspect of the new social complex inevitable as the result of computers and automation. There is a point at which any effort to hold back or contain a technical improvement becomes futile -- the point at which it becomes more profitable to violate any restriction than to conform to it. To observers living in the 19th century, the anti-machine riots in England appeared to demonstrate that the mechanization of industry would be achieved only slowly and with great difficulty. But the manifestations proved a wave on the surface only -- the appearance was illusory.
The Human Relations of Computers and Automation

Computers and Size of Business

Equally striking is the deducible effect of computers on the size of business. Tenderness for the small, independent business man is one of the most cherished of American economic ideas, but the computers are facing him with a type of pressure he has never before. Without the use of computer time, he will in effect, be operating blind in competition with large organizations which can afford a lot of computer time, and which can effect enormous economies by an expenditure on computer time in three days of as much as the small business man makes in a month.

Perhaps small business men can form cooperatives to rent computer time, but until it has actually been done, this solution would appear of doubtful validity. The problems of a small business, its logistic support, and sales operations, are not much less in complexity than those of a large one. Thus, relative to the scale of operations, the small business requires more computer time and computer expense than the larger one. It seems almost inevitable that computers as a factor in production will favor bigger business concentrations. It is not without significance that the greatest single employer of computers today is the biggest business of all -- the U. S. Government.

Address Changes. If your address changes, please notify us giving both old and new addresses, and allow three weeks for the change.

Manuscripts. We desire to publish articles that are factual, useful, understandable, and interesting to many kinds of people engaged in one part or another of the field of computers and automation. In this audience are many people who have expert knowledge of some part of the field, but who are laymen in other parts of it. Consequently, a writer should seek to explain his subject, and show its context and significance. He should define unfamiliar terms, or use them in a way that makes their meaning unmistakable. He should identify unfamiliar persons with a few words. He should use examples, comparisons, analogies, etc., whenever they may help readers to understand a difficult point. He should give data supporting his argument and evidence for his assertions. An article may certainly be controversial if the subject is discussed reasonably. Ordinarily, the length should be 1000 to 4000 words, and payment will be $10 to $50 on publication. A suggestion for an article should be submitted to us before too much work is done. To be considered for any particular issue, the manuscript should be in our hands by the 5th of the preceding month.
Glossary of Terms in the Field of Computers and Automation

(Glossary, second edition, cumulative November 3, 1954)

absolute address -- Digital Computer Programming. The label assigned by the machine designer to a specific register or location in the storage.

address coding -- Coding that uses absolute addresses.

access time -- Digital Computer. The time interval between the instant at which the arithmetic unit calls for information from the memory unit and the instant at which the information is delivered from storage to the arithmetic unit. It is the time between the instant at which the arithmetic unit starts to send information to the memory unit and the instant at which the storage of the information in the memory unit is completed.

accumulator -- Digital Computers. (1) A unit in a digital computer where numbers are totaled, that is, accumulated. (2) A register in the arithmetic unit of a digital computer where the result of arithmetic or logical operations is first produced. Usually the accumulator stores one quantity and upon receipt of a second quantity, it forms the sum of the first and the second quantities and stores that instead. Sometimes the accumulator is able to perform other operations upon a stored quantity in its register such as sensing, shifting, complementing, etc.

accuracy -- Correctness, or freedom from error.

address -- Digital Computers. A label, name, or number identifying a register, a location, or a device where information is stored. See also:

analogue -- Digital Computers. The section of the memory where each individual register bears an address. -- In storage on magnetic tape, usually only blocks of a number of items of information have addresses, and an individual item does not have an individual address associated with it.

alpha-numeric -- A system of abbreviations used in preparing information for input into a machine, such that information may be reported not only in numbers but also in letters and words. For example, Boston, New York, Philadelphia, Washington, may in alphabetic coding be reported as BS, NY, PH, WA. Some computers will not accept alphabetic coding but require all abbreviations to be numerical, in which case these places might be coded as 0, 1, 2, 3.

analog -- Using physical variables, such as distance or rotation or voltage, or measurements of similar physical quantities, to represent and correspond with numerical variables that occur in a computation; contrasted with "digital".

analog computer -- A computer which calculates by using physical variables of the variables. Usually a one-to-one correspondence exists between each numerical variable occurring in the problem and a varying physical measurement in the analog computer.

arithmetical operations -- An operation in which numerical quantities form the elements of the calculation. Such operations include the "fundamental operations of arithmetic", which are addition, subtraction, multiplication and division.

arithmetical shift -- The multiplication or division of a quantity by a power of the base of nota-
In binary notation, the result of two arithmetic changes to the left is 101100, which represents forty-four.

arithmetic unit - Digital Computers. The portion of the hardware of a computer where arithmetic and logical operations are performed on information.

asynchronous computer - Digital Computers. An automatic computer where the performance of any operation starts as a result of a signal that the previous operation has been completed, contracted with "synchronous computers," which see.

automatic carriage - Punch Card Machine. A writing carriage which is automatically controlled by information and program so as to feed forms or continuous paper, space, skip, eject, tabulate, etc. It may produce any desired style of presentation of information on separate forms or on continuous paper.

automatic checking - Computers. Provision, constructed in hardware, for automatically verifying the information, transmitted, manipulated or stored by any device or unit of the computer. Automatic checking is "complete" when every process in the machine is automatically checked; otherwise it is partial. The term "extent of automatic checking" means either (1) the relative proportion of machine processes which are checked, or (2) the relative proportion of machine hardware devoted to checking.

automatic computer - A computer which automatically handles long sequences of reasonable operations with information.

automatic controller - A device which controls a process by (1) automatically receiving measurements of one or more physical variables of the process, (2) automatically performing a calculation, and (3) automatically issuing suitable varied actions, such as the relative movement of a valve, so that the process is controlled as desired; for example, a flyball governor on a steam engine; an automatic pilot.

automatic programming - Digital Computer Programming. Any technique whereby the computer itself is used to transform programming from a form that is easy for a human being to produce into a form that is efficient for the computer to carry out. Examples of automatic programming are compiling routines, interpreter routines, etc.

automation - 1. Process or result of rendering machine self-acting or self-moving; rendering automatic. 2. Theory or art or technique of making a device or machine or an industrial process more fully automatic. 3. Making automatic the process of moving pieces of work from one machine tool to the next.

available machine time - Time that a computer has but the power turned on, is not under maintenance and is known or believed to be operating correctly.

average calculating operation - A common or typical calculating operation longer than an addition and shorter than a multiplication; often taken as the mean of nine additions and one multiplication.

B: base - Numbers. Ten in the decimal notation of numbers, two in the binary notation of numbers, eight in octal notation, and in general the radix in any scale of notation for numbers.

binary - Involving the integer two. For example, the binary number system uses two as its base of notation. A binary choice is a choice between two alternatives; a binary operation is one combining 2 quantities.

binary cell - An element that can have one of the other two stable states or positions and so can store a unit of information.

binary-coded decimal notation - One of many systems of writing numbers in which each decimal digit of the number is expressed by a different code written in binary digits. For example, the decimal digit zero may be represented by the code 0000, the decimal digit one may be represented by the code 0010, etc.

binary digit - A digit in the binary scale of notation. This digit may be only 0 (zero) or 1 (one). It is equivalent to an "on" condition or an "off" condition, a "yes" or a "no," etc.

binary notation - The writing or recording of numbers in the scale of two. The first dozen numbers zero to eleven are written 0, 1, 10, 11, 100, 101, 110, 111, 1000, 1001, 1010, 1011. The positions of the digits designate powers of two; thus 1010 means 1 times two cubed or eight, 0 times two squared or four, 1 times two to the first power or two, and 0 times two to the zero power or one; this is equal to one eight plus no four's plus one two plus no ones, which is ten.

binary number - A number written in binary notation.

binary point - In a binary number, the point which marks the place between integral powers of two and fractional powers of two, analogous to the decimal point in a decimal number. Thus, 10.101 means four, one half, and one eighth.

binary to decimal conversion - The mathematical process of converting a number written in binary notation to the equivalent number written in the ordinary decimal notation.

biquinary notation - Numbers. A scale of notation in which the base is alternately 2 and 5. For example, the number 3671 in decimal notation is 03 11 12 01 in biquinary notation; the first of each pair of digits counts 0 or 1 units of five, and the second counts 0, 1, 2, 3, or 4 units. For comparison, the same number in Roman numerals is MMMDCLXXI. Biquinary notation expresses the representation of numbers by the abacus, and by the two hands and five fingers of man; and has been used in some automatic computers.

bit - A binary digit; a smallest unit of information; a "yes" or a "no"; a single pulse in a group of pulses.

block - Digital Computers. A group of consecutive machine words considered or transferred as a unit, particularly with reference to input and output.

bootstrap - Digital Computer Programming. The coded instructions at the beginning of a program or a separate final program, used to put a program into the computer.

break-point - Digital Computer Programming. A point in a routine at which the computer may be stopped for an operator's check of the progress of the routine.

buffer - Circuits. An isolating circuit used to avoid any reaction of a driven circuit upon the corresponding driving circuit.
circuit having an output and a multiplicity of inputs so designed that the output is energized whenever one or more inputs are energized. Thus, a buffer performs the circuit function which is equivalent to the logical "or", which see.

buffer storage -- Digital Computers. 1. Equipment linked to an input device, in which information is assembled from external storage and stored ready for transfer to internal storage. 2. Equipment linked to an output device into which information is transmitted from internal storage. A held for transfer to external storage. Computation continues while transfers between buffer storage and external storage take place.

cell, Digital Computers. A path over which information is transferred, from any of several destinations; a channel, line, or trunk.

cell number -- Digital Computer Programming. A set of characters identifying a subroutine, and containing information concerning parameters to be inserted in the subroutine, or information to be used in generating the subroutine, or information related to the operands.

cell word -- Digital Computer Programming. A cell number which fills exactly one machine word.

capacity -- Digital Computers. 1. The number of digits or characters which may usually be processed in a computer, as in "the capacity of the computer is ten decimal digit numbers". 2. The upper and lower limits of the numbers which may regularly be handled in a computer, as "the capacity of the computer is +0.0000 00001 to .99999 99999". Quantities which are beyond the capacity of the computer usually interrupt its operation in some way.

card, Digital Computers. A card of constant size and shape, adapted for being punched in a pattern which has meaning. The punched holes are sensed electrically by wire brushes or mechanically by metal fingers. Also called "punch card."

One of the standard punch cards (made by International Business Machines Corporation) is 7 and 3/8 inches long by 3 and 1/4 inches wide, and contains 80 columns in each of which any one of 12 positions may be punched.

One card column, or punch card column. One of a number of columns (45, 80, or 90) in a punch card into which information is entered by punches.

card feed, Punch Card Machines. A mechanism which moves cards one by one into a machine.

card field, Punch Card Machines. A set of card columns fixed as to number and position, into which the same item of information is regularly entered; for example, purchase order numbers of fixed decimal digits might be punched regularly into the card field consisting of card columns 11 to 15.

card stacker, Punch Card Machines. A mechanism that stacks cards in a pocket or bin after they have passed through a machine. Sometimes called "card hopper."

card punch, Punch Card Machines. A mechanism that causes the information in cards to be read, usually by passing them under copper wire brushes or across metal fingers.

card punch, Punch Card Machines. A mechanism which punches cards, or a machine which punches cards according to a program.

carry -- arithmetic. The digit to be taken to the next higher column (and there added) when the sum of the digits in one column equals or exceeds the base.

cathode ray tube -- Digital Computers. A large electronic vacuum tube containing a screen on which information, expressed in pulses in a beam or ray of electrons from the cathode, is stored by means of the presence or absence of spots bearing electrostatic charges. The capacity usually is from 256 to 1024 spots.

cell, Digital Computers. Storage for one unit of information, usually one character or one machine word. More specific terms ("column, location, block") are preferable since there is little uniformity in the use of the term "cell."

channel, Digital Computers. 1. A path along which information, particularly a series of digits or characters or units of information, may flow or be stored. For example, in the machine known as a punch card reproducer, information (in the form of punch cards) may flow in either one of two card channels which do not physically connect. 2. Magnetic Tape or Magnetic Drum. A path parallel to the edge of the tape or drum along which information may be stored by means of the presence or absence of polarized spots. Single or in sets. 3. Delay Line Memory such as a Mercury Tank. A circular path forward through the delay line memory and back through electrical circuits along which a pattern of pulses representing information may be stored.

character, Digital Computers. 1. A decimal digit 0 to 9, or a letter A to Z, either capital or lower case, or a punctuation symbol, or any other single symbol (such as appear on the keys of a typewriter) which a machine may take in, store, or put out. 2. A representation of such a symbol in a pattern of ones and zeros representing a pattern of positive and negative pulses.

check digit, Digital Computers. One or more digits carried along with a machine word (i.e., a unit item of information supplied by the machine) to report information about the machine word. In such a manner that if a single error occurs (excluding two-compensating errors), the check will fail and give rise to an error alarm signal. For example, the check digit may be 0 if the sum of other digits in the word is odd, and the check digit may be 1 if the sum of other digits in the word is even.

circulating memory, Digital Computers. A device using a "delay line" which stores information in a train of pulses or waves, as a pattern of the presence or absence of such pulses, where the pattern of pulses issuing at the final end of the delay line is detected electrically, amplified, reshaped, and reinserted in the delay line at the beginning end.

