

# COMPUTERS AND AUTOMATION

CYBERNETICS • ROBOTS • AUTOMATIC CONTROL

Solving Problems with Digital Computers

. . . Alston S. Householder

The Day of Reckoning

. . . Jackson W. Granholm

The Operation of a Computer Away from  
a Central Staff

. . . Howard Bromberg

Word Length in Digital Computers

. . . D. D. McCracken

Free Use of the Toronto Computer, and  
the Remote Programming of It (Part 2)

. . . C. C. Gotlieb and others

Vol. 5  
No. 7

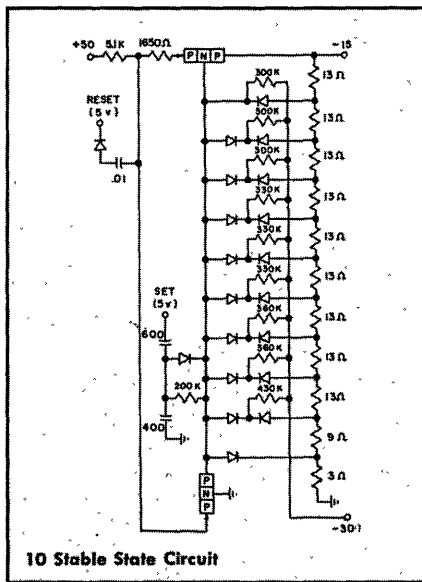
July  
1956

putting **IDEAS** to work—research at **IBM**