closed subroutine, Digital Computer Programming. A subroutine with the following property: (1) it is stored separately from the main routine; (2) at the proper point in the main routine, a jump instruction transfers control to the beginning of the subroutine; (3) at the end of the subroutine, another jump instruction transfers control back to the proper point in the main routine.
GLOSSARY

clear (verb) — Digital Computers. To replace information in a register by zero, as expressed in the number system employed.
code (noun) — Computers. A system of symbols for representing information in a computer, and the rules for associating them.
code (verb) — Computers. To express information, particularly problems, in language acceptable to a specific computer.
coded decimal (adjective) — Computers. A form of notation by which each decimal digit separately is converted into a pattern of binary ones and zeros. For example, in the "8-4-2-1" coded decimal notation, the number twelve is represented as 0001 0010 (for 1, 2) whereas in pure binary notation it is represented as 1100. Other coded decimal notations are known as: "5-4-2-1", "excess three", "8-4-2-1", etc.
coded decimal digit — A decimal digit which is expressed by a pattern of four or more ones and zeros.
coded program — A program which has been expressed in the code for a computer.
coder — A person who translates a sequence of instructions for an automatic computer to solve a problem into the precise codes acceptable to the machine.
coding — The list in computer code of the successive computer operations required to carry out a given routine or subroutine or solve a given problem.
coding line — A single command or instruction written usually on one line, in a code for a computer to solve a problem.
collate — To combine two sequences of items of information in any way such that the same sequence is observed in the combined sequence. For example, sequence 12, 29, 42, 48, 40 may be collated into 12, 23, 24, 29, 42, 48. More generally, to combine two or more similarly ordered sets of items to produce another ordered set composed of information from the original sets. Both the number of items and the size of the individual items in the resulting set may differ from those of either of the original sets and of their sums.
collector — Punch Card Machine. A machine which has two card-feeders, four card pockets, and three stations at which a card may be compared or sequenced with regard to other cards, so as to determine the pocket into which it is to be placed. The machine is particularly useful for matching detail cards with master cards, for merging cards in proper sequence into a file of cards, etc.
column — 1. Writing. The place or position of a character or a digit in a word, or other unit of information. 2. Computers. One of the characters or digits in a positional notation representation of a unit of information. Columns are usually numbered from right to left, zero being the rightmost column if there is no decimal (or binary, or other) point, or the column immediately to the left of the point if there is one. 3. Arithmetic. A position or place in a scale of notation, such as 5076, written in a scale of notation corresponding to a given power of the radix. The digit located in any particular column is the coefficient of the corresponding power of the radix; thus, in the foregoing example is the coefficient of 10^2.
command — A pulse, signal, or set of signals initiating one step in the performance of a computer operation.
comparator — 1. Circuit. A circuit which compares two signals and supplies an indication of agreement or disagreement, or a mechanism by means of which two items of information may be compared in certain respects, and a signal given depending on whether they are equal or unequal. 2. Computers. A device for comparing two different transmissions of the same information to verify agreement or determine disagreement.
comparison — Computers. The act of comparing and, usually, acting on the result of the comparison. The common forms are comparison of two numbers for identity, comparison of two numbers for relative magnitude, and comparison of two signs plus or minus.
compiler — Digital Computer Programming. A program-making routine, which produces a specific program for a particular problem by the following process: (1) determining the intended meaning of an element of information expressed in pseudo-code; (2) selecting or generating (i.e., calculating from parameters and skeleton instructions) a subroutine; (3) transforming the subroutine into specific coding for the specific problem, assigning specific memory registers, etc., and entering it as an element of the problem program; (4) maintaining a record of the subroutines used and their position in the program; and (5) continuing to the next element of information in pseudo-code.
compiling routine — Computers. A routine by means of which a computer can itself construct the program to solve a problem by assembling, fitting together, and copying other programs stored in its library of routines. Same as "compiler", which see.
complement — Arithmetic. A quantity which is derived from a given quantity, expressed in notation to the base n, by one of the following rules: (a) complement on n, subtract each digit of the given quantity from n - 1, add unity to the rightmost digit, not zero and perform all resultant carries. For example, the two's complement of binary 11010 is 00110; the ten's complement of decimal 679 is 321. (b) Complement on n: subtract each digit of the given quantity from n - 1. For example, the ones complement of binary 11010 is 00101; the nine's complement of decimal 679 is 320. The complement is frequently employed in computers to represent the negative of the given quantity.
complete operation — Computers. A calculating operation which includes (1) obtaining all the numbers entering into the operation out of the memory, (2) making the calculation, (3) putting the results back into the memory, and (4) obtaining the next instruction.
computer — 1. A machine which is able to calculate or compute, that is, which will perform sequences of reasonable operations with information, mainly arithmetical and logical operations. 2. More generally, any device which is capable of accepting information, applying definite reasonable processes to the information, and supplying the results of these processes.
computing machinery — Machinery which is able to
GLOSSARY

take in and give out information, perform reasonable operations with the information, and store information.

computer code — Computers. The code expressing the operations built into the hardware of the computer.

computer operation — Computers. The electronic, mechanical, or other physical operation of hardware in a computer resulting from an instruction given to the computer.

conditional — Computers. Subject to the result of a comparison made during computation; subject to human intervention.

conditional breakpoint instruction — Digital computer Programming. A conditional jump instruction which, if some specified switch is set, will cause the computer to stop, after which either the routine may be continued as before or a jump to another route may be directed.

conditional transfer of control — Digital Computers. A computer instruction which when reached in the course of a program will cause the computer either to continue with the next instruction in the original sequence or to transfer control to another stated instruction, depending on whether some specified condition has been true or false.

contents — Digital Computers. The information stored in any part of the computer memory. The symbol "(..)" is often used to indicate the contents of... ; for example, (m) indicates the contents of the storage location whose address is m.

control (verb) — Digital Computers. To direct the sequence of execution of the instructions to a computer.

control circuits — Digital Computers. The circuits which effect the carrying out of instructions in proper sequence.

control register — Digital Computers. The register which stores the current instruction governing the operation of the computer for a cycle.

control sequence — Digital Computers. The normal sequence of selection of computer instructions for execution. In some computers, one of the addresses in each instruction specifies the control sequence. In most other computers the sequence is consecutive except where a jump occurs.

control unit — Digital Computers. That portion of the hardware of an automatic digital computer which directs the sequence of operations, interprets the coded instructions, and initiates the proper signals to the computer circuits to execute the instructions.

converter — A machine which changes information in one kind of language acceptable to a machine into corresponding information in another kind of language acceptable to a machine. For example, a machine which takes in information expressed in punch cards and produces the same information expressed in magnetic tape is a "converter". Often the machine possesses limited computing facilities, spoken of as "editing facilities".

copy — Digital Computers. To transfer information stored in one memory register into another memory register, leaving unchanged the information in the first register, and replacing whatever was previously stored in the second register.

counter — A mechanism which either totals digital numbers, or allows digital numbers to be increased by additions of one in any column of the number. It is also able to be reset to zero.

cramped leap-frog test — Digital Computer Programming. A variation of the leap-frog test described below, modified so that it repeats its tests from a single set of storage locations and does not "leap".

cybernetics — 1. The study of control and communication in the animal and the machine. 2. The art of the pilot or steersman. 3. The comparative study of complex information-handling machinery and the nervous systems of the higher animals including man in order to understand better the functioning of brains.

cycle (verb) — Computers. To repeat a set of operations a specified number of times including, when required, supplying necessary memory location address changes by arithmetic processes or by means of a hardware device such as a cycle-counter.

cycle (noun) — 1. A set of operations repeated as a unit. 2. Computers. The smallest period of time or complete process of action that is repeated in order. In some computers, "minor cycles" and "major cycles" are distinguished. 3. Computer Arithmetic. A shift of the digits of a number such that digits removed from one end of the word are inserted in sequence at the other end of the word, in circular fashion.

cycle criterion — Digital Computer Programming. The total number of times that a cycle is to be repeated, or the register which stores that number.

cycle index — Digital Computer Programming. The number of times a cycle has been executed; or the difference (or the negative of the difference) between that number and the number of repetitions desired.

cycle reset — Digital Computer Programming. The returning of a cycle index to its initial value.

cycle shift — Computer Arithmetic. A shift of the digits of a number for the characters of a word in which digits removed from one end of the word are inserted in the same sequence at the other end of the word, in circular fashion.

cycle telling — Digital Computers.

c: DC jump — Digital Computers. The condition resulting when direct current power is withdrawn from a computer which uses volatile storage, i.e., loss of information stored in such storage.

debug — Computers. To isolate and remove mistakes from a computer or mistakes from a program, usually done with hardware devices.

decade — A group of ten; for example, a "decade counter" will count to ten in one column or place of a decimal number.

decimal digit — One of the symbols 0, 1, 2, 3, 4, 5, 6, 7, 8, 9 when used in numbering in the scale of ten. Two of these digits, 0 and 1, are of course also binary digits when used in numeration in the scale of two.

decimal notation — The writing of quantities in the scale of ten.

decimal point — In a decimal number, the point
GLOSSARY

decimal-to-binary conversion — Mathematical process of converting a number written in the scale of ten into the same number written in the scale of two.
delay line — Computers. A device which stores information in a train of pulses or waves, and as a pattern of the presence or absence of such waves. An example of a delay line in everyday life is an echo; the air and a reflecting wall momentarily store a train of sound waves. In a computer delay line, the medium may be mercury, the container a pipe, and the pulses issuing at the final end may be detected electrically, amplified, reshaped, and reinserted at the beginning end.
diagnostic routine — Digital Computer Programming. A specific routine designed to locate either a malfunction in the computer or a mistake in coding.
diagram — Digital Computer Programming. A schematic representation of a sequence of subroutines designed to solve a problem. It is a less detailed and less symbolic representation than a flow chart and frequently includes descriptions in English words.
differential analyzer — An analog computer designed particularly for solving or “analyzing” many types of differential equations.
differentiator — Analog Computers. A device whose output signal is proportional to the derivative of an input signal.
digit — 1. One of the symbols 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, used in a decimal, is the scale of ten. 2. One of these symbols and sometimes also letters expressing integral values ranging from 0 to n inclusive, used in a scale of numbers to the base n.
digital — Using numbers expressed in digits and in a scale of notation, in order to represent all the variables that occur in a problem.
digital computer — A computer which stores large numbers expressed in digits and uses and moes expressed usually in 1’s and 0’s, to represent all the variables that occur in a problem.
digitize — To change an analog measurement of a physical variable into a number expressed in digits in a scale of notation.
double precision — Digital Computers. Having twice as many digits as the quantities normally handled in the computer. For example, in the case of a desk calculator regularly handling ten place decimal numbers, computation with 20 place numbers by keeping track of the 10 place fragments, is “double precision” computation.
down-time — Computer Operation. Time when a computer is malfunctioning, or not operating correctly, due to hardware failures.
dump — Digital Computer Programming. An artificial address, instruction, or other unit of information inserted solely to fulfill prescribed conditions (such as word-length or block-length) without affecting operations.
dump — Computer Operation. To withdraw all power accidentally or intentionally.
duplication check — A check which requires that the results of two independent performances (either concurrently on duplicate equipment or at a later time on the same equipment) of the same operation be identical.
dynamic storage — Storage such that information at a certain position is changing over time and so is not always available instantly; for example, acoustic delay line storage or magnetic drum storage.
dynamic subroutine — Digital Computer Programming. A subroutine which involves parameters, such as decimal point position or item size, from which a relatively coded subroutine is derived. The computer itself is expected to adjust or generate the subroutine according to the parametric values chosen.
ed: edit — Digital Computer Programming. To arrange or rearrange information, for the output unit to print. Editing may involve the deletion of unwanted data, the selection of pertinent data, the insertion of invariant symbols such as page numbers and typewriter characters, and the application of standard processes such as zero-suppression.
education of a computer — Computers. Preparing and assembling programs for a computer so that the computer can itself put together many programs for many purposes. This greatly reduces the time required from human programmers to program the computer.
electric typewriter — A typewriter having an electric motor and the property that almost all the operations of the machine after the keys are touched by human fingers are performed by electric power instead of the power of human fingers and hands.
electronic (as contrasted with “electric”) — In general, dealing with flows of small numbers of electrons in a vacuum, as contrasted with flows of large numbers of electrons along wire conductors.
electronic calculating punch — Punch Card Machines. A punch card machine which, in each fraction of a second reads a punch card passing through the machine, performs a number of sequential operations, and punches a result on the punch card.
electrostatic storage — Storage of information in the form of the presence or absence of spots bearing electrostatic charges. See "meth-ode-ray" tube.
equation solver — A computing device, often analog, which is designed to solve systems of linear simultaneous (non-differential) equations or find the roots of polynomials, or both.
equivalent binary digits — Number of binary digits equivalent to a given number of decimal digits or other characters. When a decimal number is converted into a binary number, the number of binary digits necessary is in general equal to about 3 1/3 times the number of decimal digits. In coded decimal notation, the number of binary digits necessary is ordinarily 4 times the number of decimal digits.
erasable storage — Storage media which can be erased and reused; for example, magnetic tapes.
etase — Digital Computers. 1. To remove information from storage and leave the space available for recording new information. 2. To replace all the binary digits in a storage device by binary zeros. In a binary computer, erasing is equivalent to clearing, while in a coded decimal computer where the pulse code for decimal zero may contain binary ones, clear-
ing leaves decimal zero while erasing leaves all-zero pulse codes.

error — The amount of loss of precision in a quantity, the difference between an accurate quantity and its calculated approximation. Errors occur in numerical methods; mistakes occur in programs, coding, data transcription, and operating; malfunctions occur in computers.

excess-three code — A coded decimal notation for decimal digits which represents each decimal digit as the corresponding binary number plus three. For example, the decimal digits 0, 1, 8, 9, are represented as 0011, 0100, 1011, 1100, respectively. As may be seen, in this notation, the mines complement of the decimal digit is equal to the ones complement of the corresponding four binary digits.

exchange — Digital Computer Programming. To interchange the contents of two storage devices or locations.

executive routine — Digital Computer Programming. A routine designed to process and control other routines.

external memory — Digital Computers. Material separate from the computer itself, but holding information in a form accessible to the machine, as for example, on recorded magnetic tape in a closet, or punch cards in filing cabinets.

extract — Computers. 1. To obtain certain digits from a machine word, as may be specified. For example, if the ten-digit number 0000011100 is stored in a machine register, the computer can be instructed to "extract" the eighth digit (in this case/one) and correspondingly perform a certain action. 2. Computers. To replace the contents of specific columns of one machine word by the contents of the corresponding columns of another machine word, depending on the information. 3. To remove from a set of items information all those items that meet some arbitrary condition.

F: flip — 1. Punch Card Machines. A set of one or more columns in each of a number of punch cards, which is regularly used to report a standard item of information. For example, if columns 16 to 19 are regularly used to report weekly rate of pay, then these columns would constitute a field. 2. Computers. A set of one or more characters (not necessarily alloying in the same word) which is treated as a whole; a unit of information.

fixed-cycle operation — Computers. Organization of a computer whereby a fixed time is allocated to operations, although they may actually take less time than is allocated. This is the type of operation of a "synchronous" computer.

fixed-point arithmetic — Computers. Calculation using or assuming a fixed or constant location of the decimal point or the binary point in each number.

fixed-point representation — Arithmetic. An arithmetical notation in which all numerical quantities are expressed as the same specified number of digits, with the point implicitly located at the same specified position; a constant position.

flip-flop — Circuits. An electronic circuit having two stable states, two input lines, and two corresponding output lines such that a change exists on either one of the output lines if and only if the last pulse received by the flip-flop is on the corresponding input line.

floating-point calculation — Computers. Calculation taking into account varying location of the decimal point (if base 10) or binary point (if base 2), and consisting of writing each number by specifying separately its sign, its coefficient, and its exponent affecting the base. For example, in floating-point calculation, the decimal number -6.38028 might be reported as -6.38028 x 10^9.

flow chart — Digital Computer Programming. A graphical representation of a sequence of programming operations, using symbols to represent operations such as compute, substitute, compare, jump, copy, read, write, etc. A flow chart is a more detailed representation than a diagram, which see.

force (verb) — Digital Computer Programming. To intervene.

four-address (adjective) — Digital Computer Programming. Having the property that each complete instruction specifies the operation and the addresses of four registers. Usually each instruction contains the addresses of three operands (i.e., the numbers being operated with), the operation, and the address of the next order.

function switch — Circuits. A network or circuit having a number of inputs and outputs and so connected that signals representing information expressed in a certain code, when applied to the inputs, cause output signals to appear which are a function of the input information.

function table — 1. Mathematics. A table of the values for a mathematical function. 2. Computers. A hardware device or a program which translates from one representation of information to another representation.

G: gate — Circuits. An electronic circuit with two inputs and one output, which has the property that the output is one if and only if some specified combination of inputs occurs on the two input lines. The combination may be the presence of pulses on both input lines, which is called an "and" gate, or the presence of a pulse on one line and the absence of a pulse on the other line, which is called an "except" gate or inhibitory gate.

general routine — Digital Computer Programming. A routine expressed in computer coding designed to solve a class of problems, specializing to a specific problem when appropriate parametric values are supplied.

generate — Digital Computer Programming. To produce coding by assembling and modifying primitive elements; similar to generation of a line by a point, a plane by a line, etc.

generator — Digital Computer Programming. A computer program which generates coding.

H: half-adder — Circuits. A circuit having two output channels for binary signals (either zero or one) in which the output signals are related to the input signals according to the following table:

<table>
<thead>
<tr>
<th>Input</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>A B</td>
<td>S C</td>
</tr>
<tr>
<td>0 0</td>
<td>0 0</td>
</tr>
<tr>
<td>0 1</td>
<td>1 0</td>
</tr>
<tr>
<td>1 0</td>
<td>1 0</td>
</tr>
<tr>
<td>1 1</td>
<td>0 1</td>
</tr>
</tbody>
</table>

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The circuit expresses in hardware a part of the functions necessary for binary addition. The letter S stands for "sum without carry"; the letter C stands for "carry". With two halfadders, and another circuit properly transferring the carry from one column to the next column, a circuit which will perform binary addition can be constructed.

Hardware — Computers. The mechanical, magnetic, electrical, and electronic devices from which a computer is constructed.

Head — Computers. Same as "magnetic head", a small electromagnet used for reading, recording or erasing polarized spots on a magnetic surface.

Hold — Computers. To retain the information contained in one storage device after copying it into a second storage device. Opposed to "clear" holding beam — Computer Circuits. A diffuse beam of electrons for regenerating the charges stored on the dielectric surface of an electrostatic memory tube or cathode ray storage tube.

Ignore (noun) — Output Devices. A typewriter character indicating that no action whatsoever be taken. In the system of coding punched in Teletype or Flexowriter paper tape, the character "all holes punched" is an ignore.

Infinity — Computers. Any number larger than the maximum number that the computer is able to store in any register. When such a number is calculated, the computer usually stops and signals an alarm indicating an overflow.

Information — 1. A set of marks or an arrangement of hardware that has meaning or that designates one out of a finite number of alternatives. 2. Any facts or data.

Information word — Computers. 1. Machine word.
   2. The information content of a machine word.
   A machine word often includes the separating space between it and the following (or preceding) word.

Inherent error — Machine Computation. The error in the initial values, especially the error accumulated from the previous steps in a step-by-step integration.

Input — Computers. Information transferred from secondary or external storage into the internal storage of the computer.

Input block — Computers. A section of the internal storage reserved for receiving and processing input data.

Input equipment — Computers. The equipment used for taking information into a computer.

Input unit — Computers. The unit which takes into the computer information from outside the computer.

Instruction — Computers. A machine word or a set of characters in machine language which directs the computer to take a certain action. More specifically, a set of characters which defines a particular operation together with one or more addresses (to no address) and which, as a unit, causes the computer to operate accordingly on the indicated quantities. Note: The term "instruction" is preferred over the terms "command" and "order"; "command" is reserved for electronic signals; "order" is reserved for uses in the meaning "sequence", as in "the order of the character's input".

Instruction code — Digital Computer Programming. The system of symbols, names, and definitions of all the instructions that are directly intelligible to a given computer or a given executive routine.

Interpreter — Analog Computers. A device whose varying output is proportional to the integral of a varying input magnitude.

Interlace — Computers. To assign successive memory locations to physically separated memory locations on a magnetic drum, for example, in such a way that access time to successive memory locations is greatly reduced.

Internal memory — Computers. The total memory or storage which is accessible automatically to the computer without human intervention. This equipment is an integral physical part of the computer and is directly controlled by the computer.

Internal storage — Computers. Same as internal memory, which see.

Interpretive code — Digital Computer Programming. An executive routine which, as the computation progresses, translates a stored program expressed in some machine-like pseudo-code into machine code and performs the indicated operations, by means of subroutines, as they are translated. An interpreter is essentially a closed subroutine which operates successively on an indefinitely long sequence of program parameters (the pseudo-instructions and operands). It may usually be entered as a closed subroutine and left by a pseudo-code exit instruction.

Interpretive routine — Same as "interpreter", which see.

Item — 1. A separate piece of information; a separate particular.
   2. Digital Computer Programming. A group of fields reporting information about a person or object. An example of an item is a punch card punched with employee's name in columns 1 to 12, employee number in columns 13 to 15, weekly rate of pay in columns 16 to 19, and other standard information about the employee in other columns.

Jump — Digital Computer Programming. An instruction or signal which, conditionally or unconditionally, specifies the location of the next instruction and directs the computer to that instruction. A jump is used to alter the normal sequence in the control of the computer. Under certain special conditions, a jump may be caused by the operator's throwing a switch.

Key — Digital Computer Programming. A set of characters, forming a field, used to identify an item.

Latency — Digital Computer Programming. Delay while waiting for information called for from the memory to be delivered to the arithmetic unit. More specifically, in a serial storage system, latency is the access time minus the word time. For example, latency is the time spent waiting for the desired memory location to arrive under the heads on a magnetic drum.

Leaping test — Computer Operation. A program to test the internal operation of a computer,
characterized by the property that it performs a series of arithmetical or logical operations on one section of memory locations, then transfers itself to another section, checks to see that the transfer is correct, and then begins the series of operations over again. Eventually the checking program will have occupied every possible position in the memory and will begin again. The term "leapfrog" comes from the indicated jump in the position of the checking routine as seen on a monitoring cathode ray tube when it transfers itself.

**library** — Digital Computer Programming. A collection of standard and fully tested programs, routines, and subroutines, by means of which many types of problems and parts of problems can be solved.

**line-printing** — Printing of a whole line of characters at one time, usually by means of one typebar (bearing all characters) for each character space in the line.

**location** — Digital Computers. A storage position in the main internal storage or memory, storing one computer word; a storage register.

**logic** — Computers. In the phrase "logic of the computer", same as "logical design", which see.

**logical comparison** — Logic. The operation of comparing A and B; the result is 1 or yes if A is the same as B and 0 or no if A is not the same as B (or vice versa).

**logical design** — Computers. Design that deals with the logical and mathematical interrelationships that must be implemented by the hardware.

**logical operations** — Computers. The operations of comparing, selecting, making references, etc., where-in essence—one and zero corresponding to yes and no constitute the elements (yes-or-no quantities) being operated on.

**loop** — Digital Computer Programming. Repetition of a group of instructions in a routine.

**M** — machine cycle — Computers. The smallest period of time or complete process of action that repeats itself in order. In some computers, "minor cycles" and "major cycles" are distinguished.

**machine language** — Computers. Information in the physical form which a computer can handle. For example, punched paper tape is machine language, while printed characters on paper are not usually machine language.

**machine word** — Digital Computers. A unit of information that is a standard number of characters, which a machine regularly handles in each register. For example, a machine may regularly handle numbers or instructions in units of 36 binary digits: this is then the "machine word".

**magnetic core** — Computers. A form of storage element where information is represented by the polarization north-south or south-north of a wire-wound magnetically permeable core, which may be straight or donut-shaped, etc.

**magnetic drum** — Computers. A rapidly rotating cylinder, the surface of which is coated with a magnetic material on which information may be stored as small polarized spots.

**magnetic head** — Computers. A small electromagnet used for reading, recording, or erasing polarized spots on a magnetic surface.

**magnetic memory** — Computers. Any portion of the memory which makes use for storage of the magnetic properties of materials.

**magnetic tape** — Tape made of paper, metal or plastic, coated or impregnated with magnetic material, on which polarized spots representing information may be stored.

**magnetic wire** — Wire made of magnetic material on which polarized spots representing information may be stored.

**major cycle** — Computers. In a memory device which provides access to storage positions one after another, the time interval between successive appearances of the same storage position. In other words, this is the time for one rotation of a magnetic drum or one recirculation of pulses in a delay line. It is an integral number of minor cycles.

**malfunction** — Computers. A failure in the operation of the hardware of a computer.

**marginal checking** — Computer Circuits. A system of designing electronic circuits so that the voltage of the heaters of the tubes, ordinarily established at 6.3 volts, may be lowered if desired to 5 or 4.7 volts, and the circuits then tested to determine if they still continue to operate satisfactorily.

**master clock** — Computers. The primary source of timing signals.

**mathematical check** — A check making use of mathematical identities or other properties. For example, multiplication may be verified by the mathematical check that A multiplied by B is the same as B multiplied by A, the two multiplications being performed at different times and compared with each other. Frequently a small degree of discrepancy is acceptable; this is referred to as the tolerance.

**mathematical logic** — Exact reasoning about non-numerical relations using symbols that are efficient in calculation. Also called "symbolic logic".

**mercury memory** — Digital Computers. Delay lines using mercury as the medium for storage of a circulating train of waves or pulses.

**memory** — Computers. The units which store information in the form of the arrangement of hardware or equipment in one way or another. Same as "storage". 27. Any device into which information can be introduced and then extracted at a later time.

**memory capacity** — The amount of information which a memory unit can store. It is often measured in the number of decimal digits or the number of binary digits which the memory unit can store. Other measures of memory capacity have also been defined.

**mercury tank** — A container of mercury holding one or more delay lines storing information.

**merge** — To produce a single sequence of items, ordered according to some rule (i.e., arranged in some orderly sequence), from two or more sequences previously ordered according to the same rule, without changing the items in size, structure, or total number. Merging is a special case of collating.

**message** — A group of words, variable in length, transported as a unit.

**microsecond** — A millionth of a second.

**millisecond** — A thousandth of a second.

**minimum access programming** — Digital Computer Programming. Programming in such a way that
minimum waiting time is required to obtain information out of the memory. Also called "minimum latency programmming." In a computer with a serial memory, a routine coded with judicious arrangement of data and instructions in such a way that actual waiting time for information from the memory is much less than the expected random access waiting time.

minimum access routine -- Digital Computer Programming. In a computer with a serial memory, the time required for the transmission of one machine word, including the space between words.

minimum latency programming -- Same as "minimum access programming," which see.

minimum latency routine -- Same as "minimum access routine," which see.

modified -- Digital Computer Programming. A quantity, sometimes the cycle index, used to alter the address of an operand.

modified routine inserted directly into a sequence forming a program. When a problem is stated in pseudo-code, each step must sometimes be assigned an operation number.

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modifier -- Digital Computer Programming. A quantity, sometimes the cycle index, used to alter the address of an operand.

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octal digit -- One of the symbols 0, 1, 2, 3, 4, 5, 6, 7 when used as a digit in numbering in the scale of eight.

octal notation -- Notation of numbers in the scale of eight. For example, the number 217 in this scale means 2 times 8 squared (2 x 64 = 128), plus 1 times 8, plus 7, which equals 143 in decimal notation. The number 217 in octal is equal to 100, 001, 111 in binary, each octal digit being changed directly into its binary equivalent. The octal notation is rather convenient in dealing with binary machines because octal numbers are easier for human beings to read than binary numbers, and yet the conversion is immediate.

odd-even check -- The sum of a digit carried along as a check which is 1 if the total number of ones in the machine word is even, and which is 0 if the total number of ones in the machine word is odd, or vice versa.

one-address (adjective) -- Digital Computer Programming. Having the property that each complete instruction includes an operation and specifies the location of only one register in the memory. Also called "single-address".

one-time data reduction -- Reduction of data that is just as fast as the data flows into the reduction process.

open subroutine -- Digital Computer Programming. A subroutine inserted directly into a linear sequence of instructions, not entered by a jump instruction. Such a subroutine must be reentered at each point that it is needed in a routine.

operand -- Computers. Any one of the quantities entering into or arising from an operation.

operand -- Computers. Any one of the quantities entering into or arising from an operation.

operand -- Computers. Any one of the quantities entering into or arising from an operation.

operand -- Computers. Any one of the quantities entering into or arising from an operation.

operator -- Computers. The person who actually operates the computer, puts problems on, presses the start button, etc.

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secondary or external storage. 2. Information transferred to any device outside of the computer.

output block — Digital Computers. A segment of the internal storage reserved for receiving data to be transferred out.

output equipment — Computers. The equipment used for transferring information out of a computer.

output unit — Computers. The unit which delivers information outside the computer in acceptable language form to the output equipment.

overflow — Computers. In a counter or register, the production of a number which is beyond the capacity of the counter. For example, adding two numbers, each within the capacity of the registers holding them, may result in a sum beyond the capacity of the register that is to hold the sum: overflow.

parallel operation — Computers. The flow of information through the computer or any part of it using two or more lines or channels simultaneously.

parallel storage — Computers. Storage in which all bits or characters, or words are essentially equally available in space, without time being one of the coordinates. Parallel storage contrasts with serial storage, in which words are in parallel, the storage is said to be parallel by words; when characters within words are dealt with simultaneously, not one after the other, the storage is parallel by characters.

parameter — Digital Computer Programming. In a subroutine, a quantity which may be given different values when the subroutine is used in different parts of a main routine, but which usually remains unchanged throughout any one such use. To use a subroutine successfully in many different programs requires that the subroutine be adaptable by changing its parameters.

parity check — Use of a digit (called the "parity digit") carried along as a check which is 1 if the total number of ones in the machine word is odd, and 0 if the total number of ones in the machine word is even. See "odd-even check".

path — Digital Computer Programming. A section of coding inserted into a routine (usually by explicitly transferring control from the routine to the path and back again) to correct a mistake or alter the routine.

permanent memory — Computers. Storage of information which remains intact when the power is turned off; for example, storage on a magnetic drum.

plotting board — Computers. An output unit which plots the curves of one or more variables as a function of one or more other variables.

plugboard — Punch Card Machines. A removable board holding many hundreds of electric terminals into which short connecting wire cords may be plugged in patterns varying for different programs for the machine. To change the program, one wired-up plugboard is removed and another wired-up plugboard is inserted. A plugboard is equivalent to a program tape which presents all instructions to the machine at one time. It relies on X-punches and other signals in the punch cards passing through the machine to cause different selections of instructions in different cases.

plug-in-unit — A subassembly of tubes, resistors, condensers, diodes, etc., wired together, which is of a standard type and which as a whole can be plugged in or pulled out easily.

point — Arithmetic. In a scale of notation, the position designated with a dot that marks the separation between the integral and fractional parts of the number. Called "decimal point" in the scale of 10 and "binary point" in the scale of 2.

post mortem (noun) — Digital Computer Programming. A diagnostic routine which either automatically or when called for, prints out information concerning the contents of all or a specified part of the registers of the computer, after a problem tape has "died" on the computer. The purpose of a post mortem tape is to assist in the location of an error in coding the program or in machine function.

precision — Computation. The degree of exactness with which a quantity is stated, as contrasted with "accuracy", which is the degree of exactness with which a quantity is known or observed. The number of significant figures measures the precision of a number. For example, in "computer power required is 55,7043 kilowatts", the number is precise to six figures, but its accuracy certainly is much less.

prestore — Digital Computer Programming. 1. To set an initial value for the address of an operand or a cycle index. 2. To store a quantity in an available or convenient location before it is required in a routine.

printer — Computers. An output mechanism which prints or typewrites characters.

program (noun) — Computers. 1. A precise sequence of coded instructions for a digital computer to solve a problem. Note: For this meaning, the term "routine" is preferred by some people. 2. A plan for the solution of a problem. A complete program includes plans for the transcription of data, coding for the computer, and plans for the effective use of the results.

program (verb) — To make a program.

program parameter — Digital Computer Programming. A parameter incorporated into a subroutine during computation. A program parameter frequently comprises a word stored relative to either the subroutine or the entry point and dealt with by the subroutine during each reference. It may be altered by the routine. It may vary depending on point of entry.

program register — Digital Computers. The register in the control unit of the computer which stores the current instruction of the program and thereby completely controls the operation of the computer during the cycle of execution of that instruction. Same as "control register". Also called "program control unit".

programmed checking — Computers. A system of checking whereby (1) before running any problem a sample problem of the same type with known answer is run, and (2) mathematical or logical checks of operations, such as comparing...
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A x B with B x A, are included in the program for P, and (3) reliance is placed on a very high probability of correctness rather than built-in error-detection circuits.

programmer — A person who prepares sequences of instructions for a computer, without necessarily converting them into the detailed codes.

program-sensitive error — Computers. An error arising from unforeseen behavior of some circuits, discovered when a comparatively unusual combination of program steps occurs.

program step — Computers. A step in a program, usually one instruction.

program tape — Computers. The tape which contains the sequence of instructions to the computer for solving a problem.

pseudo-code — Digital Computer Programming. An arbitrary-code, independent of the hardware of a computer, which must be translated into computer code if it is to direct the computer.

pseudo-random (adjective) — Computation. Having the property of being produced by a definite calculation process, but at the same time satisfying one or more of the standard tests for statistical randomness.

pulse — Circuits. In general, a sharp difference between the normal level of some medium corresponding to the average height of a wave and a high or low level of that medium corresponding to the crest or trough of a narrow wave; often, a sharp voltage change.

pulse code — A set of pulses to which a particular meaning has been assigned; the binary representations of a character.

punch card — Computers. A card of constant size and shape, suitable for punching in a pattern that has meaning, and for being handled mechanically. The punched holes are usually sensed electrically by wire brushes or mechanically by metal fingers.

punch card machinery — Machinery which operates with punch cards.

punched tape — Paper tape punched in a pattern of holes so as to convey information.

punch position — In the case of 80-column punch cards, the position of a punch in a row on the card, denoting a decimal digit 0 to 9, or what are called an "X punch" (row 11), or a "Y punch" (row 12).

Q: Quantity — A positive or negative real number in the mathematical sense. Note: The term "quantity" is preferred by some computer people for referring to numeric data; the term "number" is preferred in the sense of integer or natural number, as in "the number of digits".

R: random access — Computers. Access to the memory or storage under conditions where the next register from which information is to be obtained is chosen at random. For example, access to names in the telephone book is "random access"; the next name that anyone is going to look up in the book may be almost anywhere in the book with roughly equal probability.

random access programming — Programming a problem for a computer without regard to the time for access to the information in the registers called for in the program. Contrasted with "minimum access programming".

random number — A number formed by a set of digits selected from a random sequence of digits. A sequence of digits is random when its construction by a process under which each successive digit is equally likely to be any of the base n.

read memory — Computers. The section of the whole memory from which information may be obtained the most rapidly.

read — Computers. To copy, usually from one form of storage to another, particularly from external or secondary storage to internal storage. 2. To sense the meaning recorded in arrangements of hardware.

read-around-ratio — Digital Computers. In cathode-ray-tube storage, the number of times that information can be recorded successively as an electrostatic charge on a single spot in the array, before the charge on surrounding spots in the array must be restored if not to be lost. This number is referred to also as the "read-around".

real time — In solving a problem, a speed sufficient to give an answer in the actual time during which the problem must be solved. For example, in the case of a human being driving a motor car: at 30 miles an hour he can regularly solve nearly all his problems in real time; and at 100 miles an hour he will regularly fail to solve some of his problems in real time.

real time operation — Computer Operation. Solving problems in real time. More precisely, processing data in time with a physical process so that the results of the data-processing are useful in guiding the physical operation.

red-tape operations — Digital Computer Programming. Computer operations called for by a program which do not directly contribute to solving the problem, namely, arithmetical, logical, and transfer operations used in modifying the address section of other instructions, in counting cycles, in rearranging data, etc.

redundant check — Computers. A check which uses extra digits in machine words, but not complete duplication, to help detect malfunctions and mistakes.

red — A spool of tape, generally magnetic tape.

reference record — Digital Computer Programming. An output of a compiler that lists the operations and their position in the final specific routine, and contains information describing the segmentation and storage allocation of the routine.

regenerate — Digital Computers. In the operation of electrostatic storage, to restore information currently held in a cell on the cathode ray tube screen in order to counteract fading and disturbances.

register — Computers. The hardware for storing one machine word.

relative address — Digital Computer Programming. A label used to identify the position of a memory location in a routine or subroutine. Relative addresses are translated into absolute addresses by adding some specific "reference" address, usually the address at which the first word of the routine is stored. For
example, if a relative address instruction specifies an address \( n \) and the address of the first word of the routine is \( k \), then the absolute address of the memory location is \( n+k \).

relative coding — Digital Computer Programming.

Coding in which all addresses refer to an arbitrarily selected position, or in which all addresses are represented symbolically.

reset rate — Computers. The fastest rate of electronic pulses usually used in the circuits of the machine.

reproducer — Punch Card Machines. A punch card machine that punches cards to agree as may be specified with other cards.

rerun — Digital Computer Programming. To run a program or a portion of it over again on the computer.

rerun point — Digital Computer Programming. One of a set of planned-for points in a program such that if an error is detected in between two such points, to rerun the problem is only necessary to go back to the last rerun point, instead of returning to the start of the problem. Rerun points are often three to five minutes apart so that very little computer time is required for a rerun. All information pertinent to a rerun is available in standby registers during the whole time from one rerun point to the next.

rerun routine — Digital Computer Programming. A routine designed to be used in the wake of a malfunction or a mistake to reconstitute a routine from the last previous rerun point.

reset — To return a register to zero or to a specified initial condition.

resolver — Analog Computers. A device for resolving a vector into two mutually perpendicular components.

rewind — Computers. To return a magnetic tape to its beginning.

rollback — Digital Computer Programming. Same as "rerun", which see.

reset — Computers. To return a cycle index, a variable address, or other computer word to its initial value. See also "reset".

round off — Computers. To change a more precise quantity to a less precise one, usually choosing the nearest less precise one; see "precision".

rounding error — Computers. The error resulting from dropping certain less significant digits of a quantity, and applying some adjustment to the more significant digits retained. Also called "round-off error". A common round-off rule is to take the quantity to the nearest digit. Thus \( 3.14159265 \ldots \) rounded to four decimals is \( 3.1416 \). Note: Alston S. Householder suggests the following terms: "initial errors", "generated errors", "propogated errors" and "residual errors". If \( x \) is the true value of the argument, and \( x^* \) the quantity used in computation, then, assuming one wishes \( f(x) \), \( x - x^* \) is the initial-error; \( f(x^*) - f(x^*) \) the propagated error. If \( f_0 \) is the Taylor, or other, approximation utilized, then \( f(x^*) - f(x^*) \) is the residual error. If \( f^* \) is the actual result then \( f_0 - f^* \) is the generated error, and this is what builds up as a result of rounding.

routine — Digital Computers. 1. A sequence of operations which a digital computer may perform.

2. The sequence of instructions determining a program or a part of a program.

GLOSSARY

test out (verb) — Computers. To read out of a register or counter by the following process: add to the digits in each column simultaneously; do this 10 times (for decimal numbers); when the result in each column changes from 9 to 0, issue a signal.

run (noun) — Computers. 1. One performance of a program on a computer. 2. Performance of one routine, or several routines during which the human operator does not have to do anything.

s: scale (verb) — Computers. To change the scale, that is, the unit in which a variable is expressed so as to bring it within the capacity of the machine or program at hand.

scale factor — Computers. One or more factors used to multiply or divide quantities occurring in a problem and convert them into a desired range, such as the range from plus one to minus one.

segment — Circuits. In an electrostatic storage tube, the surface where electrostatic charges are stored. In a pentode, one of the grids.

secondary storage — Computers. Storage that is not an integral part of the computer but directly linked to and controlled by the computer; for example, magnetic tapes.

segment (noun) — Digital Computer Programming. The routine too long to fit into internal storage, a part short enough to be stored entirely in the internal storage yet containing the coding necessary to call in and jump automatically to other segments. Routines which exceed internal storage capacity may be automatically divided into segments by a compiler.

segment (verb) — To make segments.

dense (verb) — Computers. 1. To determine the arrangement of some element of hardware, especially a manually-set switch. 2. To read holes punched in paper.

sentinel — Digital Computer Programming. A symbol marking the beginning or the end of some piece of information such as a field, item, block, tape, etc. a tag.

select — Logic. To take A if the report on a certain condition is yes, and take B if the report is no.

selector — Punch Card Machines. A mechanism which reports a condition and causes a card or an operation to be selected accordingly.

sequence (verb) — Logic. To select A if A is greater than or equal to B, and select B if A is less than B, or some variation of this operation.

sequence checking routine — A checking routine which checks on every instruction executed, printing certain data. It may be designed to print but the coded instruction with addresses, and the contents of each of several registers for each instruction as it is executed. Or it may be designed to print out only selected data, such as transfer instructions when they occur, and the quantity actually transferred. Many variations are possible. A good flexible sequence checking routine will provide for several variations in itself.

- 20 -
sequence-control tape -- Program tape. (Obs o-
seous term).

sequential control -- Computers. The manner of
control of a computer in which instructions to
it are set up in a sequence and are fed into the
computer during the solution of a problem.

sequencer -- Punch Card Machines. A mechanism
which will put items of information in sequence.
It will determine if A is greater than, equal to,
or less than B, and will accordingly route
route cards containing A and B into a pocket at dif-
f erent times.

serial -- Computers. Handled one after the other
in a single piece of equipment.

serial operation -- Computers. The flow of in-
formation through the computer or in any part
of it using only one line or channel at a time.
Contrasted with "parallel operation:"

serial storage -- Computers. Storage in which
time is one of the coordinates used to locate
given bit, character, or (especially) word.
Storage in which words, within groups of several
words, appear one after the other in
time sequence, and in which access time therefore
includes a variable latency or waiting
time of zero to many word-times, is said to be
serial by word. Storage in which the indivi-
dual bits comprising a word appear in time
sequence is serial by bit. Storage for coded-
decimal or other non-binary numbers in which
the characters appear in time sequence is serial
by character; for example, magnetic drums
are usually serial by word but may be serial
by bit, or serial by character and parallel by bit, etc.

serial transfer -- Computers. A system of data
transfer in which the characters of an element
of information are transferred in sequence over
a single path in consecutive time posi-
tions.

service routine -- Digital Computer Programming.
A routine designed to assist in the actual op-
eration of the computer. Tape comparison,
block location, certain post mortems, and cor-
correction routines fall in this class.
shift -- To move the characters or a unit of in-
formation columnwise right or left. In the
case of a number, this is equivalent to multi-
plying or dividing by a power of the base of
notation (usually ten or two). This is regu-
larly performed as a special rapid operation,
much faster than usual multiplication or divi-
sion.

sign digit -- A zero used to designate the
algebraic sign of a quantity plus or minus.

significant digits -- If the digits of a number
are ranked according to their significance,
and the magnitude of a digit is greater
when it occupies a column corresponding to a
higher power of the base, then the significant
digits of a number are a set of digits from
consecutive columns beginning with the most
significant digit different from zero and end-
ning with the least digit whose value is known
or assumed to be relevant.

simulation -- The representation of physical sys-
tems by computers, models, and associated e-
equipment.

single-address -- Same as "one-address", which see.

GLOSSARY

break (noun) -- An instruction to proceed to the
next instruction; a "blank" instruction.

slow memory -- Computers. Sections of the mem-
ory from which information may be obtained
automatically but not at the fastest rate of
the several sections.

sonic delay line -- A delay line which uses pulses
in the molecules of the medium, in contrast
with an electrical delay line which uses elec-
trical pulses in a wire or in an assembly of
coils and capacitors.

sort -- To arrange items of information according
to rules dependent upon a key or field con-
tained by the items, such as previously chosen
classes of items.

sorter -- Punch Card Machines. A machine which
sorts cards according to the punches in a speci-
fied column of the card.

specific coding -- Digital Computer Programming.
Coding in which all addresses refer to spe-
cific registers and locations.

specific routine -- Digital Computer Programming.
A routine expressed in specific computer cod-
ing designed to solve a particular mathemati-
cal, logical, or data-handling problem.

standardize -- Computation. To adjust the ex-
ponent and coefficient of a floating-point
result so that the coefficient lies in the
prescribed normal range.

static storage -- Computers. Storage such that
information is fixed in space and available
at any time provided the power is on; for ex-
ample, flop, electrostatic, or coincident cur-
current magnetic core storage.

static subroutine -- Digital Computer Program-
ing. A subroutine which involves no param-
eters other than the addresses of the oper-
ands. This is a subroutine which requires
only the relative addresses of the operands,
their insertion, and its transformation from
relative to specific coding.

storage -- Computers. 1. The unit which holds or
retains items of information. 2. Any de-
vice into which information can be introduced,
held, and then extracted at a later time. The
mechanism or medium in which the informa-
tion is stored need not form an integral part of
a computer. Synonyms: memory, store (in Eng-
lish usage).

storage capacity -- Same as "memory capacity",
which see.

storage operation -- One of the operations of
reading, transferring, storing, or writing
information.

storage register -- A register in the memory or
storage of the computer, in contrast with a
register in one of the other units of the
computer.

storage tube -- Same as "electrostatic storage
tube", which see.

store (noun) -- Same as "storage", which see.

store (verb) -- To transfer a piece of informa-
tion to a device from which the informa-
tion unaltered can be obtained at a later time.

subprogram -- A part of a program.

subroutine -- Computers. 1. A short or repeated
sequence of instructions for a computer to
direct the computer to carry out a well-defined
GLOSSARY

(mathematical or logical operation; a subunit of a routine. A subroutine is often written in relative or symbolic coding even when the routine to which it belongs is not.

summary punch — Punch Card Machines. A punch card machine which may be attached by a many-wire cable to another machine (for example, a tabulator), and which will punch out on a card the information produced or calculated or summarized by the other machine.

summation check — Computer Operation. A redundant check in which groups of digits are summed, usually without regard for overflow, and that sum checked against a previously computed sum to verify accuracy of computation.

symbolic address — Digital Computer Programming. A label chosen to identify a particular word, function or other information in a routine, independent of the location of the information, within the routine. Also called "floating address".

symbolic logic — Exact reasoning about nonnumerical relations using symbols that are efficient in calculation. A branch of the subject known as Boolean algebra has been of considerable assistance in the logical design of computing circuits. Also called "mathematical logic".

synchronous computer — An automatic digital computer where the performance of all operations starts with equally spaced signals from a master clock, thus.

T: Tabulator — Punch Card Machines. A punch card machine which takes in punch cards and instructions and produces lists, totals, and tabulations of the information on separate forms or on continuous paper.

tap — Digital Computer Programming. A unit of information, whose composition differs from that of other members of the set so that it can be used as a marker or label; a sentinel.

tank — A unit of delay-line storage, usually of memory and operating acoustically, containing a set of channels each forming a separate circulation path.

tape — Computers. Magnetic tape or punched paper tape, sometimes other kinds of tape.

tape feed — A mechanism which will feed tape to be read or sensed by the machine.

temporary storage — Computers. Internal storage locations reserved for intermediate and partial results.

test routine — Digital Computer Programming. A routine designed to show that a computer is functioning properly.

three-address (adjective) — Digital Computer Programming. Having the property that each complete instruction includes an operation and a and specifies the location of three registers.

torque amplifier — Analog Computers. A device permitting input and output of one revolving work to rotate the output shaft in positional correspondence with the input shaft without imposing any significant torque on the input shaft.

track — Computers. In a magnetic drum or magnetic tape, a single path containing a set of pulses.

transcribe — To copy, with or without translating, from one external storage medium to another.

transfer (verb) — 1. To transfer data; to copy, exchange, read, record, store, transmit, transport, or write data. To transfer does not modify the information. 2. To transfer control of a computer.

transfer (noun) — An act of transferring.

transfer check — A check that an operation of transferring has been correctly carried out.

transfer instruction — Digital Computer Programming. An instruction or signal which conditionally or unconditionally specifies the location of the next instruction and directs the computer to that instruction.

transform — Digital Computer Programming. To change information in structure or composition without significantly altering the meaning or value; to normalize, edit, or substitute.

translate — Computers. To change information from one language to another without significantly affecting the meaning.

trouble-location problem — A test problem whose incorrect solution supplies information on the location of faulty equipment; usually a check problem has shown that a fault exists.

trouble-shoot — To search for the cause for an error or a computer malfunction in order to remove it.

truncation — Computers. To drop digits of a number or terms of a series thus lessening precision. See "precision". For example, the number π "3.14159265..." is "truncated" to three figures in "3.14".

truncation error — Computation. The error resulting from the use of only a finite number of terms of an infinite series, or from the approximation of operations in the infinitesimal calculus by operations in the calculus of finite differences.

trunk — A path over which information is transferred; a bus.

twin check — A continuous check of computer operations achieved by duplication of the hardware to perform them together with automatic comparison.

two-address (adjective) — Digital Computer Programming. Having the property that each complete instruction includes an operation and specifies the location of two registers, usually one containing an operand and the other the result of the operation.

U: unconditional transfer — Digital Computer Programming. In a digital computer which ordinarily obtains its instructions serially from an ordered sequence, an instruction which causes the following instruction to be taken from an address which is not the next one in the sequence.

unwind — Digital Computer Programming. To code explicitly, at length and in full, all the operations of a cycle, in such a way as to eliminate all red-tape operations. Unwinding may be performed automatically by the computer during assembly, generation, or compilation.

unpack — Digital Computer Programming. To separate packed items of information each into a separate-machine word. See "pack".

validity — Computation. Correctness, especially the degree of closeness by which an iterated approximation approaches the desired correct result.

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variable cycle operation — Computer Operation. Operation of a computer whereby any cycle of operation may be longer or shorter than the average. This is the kind of operation in an "asynchronous computer".

variable cycle operation — Computer Operation. Operation of a computer whereby any cycle of operation may be longer or shorter than the average. This is the kind of operation in an "asynchronous computer".

verify — 1. Punch Card Machines. A punch card machine operated manually which reports by signals whether punched holes have been inserted in the wrong places in a punch card or have not been inserted at all. 2. Computers. An auxiliary device on which a previous manual transcription of data can be verified by comparing a current manual transcription of it character-by-character during the current process.

volatile memory — Computers. Memory or storage having the property that if the power is turned off, the information vanishes; delay line memory, electrostatic storage tubes.

volatile storage — Same as "volatile memory".


word — Digital Computers. An ordered set of letters which has at least one meaning, and is stored and transferred by the computer circuits as a unit. Also called "machine word". Ordinarily, a word has a fixed number of characters, and is treated by the control unit as an instruction, and by the arithmetic unit as a quantity. For example a computer may regularly handle numbers or instructions in units of 30 binary digits.

word-time — Digital Computers. Especially in reference to words stored serially, the time required to transfer a machine word from one storage device to another.

working storage — Digital Computers. A portion of the internal storage reserved for data upon which operations are currently being performed, and for intermediate and partial results, as a work-sheet in pencil and paper calculation.

write — Digital Computers. 1. To copy information usually from internal to external storage. 2. To transfer information to an output medium. 3. To record information in a register, location, or other storage device or medium.

Z: zero — Digital Computers. The computer's conceptions of zero. Note: The computer may provide for two zeros. Positive binary zero is represented by the absence of digits or pulses in a word. Negative binary zero in a computer operating with ones' complements may be represented by a pulse in every pulse position in a word. In a coded decimal computer, decimal zero and binary zero may not have the same representation. In most computers, there exist distinct and valid representations both for positive and for negative zero.

zero-address instruction — Digital Computers. An instruction specifying an operation in which the location of the operands are defined by the computer code, so that no address need be given explicitly.

zero-access storage — Digital Computers. Storage for which the latency or waiting time is always negligible.

zero-suppression — The elimination of non-significant zeros to the left of the integral part of a quantity before printing is begun. To suppress these zeros is one of the operations in editing.

zone — 1. Punch Cards. Any of the three top positions 12, 11, and 0. In these zone positions a second punch can be inserted, so that with punches in the remaining positions 1 to 9, enough two-punch combinations are obtained to represent alphabetic characters. 2. Digital Computers. A portion of internal storage allocated for a particular purpose.

GLOSSARY

ROSTER OF ORGANIZATIONS IN THE FIELD OF COMPUTERS AND AUTOMATION

(Supplement, information as of November 3, 1954)

The purpose of this Roster is to report organizations (all that are known to us) making or developing computing machinery, or systems, or data-handling equipment, or equipment for automatic control and materials handling. In addition, some organizations making components may be included in some issues of the Roster. Each Roster entry when it becomes complete contains: name of the organization, its address and telephone number, nature of its interest in the field, kinds of activity it engages in, main products in the field, approximate number of employees, year established, and a few comments and current news items. When we do not have complete information, we put down what we have.

We seek to make this Roster as useful and informative as possible, and plan to keep it up to date in each issue. We shall be grateful for any more information, or additions or corrections that any reader is able to send us.

Although we have tried to make the Roster complete and accurate, we assume no liability for any statements expressed or implied.

This listing is a supplement to the cumulative Roster in the November, 1954 issue of "Computers and Automation", vol. 3, no. 9, and contains only additions or revisions as compared with that listing.

Abbreviations

The key to the abbreviations follows:

Size

Ls Large size, over 500 employees
Ms Medium size, 50 to 500 employees
Ss Small size, under 50 employees (no. in parentheses is approx. no. of employees)

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(The Bibliography will be published in a forthcoming issue; Part 1 was published in the November, 1954, issue)

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A d-c electronic analog computer should include devices for multiplying a machine variable by a positive or negative coefficient, for generating the sum of two or more machine variables, for generating the product of two machine variables, for generating arbitrary functions of machine variables, and for generating the time integral or the time derivative of a machine variable. The three basic elements which are interconnected to perform many of these functions are resistors, capacitors, and d-c amplifiers. The d-c amplifier is really the heart of this computer. Interconnections are made easily by means of patch cords and front panel jacks. Potentiometers can be used to set constant coefficients or can be wound to represent special functions. Multiplication or division can be effected by servomotor positioned potentiometers and trigonometric functions can be obtained by means of resolvers. The computer would also include regulated power supplies to furnish the voltages needed for the operation of the electronic components, means for recording or measuring the d-c voltage in the machine, and control circuits for starting the computation with the correct initial condition settings and for stopping the machine after the computation is completed.

D-C electronic analog computers have been used to solve linear differential equations with constant coefficients, linear ordinary differential equations with variable coefficients, nonlinear ordinary differential equations, and sets of linearly independent simultaneous equations. They have been used to study separately excited generators, to study variable displacement hydraulic systems, for trajectory calculations, to solve aircraft flight equations, and for the analysis and synthesis of servomechanisms.

Special Purpose Computers

Because analog computers are reliable in operation, capable of continuous service over extended periods, and comparatively small and inexpensive, many have been constructed for special problems. One computer was constructed to determine the yield of radioactive isotopes produced by a pile or other source of radiation. This computer could be used for any problems involving similar equations. Another was built to rapidly evaluate \( \cosh 2a \) for \( a = A \), where \( S, T, \) and \( A \) were known. Others have been constructed for the solution of phase equilibria in flash vaporization of mixtures of hydrocarbons, for solving secular equations, for the solution of partial differential equations, for analyzing wave equation boundary value problems, and for multicomponent fractionation calculations.

Application of Analog Computers to Heat Transfer Problems

Analog computers of various types have been used to obtain solutions to many problems concerned with the transfer of heat. Those problems specified by ordinary or partial differential equations or involving unsteady state heat transfer can be solved by means of general purpose electrical computers. The general purpose computer at the California Institute of Technology has been used to solve the ordinary differential equations concerned with the temperature rise in rotating electric machines during variable load cycles, to find the steady-state temperature distribution in a gas turbine rotor, and to solve various partial differential equations. Electric circuit models for partial differential equations have been described by Kron. The Heat and Mass Flow Analyzer (HMFA) at Columbia University is designed primarily for solving problems of unsteady-state heat conduction in solids with definite radiation and convection boundary resistances. The HMFA is a continuation in this country by Victor Paschkis of work done in Europe on a method first devised by C. L. Beuk en. It has been used to provide solutions to many problems — including those involved in regenerator operation, solidification of metals, determination of economical insulation thickness, the influence of through metal on heat loss from insulated walls, and the setting up of charts and graphs on heat conduction problems. Temperature patterns have been determined by geometrical analog methods. This method consists of setting up an electrically conductive flat sheet to represent the heat transfer problem in question (current flow represents heat flow), applying the proper potentials to the edges of the sheet, and finding potential (temperature) patterns by means of a probe. Special electrical analog techniques have been used to analyze heat exchanger performance. Special electrical analog computers have been constructed for particular thermodynamic calculations, for analyzing a heating system, and for studying the thermal behavior of houses. Also, hydraulic and air flow analogy techniques have been used to

(continued on page 27)
LET G-E TUBE SERVICE
INCREASE YOUR SHARE OF A
FAST-GROWING COMPUTER MARKET

Estimates say that the computer market—business, military, and research—will triple in the next five years. Here are substantial sales and profits for computer builders who can meet their customers' demands for fast, efficient equipment.

G.E. offers experience and facilities to strengthen your competitive position ... will analyze your circuit in terms of its specific tube requirements, and select the right types to give you optimum performance. You will receive every help in actually testing G-E tubes in your computer, from the time the latter is still in the "breadboard" stage.

Special computer tubes were pioneered by General Electric. G.E. is their largest builder. In line with performance requirements that become steadily more advanced, G.E. is devoting extensive research and development to still newer tubes for tomorrow's circuits—types that will be available for you when you need them.

G.E. offers you close cooperation at the tube-design level ... application help by experienced tube engineers ... local-laboratory help in checking tube performance in your circuits ... fast order and delivery service from G-E tube warehouses coast-to-coast.

Most important of all, General Electric has ready ... now ... a line of special computer tubes for your immediate needs. They are described on the next page.
5 SPECIAL G-E TUBES FOR COMPUTERS...
DESIGNED FOR HIGH-SPEED CIRCUITS

ALSO: 5 important reasons why these G-E computer tubes all do an efficient job...reliably:

High-perveance design.
Low heater power requirement.
Balanced, sharp cut-off characteristics.
Cathodes specially designed for on-off dependability.
Life-tested under cut-off conditions.

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GL-6211
9-pin medium-mu twin triode for binary-counter or amplifier applications.
Max cathode current, per section 14 ma
Max dissipation, per plate 1 w
Max tube dissipation 2 w
Grid voltage required to cut off plate current —10 v
Heater current .3 amp

GL-5965
9-pin twin triode for high-speed computer use as binary-counter or amplifier tube.
Max cathode current, per section 15 ma
Max dissipation, per plate 2.2 w
Max tube dissipation 4 w
Grid voltage required to cut off plate current —5.5 v
Heater current .45 amp

GL-5915-A
Dual-control heptode, for use primarily as a coincidence-gating tube.
Max cathode current 20 ma
Grid voltage required to cut off plate current —10 v
Typical plate current in gating service ("on" condition) 5.8 ma

GL-6463
9-pin high-capacity twin triode for extra-fast computers. Especially suited to frequency-divider circuits.
Max cathode current, per section 28 ma
Max dissipation, per plate 4 w
Max tube dissipation 7 w
Grid voltage required to cut off plate current —11 v
Heater current .6 amp

GL-5844
Medium-mu twin triode, for use as counter or amplifier tube in moderately high-speed computers.
Max cathode current, per section 9 ma
Max dissipation, per plate .5 w
Max tube dissipation 1 w
Grid voltage required to cut off plate current —10 v
Heater current .3 amp

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mathematical study of heat transfer problems.

When a solid mass changes temperature as a result of the exchange of heat between itself and its surroundings, there are variable temperature gradients in the mass, a series of isothermal surfaces, a nonuniform changing field within it, related to the time rate of heat gained or lost by the mass, and a time to attain steady state. This is known as the unsteady state of heat transfer and may be associated with heat transfer through the mass into one face and out from another.133

Mathematical calculations of the effect of any imposed conditions on a given mass defined by shape, size, and the physical properties of its materials, have depended upon the solution of Fourier's differential equations for these conditions. Those cases that can thus be solved with acceptable simplicity are relatively few in number and exclude most of those of industrial importance. The difficulties imposed by the mathematical approach are partially overcome by graphical methods. These methods are based on the replacing of each differential equation by an equation of finite differences, a process sometimes called step integration. Graphical methods, however, are tedious and of limited application. Experimental solutions of industrial problems of unsteady state heat transfer, depending upon inserted thermocouples or other thermometric devices and upon some means of measuring the rate of heat transfer, are difficult, expensive, and often impossible under service conditions.

In addition to these mathematical, graphical, and experimental methods133 of solving unsteady heat transfer problems, there is the electrical analogy method. The analogies between the flow of heat and the flow of electricity130 and electrical models for the solution of heat problems126 have long been known. Early models were based on a geometrical similarity between the body subjected to heat flow and the model body. The application of general purpose computers to heat transfer problems is based on the identity in form of the fundamental equations of heat flow and the flow of electricity. The electrical analog bears no geometrical similarity to the body being investigated. Thus, a single electrical general purpose computer can be used for a wide variety of heat transfer problems.

The general form for the differential equation for heat conduction in solids can be written as:

\[ \frac{\partial}{\partial t} k(x,y,z,\tau) \frac{\partial T}{\partial t} + \frac{\partial}{\partial x} k(x,y,z,\tau) \frac{\partial T}{\partial x} + \frac{\partial}{\partial y} k(x,y,z,\tau) \frac{\partial T}{\partial y} + \frac{\partial}{\partial z} k(x,y,z,\tau) \frac{\partial T}{\partial z} + q(x,y,z,\tau,\tau) = cd \frac{\partial T}{\partial t} \]  

(1)

where \( t = \) time.

\( T = \) temperature at \( x, y, z \) at time \( t \).

\( q = \) rate of heat supply per unit volume.

\( k = \) thermal conductivity \( = 1 \) (Btu/\text{hr})(sq.ft) (deg/F).

\( d = \) density = mass per unit volume.

\( c = \) specific heat = heat capacity per unit mass \( = \) Btu/(lb) (deg/F).

\( cd = C_t = \) Btu/(F/hr) (cu.ft).

If \( q = 0 \) and \( k, d, \) and \( c \) are constants, equation (1) takes the form

\[ \frac{\partial T}{\partial t} = a \left( \frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} + \frac{\partial^2 T}{\partial z^2} \right) \]

(2)

where \( a = k = \) thermal diffusivity \( = \frac{1}{R_tCt} \text{sq.ft} \text{hr} \)

The study of a thermal problem by the electrical analogy method involves the following steps:134

1. Set up the analogous conditions by calculation. To calculate the circuit for a distributed irregular region or medium of any shape, consider that the region is composed of discrete parts or sections. The size and shape of these sections are governed by the configuration of the region, the boundary conditions, and the required accuracy of solution. Each section is represented by one lump in the electrical network. The electrical values for the lumps are calculated on the basis of the geometrical dimensions of the section represented; capacitance is proportional to volume and resistance is proportional to the ratio of the thickness per cross sectional area,132 Radiation and convection surfaces for the region can be represented by boundary resistances.

2. Build the R-C circuit to represent the heat transfer problem.

3. Subject the circuit to the appropriate analogous initial and boundary conditions. Voltages would be applied to the circuit to represent temperatures and currents to represent flow. Transient or intermittent boundary conditions such as sudden applications of heat or changes in temperature can be reproduced. The resistances and capacitances can be adjusted to represent changes in \( k, c, d, \) or the surface boundary conditions.

4. Measure the electrical quantities, such as voltage and current,20 at the points at which the temperatures and heat flows are to be measured in the region or medium under investigation.

5. Convert the results of the electrical investigation into heat units by calculation.
The fundamental similarity between the defining equations for the flow of heat within a rigid body and that of charge in an electric circuit are shown in Figure 2 on page 31. The solution of heat transfer problems by this electrical analogy method is based on two principles. The first principle is the mathematical identity of the equations for heat flow and for certain electrical circuits and is exact. The second principle is the replacing of a circuit with evenly distributed properties by one with lumped properties and is approximate. Essentially this second step involves the replacing of each partial differential equation by an equation of finite differences.

To represent a one-dimensional heat-conduction problem by an electrical circuit the following procedure would apply. Such a problem might arise in the case of heat flow across an infinite slab or through a rod insulated at the sides or in the case of a steam heated insulated pipe. Express the various quantities $R_e$, $C_e$, $q$, $T$, $x_t$, and $t_t$ (defined in Figure 2 on page 31) for the thermal circuit in any desired consistent system of units. Choose a consistent system of units (not necessarily the same) for $R_e$, $C_e$, $I$, $V$, $x_e$, and $t_e$ in the analogous electrical circuit. Then make $x_e = x_t$ and divide the thermal circuit into elements of $dx_e$ length and the corresponding $R_e$, $C_e$ cable into an equal number of elements of length $dx_e$. Give every element $dx_e$ the same number of units of electrical resistance ($R_e$) and electrical capacitance ($C_e$), as the corresponding element $dx_t$ has units of thermal resistance ($R_t$) and thermal capacitance ($C_t$). It is not necessary that the thermal path be of uniform cross section or that the elements $dx_t$ be equal. Then by equations (3), (4), (5), and (6), or (7) and (8) of Figure 2, page 31, all the readings for $V$ and $I$ taken in the electrical circuit at the points defined by $x_e$ and $t_e$ will be numerically equal to values of $T$ and $q$ in the thermal circuit at points defined by $x_t$ and $t_t$ for $x_e = x_t$ and $t_e = t_t$.

Since $R_e$ and $C_e$ occur only as a product, the result will not be changed if $R_e$ and $C_e$ are changed individually. Refer to Figure 2, page 31. In equation (7), $V$ can be replaced by $nm_0eC_e$ or $nmc_0C_e/m$, and $t_e$ can be replaced by $nm_0$ without altering the form of the solution. Since in equation (3) $dV$ is replaced by $k \cdot dV$ and $R_e$ is replaced by $nm_0e$, $I$ is, therefore, replaced by $I(k/mm)$. Since in equation (5) $dV$ is replaced by $k \cdot dV$ and $C_e$ is replaced by $C_e/m$, $Q_e$ is, therefore, replaced by $Q_e(k/m)$. By suitably choosing $k$, $\mu$, and $n$, the electrical analog may be operated at convenient voltages and transient time intervals and may be built with feasible magnitudes of resistance and capacitance.

The methods used for one-dimensional problems can also be applied to three-dimensional problems. Three-dimensional problems of course require a much greater number of resistors, capacitors, and other electrical equipment. Analogous circuits for three-dimensional elements are shown in Figure 3, page 32. The connection of the resistances into a grid in accordance with the respective positions of each element and the connection of the bottom terminal of all capacitors to a common ground form the analogous circuit representing the entire body. The choice of coordinate systems depends upon the shape of the body and the boundary conditions. In many problems there is a certain degree of symmetry which can be advantageously used to reduce the number of components required in the network; e.g., in a cylindrical problem with axial symmetry it is necessary to use only a two-dimensional network $k$ in the $z$ and $r$ coordinates. Coefficients of surface heat transfer can be represented by resistances and transient boundary conditions can be approximated.

Any problem in physics or engineering which can be specified by partial differential equations, such as occur in heat flow, fluid flow, or stress problems, can be approximated by electrical networks. By extending the methods described above networks can be constructed for many more complex equations, such as those for transient heat flow.

The possibility of changing the time scale is of paramount importance for the practicability of the method. The time ratio $TR = t_e/t_t = aC_eR_e$ where $t_e$ is the time in the electrical circuit, $t_t$ is the time in the thermal circuit, $a$ is the thermal diffusivity, $C_e$ is the electrical capacitance, and $R_e$ is the electrical resistance. With a low $TR$, a heat process whose actual time may be hours or days could take a few minutes in the analog. With a high $TR$, a heat process whose actual time is fractions of a second could take several minutes in the analog. By changing the time scale, times are achieved which permit a practical experimental run and allow easy reading of the instruments.

From the standpoint of time, electrical analog heat flow computers may be divided into three groups: long-time computers whose runs last from several minutes to several hours, intermediate-time computers whose runs last from fractions of a second to several seconds, and short-time computers whose runs last fractions of a second. The RC time constant for these computers has to be considered from various aspects: namely, cost of equipment, leakage, instrumentation, and manipulation. Because of the infinite variety of the possible designs for each type it is difficult to compare costs. As far as leakage goes, the short- and intermediate-time computers permit the use of small, extremely high quality capacitors and require low resistances which result in favorable use-
Application of Analog Computers to Fluid Flow Problems

Analog computers of various types have been used to obtain solutions to many problems concerned with the flow of fluids. The Westinghouse Mechanical Transients Analyzer was used to determine flow and pressure conditions in a penstock as a function of flow at the gate.\textsuperscript{147} The general-purpose computer at the California Institute of Technology was used to solve various partial differential equations concerned with fluid flow.\textsuperscript{129} Even before 1943 an electrical device was used for the analysis of the complex problems of reservoir and well behavior.\textsuperscript{140}

Electrical analogy techniques have been advantageously employed in the analysis of many diverse hydraulic systems.\textsuperscript{150} An equivalent circuit for any hydraulic system may be readily derived from two-terminal network analogies for each hydraulic component. A table of such analogies given in the cited reference is shown in Figure 4, page 33. The equations for system behavior may then be written and solved according to standard electric network analysis procedures. These methods can be most profitably applied in the field of automatic control, particularly servomechanisms.

Network calculators, such as the one at the Illinois Institute of Technology, have been used to solve the increasingly complex problems of calculating gas flows and pressure drops in gas distribution systems.\textsuperscript{143} It is necessary to develop a relationship between analogous electrical and gas flow equations and then choose and adjust the electrical components to duplicate the gas distribution system. Also, an electrical network analyzer, comprised of special tungsten filament lamps whose nonlinear resistance characteristics closely approximate the fluid flow resistance of pipelines, has been constructed for solving the simultaneous head-loss equations for a pipeline network.\textsuperscript{148}

Two-dimensional compressible fluid flow problems have been solved on adjustable resistance d-c calculating boards.\textsuperscript{152} The convenient analogy employed is that between the equations of two-dimensional fluid flow and of conduction of electric currents in a plate for which the conductance is a function of the voltage gradient or of the current density. Since present day d-c boards are built for the analysis of short circuits in power systems, it is planned to build a new d-c board consisting of more units of higher accuracy which will be more suitable for field problems.

The Hydraulics Division of the Civil Engineering Department at the Massachusetts (continued on page 42)
<table>
<thead>
<tr>
<th>OPERATION</th>
<th>ANALOG COMPUTERS</th>
<th>OUTPUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. General</td>
<td>( L \frac{d^2y}{dt^2} + R_1 \frac{dy}{dt} + \frac{1}{C_0} y = e(t) )</td>
<td>( \text{Assume } A \to \infty )</td>
</tr>
<tr>
<td></td>
<td>( L s^2 \bar{Z}(s) + R_1 \bar{Z}(s) + \frac{1}{sC_0} \bar{Z}(s) = \bar{e}(s) )</td>
<td>( i_2 = 0 )</td>
</tr>
<tr>
<td></td>
<td>( \frac{\bar{e}(s)}{\bar{i}(s)} = \frac{Z(s)}{I(s)} = Ls + R + \frac{1}{Cs} )</td>
<td>( E_0(s) = \sum_{k=1}^{n} \frac{E_{ik}(s)}{Z_i(s)} )</td>
</tr>
<tr>
<td>2. a) Addition</td>
<td>( E_0 = \left[ \frac{R_0}{R_1} E_1 + \ldots + \frac{R_0}{R_n} E_n \right] )</td>
<td>( c) \text{ Sign change on all input variables} )</td>
</tr>
<tr>
<td></td>
<td>( E_i = -\frac{1}{R_1} \sum_{k=1}^{n} \frac{E_{ik}}{R_k} )</td>
<td>( \text{Eic = Initial Condition} )</td>
</tr>
<tr>
<td>3. Integration</td>
<td>( E_i = -\int \frac{E_0 R_0}{R_1} dt )</td>
<td>( E_0 = sR_0C_1 )</td>
</tr>
<tr>
<td></td>
<td>( C_1 \frac{dE_i}{dt} = \frac{E_i}{R_0} )</td>
<td>( E_0 = \frac{d}{dt} )</td>
</tr>
<tr>
<td>5.</td>
<td>( \frac{d^2y}{dt^2} + A \frac{dy}{dt} + B y = f(t) )</td>
<td>( y = E_0 )</td>
</tr>
<tr>
<td></td>
<td>( y = E_0 )</td>
<td>( f(t) = E_1 )</td>
</tr>
<tr>
<td></td>
<td>( s^2 Y = F(s) - A s Y - B Y )</td>
<td>( s^2 Y = F(s) - B Y - A s Y )</td>
</tr>
<tr>
<td></td>
<td>( A = \frac{1}{R_4 c_2} )</td>
<td>( B = \frac{A}{R_4 c_1} )</td>
</tr>
<tr>
<td></td>
<td>( \frac{R_6}{R_5} = 1 )</td>
<td>( \frac{R_6}{R_7} = 1 )</td>
</tr>
<tr>
<td></td>
<td>( \frac{R_{13}}{R_9} = ) ( \frac{R_{12}}{R_{10}} = \frac{R_{12}}{R_{11}} = 1 )</td>
<td>( \frac{R_{13}}{R_9} = \frac{R_{12}}{R_{10}} = \frac{R_{12}}{R_{11}} = 1 )</td>
</tr>
</tbody>
</table>

Figure 1 — Operational Amplifier Circuits
1. **Conservation of scalar quantity**
   - **ELECTRICAL**: Charge (Coulombs)
   - **THERMAL**: Heat (Btu)

2. **Scalar point function**
   - **ELECTRICAL**: Electric Potential (Volts)
   - **THERMAL**: Temperature (Degrees)

3. **Resistance concept**
   - **ELECTRICAL**: Ohm's Law
   - **THERMAL**: Fourier's Law

4. **Resistance concept**
   - \( R_e = \frac{dV}{I} \) (3)
   - \( R_t = \frac{dT}{q} \) (4)
   - \( R_e = \) electrical resistance
   - \( R_t = \) thermal resistance
   - \( I = \) current through \( R_e \)
   - \( q = \) heat flow through \( R_t \)
   - \( dV = \) difference in potential across \( R_e \)
   - \( dT = \) difference in temperature across \( R_t \)

5. **Capacity concept**
   - \( C_e = \frac{Q_e}{dV} \) (5)
   - \( C_t = \frac{Q_t}{dT} \) (6)
   - \( C_e = \) electrical capacity
   - \( C_t = \) thermal capacity
   - \( Q_e = \) charge stored in \( C_e \)
   - \( Q_t = \) heat stored in \( C_t \)
   - \( dV = \) rise in electrical potential of \( C_e \) due to \( Q_e \)
   - \( dT = \) rise in temperature of \( C_t \) due to \( Q_t \)

6. **One dimensional form of heat conduction equation for solids**
   - \( \frac{\partial V}{\partial t_e} = \frac{1}{R_e C_e} \frac{\partial^2 V}{\partial x_e^2} \) (7)
   - \( \frac{\partial T}{\partial t_t} = \frac{1}{R_t C_t} \frac{\partial^2 T}{\partial x_t^2} \) (8)
   - \( t_e = \) time in electrical circuit
   - \( t_t = \) time in thermal circuit
   - \( x_e = \) distance along cable
   - \( x_t = \) distance along flow path
   - \( V = \) electrical potential at \( x_e \) at time \( t_e \)
   - \( T = \) temperature at \( x_t \) at time \( t_t \)

7. **Flow**
   - Amperes = Coulombs/sec
   - Btu/min

8. **Capacity**
   - Farads = Coulombs/volt
   - Btu/degF

9. **Resistance**
   - Ohms = Volts/Coulomb/Sec
   - degF/Btu/min

10. **Heat flow across an infinite slab**


\[ \text{Figure 2 -- Comparison of Electrical and Thermal Relations} \]
ANALOG COMPUTERS

CARTESIAN COORDINATES

\[ C = \Delta x \Delta y \Delta z \frac{c d}{k} \]
\[ R_x = \frac{\Delta x}{\Delta y \Delta z k} \]
\[ R_y = \frac{\Delta y}{\Delta x \Delta z k} \]
\[ R_z = \frac{\Delta z}{\Delta x \Delta y k} \]

CYLINDRICAL COORDINATES

\[ C = r \Delta \theta \Delta \rho \Delta z \frac{c d}{k} \]
\[ R_r = \frac{\Delta r}{r \Delta \theta \Delta z k} \]
\[ R_\theta = \frac{\Delta \theta}{r \Delta \rho \Delta z k} \]
\[ R_\varphi = \frac{\Delta \varphi}{r \sin \varphi \Delta \rho \Delta \theta k} \]

SPHERICAL COORDINATES

\[ C = r^2 \sin \varphi \cos \theta \Delta r \Delta \theta \Delta \varphi \frac{c d}{k} \]
\[ R_r = \frac{\Delta r}{r^2 \sin \varphi \Delta \theta \Delta \varphi k} \]
\[ R_\theta = \frac{\Delta \theta}{r \sin \varphi \cos \theta k} \]
\[ R_\varphi = \frac{\Delta \varphi}{r \sin \varphi \Delta \theta k} \]

TRANSIENT HEAT FLOW EQUATION

\[ \nabla^2 T = \frac{1}{a} \frac{\partial^2 T}{\partial t^2} + f(t) \]

1/a = cd/k
f(t) - arbitrary heat function applied to system
Required boundary conditions can be handled by suitable potentials.
c - Specific heat
d - Density
k - Thermal conductivity
T - Temperature

Figure 3 -- Analogous Electrical Circuits for Three-Dimensional Thermal Elements

- 32 -
## HYDRAULIC ELEMENT | ELECTRIC ANALOGY

<table>
<thead>
<tr>
<th>Hydraulic Pressure - P</th>
<th>Voltage - E</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluid Flow Rate - q</td>
<td>Current - i</td>
</tr>
</tbody>
</table>

### Hydraulic Pumps

- Reservoir
- Pump

\[ P_i \rightarrow P_0 \]
\[ q_i \rightarrow q_0 \]

### Orifice

- \( P_i \)
- \( q_i \)
- \( q_o \)

### Boost Control Valve

- \( q_{i/2} \)
- \( P_i \)
- \( P_o \)

### Hydraulic Actuator

- Leakage resistance - \( R_k \)
- Piston area - \( A \)
- Fluid compressibility - \( \beta \)
- Cylinder volume - \( 2V_n \)
- Piston displacement - \( X_p \)

### Hydraulic Tubing

- \( P_i \)
- \( q_i \)
- \( q_o \)

- Tubing length - \( l \)
- Cross section area - \( A \)
- Fluid compressibility and tubing elasticity constant - \( \beta \)
- Fluid mass density - \( \rho \)

### Electrical Analogy

- Electric Generators
- Nonlinear Resistor
- Bridge Network
- Parallel Branch Network

\[ \dot{q} = \dot{P} \frac{X_p}{A} \]

\[ E_i \rightarrow \dot{I} \rightarrow E_o \]

\[ \frac{1}{R_t} \]

\[ \frac{1}{C_t} = \frac{1}{C_x} + \frac{1}{C_L} + \frac{1}{C_M} \]

\[ \frac{1}{C_x} = \beta A \]

\[ L_x = \frac{R}{A} \]

\[ C_x = \beta A \]

### Figure 4 -- Electrical Analogies for Hydraulic Components
<table>
<thead>
<tr>
<th>HYDRAULIC SYSTEM:</th>
<th>ELECTRICAL SYSTEM:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uniform frictionless pipe line</td>
<td>Uniform lossless transmission line</td>
</tr>
</tbody>
</table>

1. Inertia equation: \( \frac{\partial V}{\partial s} = \frac{1}{9} \frac{\partial H}{\partial t} \)

2. Continuity equation:
\[ \frac{\partial V}{\partial s} = \frac{w}{E_b} \left(1 + \frac{E_b}{E_y} \frac{D}{c}\right) \frac{\partial H}{\partial t} \]

3. Wave equations:
\[ \frac{\partial^2 H}{\partial t^2} = c^2 \frac{\partial^2 H}{\partial s^2} \]
\[ \frac{\partial^2 V}{\partial t^2} = c^2 \frac{\partial^2 V}{\partial s^2} \]

4. Propagation velocity:
\[ c = \frac{E_b/\rho}{\sqrt{1 + E_b/E_y D/c}} \]

5. Surge impedance:
\[ Z_o = \frac{c}{g} \]

6. Reflections:
- Open end: Pressure node: \( \Delta H = 0 \)
  Reflection factor: \( \gamma = -1 \)
- Closed end: Velocity: \( \Delta V = 0 \)
  Reflection factor: \( \gamma = +1 \)

- Grounded end: Voltage node: \( \Delta E = 0 \)
  Reflection factor: \( \gamma = -1 \)
- Open end: Current node: \( \Delta I = 0 \)
  Reflection factor: \( \gamma = +1 \)

---

**Figure 5 -- Electrical-Hydraulic Analogy**

**ANALOGY**

Head \( H \) \( \leftrightarrow \) Voltage \( E \)
Velocity \( V \) \( \leftrightarrow \) Current \( I \)
The following is a compilation of patents pertaining to computers and associated equipment from the Official Gazette of the United States Patent Office, dates of issue as indicated. Each entry consists of: patent number/inventor(s) / assignee / invention.

**SEPTEMBER 21, 1954: 2,691,157 / R Stuart-Williams, Milwauk e, Wisconsin**

Magnetic memory reading system


**OCTOBER 19, 1954: 2,692,082 / O Cesareo, Washingto n Twp, Bergen County, and W B Stricker, East Orange, N J / Bell Telephone Labs, Inc, New York, N Y / Automatic calculator**


**ROSTER OF ORGANIZATIONS**

* * *

(Ccontinued from page 23)

**When Established**

Le Long established organization (1922 or earlier)

Me Organization established a "medium" time ago (1923 to 1941)

Se Organization established a short time ago (1942 or later) (no. in parentheses is year of establishment)

**Interest in Computers and Automation**

Dc Digital computing machinery

Ac Analog computing machinery

Ic Incidental interests in computing machinery

Se Servomechanisms

Cc Automatic control machinery

Mc Automatic materials handling machinery

**Activities**

Ma Manufacturing activity

Sa Selling activity

Ra Research and development

Ca Consulting

Ga Government activity

Pa Problem-solving

Ba Buying activity

(Used also in combinations, as in RMSa "research, manufacturing and selling activity")

*C This organization has kindly furnished us with information expressly for the purposes of the Roster and therefore our report is likely to be more complete and accurate than otherwise might be the case. (C for Checking)

**ROSTER**

Bendix Computer Division Bendix Aviation Corporation, 5630 Arbor Vitae St., Los Angeles 45, Calif. / ORegon 8-2128 / *C Electronic information processing machines; Electronic computers; data processing equipment; automatic control systems; Decimal Digital Differential Analyzer Model D-12; general
Economies in Design of Incomplete Selection Circuits

Arnold I. Dumey
Potter Instrument Co., Great Neck, N.Y.

The design of complete rectangular switching matrices and of incomplete triode matrices has been well covered. (See "Synthesis of Electronic Computing and Control Circuits", by the Staff of the Computation Laboratory, Harvard University Press, 1951, and references cited therein.) Herein set forth is a method of producing all of the most economical choices for location of diodes where it is desired to select \(N(2^n)\) outputs individually by means of \(n\) bipolar inputs. We employ the manipulations of Boolean algebra, using for convenience \(\cdot\) = and, \(\lor\) = or. Note particularly the absorption law, \(a(\lor b) = a\lor ab\).

Consider the case of the three bipolar inputs, corresponding to \(2^0 = a, 2^1 = b, 2^2 = c\) and a matrix where it is desired to select only the combinations \(0, 1, 3, 6,\) and \(7\). In binary form:

<table>
<thead>
<tr>
<th>Column</th>
<th>Line</th>
</tr>
</thead>
<tbody>
<tr>
<td>(c)</td>
<td>(b)</td>
</tr>
<tr>
<td>(0)</td>
<td>(0)</td>
</tr>
<tr>
<td>(0)</td>
<td>(0)</td>
</tr>
<tr>
<td>(0)</td>
<td>(1)</td>
</tr>
<tr>
<td>(1)</td>
<td>(1)</td>
</tr>
<tr>
<td>(1)</td>
<td>(1)</td>
</tr>
</tbody>
</table>

To insure that line \(0\) will not be picked up if the line \(1\) is energized, the matrix must contain a rectifier on the \(0\) line in column \(a\). To prevent pickup of the \(0\) line if \(3\) is called for, there must be a rectifier in either column \(a\) or \(b\) on the \(0\) line. In other words, to shut out \(0\) if any other number is called for, we must have a rectifier at \(a\) and \(a\) or \(b\) and \(b\) or \(c\) and \(c\) or \(b\) or \(a\). Symbolically, \(a(\lor b)\) \((\lor c)(\lor b)(\lor a)\), which reduces by absorption to \(a(\lor b)\). Therefore column \(a\) and one of the other two must be rectified. For line \(1\) we need \(a(\lor b)(\lor c)(\lor b)(\lor a)\). In other words, line \(1\) needs rectifiers in columns \(a\) and \(b\).

For line \(3\): \(a(\lor b)(\lor c)(\lor b)(\lor a) = bc\)

For line \(6\): \((\lor c)(\lor b)(\lor a)a = a(\lor b)\)

For line \(7\): \((\lor c)(\lor b)(\lor a)c = ac\)

The complete network is given in Figure 1.

The Boolean expression to be reduced can be taken immediately from a symmetric table which is easy to produce for any \(n\) variables, although its size for any \(n+1\) represents an increase by a factor of 4. Such a table for \(n=4\) variables is given in Figure II, which clearly displays its method of construction and extension.

Using the table, in the example first given, the intersections of row \(0\) with columns \(1, 3, 6,\) and \(7\) yield \((\lor b)(\lor c)(\lor a)\). For row \(3\) against columns \(0, 1, 6,\) and \(7\) we get \((\lor b)(\lor a)(\lor c)\).

Obviously, where there is more than one choice, for example, line \(6\) in the problem, the point to be picked for rectification can be selected on considerations of loading, symmetry, packaging, or at random.

- END -
Figure II
Digital Computer Techniques

Applied to the design, development and application of:

- Electronic Business Systems
- Military Radar Fire Control Systems
- Aircraft Control and Navigation Systems

The successful application of Hughes airborne digital computers to high speed aircraft fire control problems has opened up an entire new area for these digital computer techniques. Similar equipment is now under development in the Advanced Electronics Laboratory to apply such digital computer systems to modern business information handling.

Areas include:

- Logical Design
- Component Development
- Programming
- Magnetic Recording
- Circuit Design
- Input & Output Devices
- Systems Analysis

Hughes developments in these fields are creating new positions in the Advanced Electronics Laboratory. Exceptional men in the following spheres of endeavor are invited to apply:

Engineers and Physicists

Computer activities embrace systems planning and analysis, design and development, system engineering and component development. Experience in these areas, as well as in application of electronic digital computers, is desirable but not essential. Analytically inclined men with backgrounds in systems work are required for this phase.

Hughes

RESEARCH AND DEVELOPMENT LABORATORIES

11211 Wisteria Street, Culver City, Los Angeles County, California

Assurance is required that relocation of the applicant will not cause disruption of an urgent military project.

---

FREQUENCY CONVERTER—MODEL 400

A 400-CYCLE POWER SUPPLY BENCH SIZE

- Plugs into 60-cycle line
- Delivers 100 volt-amperes
- Output frequency and amplitude adjustable through entire AN-E-19 Range: 380-420 cps
- 105-130 volts

Frequency Regulation: Better than ±1 cps
Voltage Regulation: Better than ±1%
Harmonic Distortion: Total better than 3%

The small size (17" long x 11½" wide x 9" high), power output (100 V-A), and low cost afford the convenience of using one converter for each bench set-up. Four hundred cycle power handling capacity need be paid for only as required.

PRECISION VOLTAGE REGULATOR—MODEL 116

400-CYCLE

- Regulation: ±0.01% for 0 to 50 VA load variation
- ±0.02% for 0 to 100 VA load variation
  (When output set to center of ±10% input voltage variation)
- Developed harmonics: better than 1%
- Transient time constant: better than 0.01 seconds

Low harmonic distortion and low transient time constant result from the use of a push-pull feedback amplifier in the output. These features, together with the unusually high regulation, suggest the superiority of the Model 116 as compared with ordinary 400-cycle regulators.

Send for complete data on these Avion products

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Altitude & Air Speed Control Units • Electronic Choppers • Electronic Inverters
Magnetic Memory Systems • Miniature Plugs-in Amplifier Units • Miniature Precision Potentiometers
Multan • Power Supplies • Replaceable Subminiature Amplifier Assemblies • Signal Generators
Austin engineers will be glad to review with you your special problems in:

- Automatic Data Recording and Processing
- Computers and Converters Analog and Digital
- Magnetic tape to punched Card Conversion
- Control Devices and Automation Systems
- Systems Engineering Services for Industry

A completely redesigned data recording system making full use of the latest printed circuit and modular construction techniques. It will accept data from 15 or more input channels on a time sharing basis. An oven-stabilized crystal-controlled time base unit initiates data samplings at precise intervals starting from either an external or internal time zero. Time numbers, data input identification and data block symbols are synthesized, and recorded with the data.

The final record can take a variety of forms. The data can be recorded on magnetic tape in any desired sequence or code. The tape itself can be the final record or it can be converted by the system to punched cards or printed or punched tape.
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Late in 1943, the Weather Bureau, U. S. Department of Commerce, developed an electronic device for stream flow routing that has proved to be highly effective in the preparation of river stage forecasts.145 It was originally designed for routing flows from point to point along a stream, but subsequent studies indicated that the equipment is equally applicable to the direct routing of effective rainfall (runoff) over relatively large basins.

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purpose digital computers ModelGG-15A and GG-15D. Ms(150) Se(1952, division; 1929, corporati) DAC RMSa
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Digital Control Systems, P. O. Box 779, La Jolla, Calif.
All employees have been transferred and certain assets have been sold to Litton Industries, Beverly Hills, Calif.
Electrodata Corporation (Consolidated Engineering Corporation affiliate), 717 N. Lake Ave., Pasadena 6, Calif. / STCamaro 8-6761 / SAC
Electronic digital computers and compelec components; input-output devices; magnetic tape units; punched card conversion equipment. Ms(200) Se(1950; parent company 1937) DAC RMSa
Electronic Engineering Co., 108 South Alvarado St., Los Angeles 57, Calif. / Dlkirk 2-7353 / DUnkirk
Magnetic Inc., Butler, Pa. / Butler 71-745 / Magnetic core materials for construction of computer memories. Ms RMSa
Minnesota Electronics Corp., 1050 University Ave., St. Paul 4, Minn. / Capital 6-6991 / C
Digital and analog computers. Magnetic components, magnetic decision elements. Data reduction systems, telemeNering. Sa(35) Se(1946) DAC RMSa
J. B. Bea Co., 1723 Cloverfield Blvd., Santa Monica, Calif. / Exbrook 3-7201 / C
Automatic control systems, general and special purpose digital computers, flight control systems for helicopters, automatic cruise control for aircraft, torpedo tracking systems, automatic data handling systems, non-linear servo systems. Magnetic drums, magnetic heads, analog-to-digital converters, etc. Analog and digital computing facility. Ms(60) Se(1951) DAC RMSa
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1. What is "COMPUTERS AND AUTOMATION"? It is a monthly magazine containing articles and reference information related to computing machinery, robots, automatic controllers, cybernetics, automation, etc. One important piece of reference information published is the "Roster of Organizations in the Field of Computers and Automation". The basic subscription rate is $4.50 a year in the United States. Single copies are $1.25. The magazine was published monthly except June and August between March, 1953, and September, 1954; prior to March 1953 it was called "The Computing Machinery Field" and published less often than ten times a year.

2. What is the circulation? The circulation includes 1200 subscribers (as of Nov. 29); over 300 purchasers of individual back copies; and an estimated 1500 nonsubscribing readers. The logical readers of COMPUTERS AND AUTOMATION are some 3500 or 4000 people concerned with the field of computers and automation. These include a great number of people who will make recommendations to their organizations about purchasing computing machinery, similar machinery, and components, and whose decisions may involve very substantial figures. The print order for the Dec. issue was 2100 copies. The overrun is largely held for eventual sale as back copies, and in the case of several issues the overrun has been exhausted through such sale. A mailing to some 2000 nonsubscribers in December, 1953 (with 173 responses up to March, 1954) indicated that two-thirds of them saw the magazine (library, circulation, or friend's copy) and of these two-thirds over 93% "liked it".

3. What type of advertising does COMPUTERS AND AUTOMATION take? The purpose of the magazine is to be factual and to the point. For this purpose the kind of advertising wanted is the kind that answers questions factually. We recommend for the audience that we reach, that advertising be factual, useful, interesting, understandable, and new from issue to issue.

4. What are the specifications and cost of advertising? COMPUTERS AND AUTOMATION is published on pages 6½" x 11" (ad size, 7½" x 10") and produced by photooffset, except that printed sheet advertising may be inserted and bound in with the magazine in most cases. The closing date for any issue is approximately the 10th of the month preceding. If possible, the company advertising should produce final copy. For photooffset, the copy should be exactly as desired, actual size, and assembled, and may include typing, writing, line drawing, printing, screened half tones, and any other copy that may be put under the photooffset camera without further preparation. Unscreened photographic prints and any other copy requiring additional preparation for photooffset should be furnished separately; it will be prepared, finished, and charged to the advertiser at small additional costs. In the case of printed inserts, a sufficient quantity for the issue should be shipped to our printer, address on request.

Display advertising is sold in units of full pages (ad size 7" by 10"; basic rate, $170) and half pages (basic rate, $90; back cover, $330; inside front or back cover, $210. Extra for color red (full pages only and only in certain positions), 35%. Two-page printed insert (one sheet), $290; four-page printed insert (two sheets), $530. Classified advertising is sold by the word (50 cents a word) with a minimum of ten words. We reserve the right not to accept advertising that does not meet our standards.

5. Rate Change. Commencing January 1, 1955, the rates will change to the rates stated above. The old rates will apply until March 1 to advertising contracts received before December 1.

6. Who are our advertisers? Our advertisers in recent issues have included the following companies, among others:

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ADVERTISING INDEX — DECEMBER, 1954

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Following is the index and a summary of advertisements. Each item contains: name and address of the advertiser/subject, the advertisement/page number where it appears/CA number in case of inquiry (see note below).

The Austin Co., 76 Ninth Ave., New York 11, N.Y. / Automatic Data Recording System / page 39 / CA No. 107

Avion Instrument Corp., 299 Highway No. 17, Paramus, N.J. / Frequency Converter, Voltage Regulator / page 38 / CA No. 108

Computers and Automation, 36 West 11 St., New York 11, N.Y. / Back Copies, Advertising, Reply Form / pages 45, 47, 49, CA No. 109

Edmund C. Berkeley and Associates, 36 West 11 St., New York 11, N.Y. / Publications, / page 39 / CA No. 110

Ferranti Electric, Inc., 30 Rockefeller Plaza, New York 20, N.Y. / Ferranti High Speed Tape Reader / page 46 / CA No. 111

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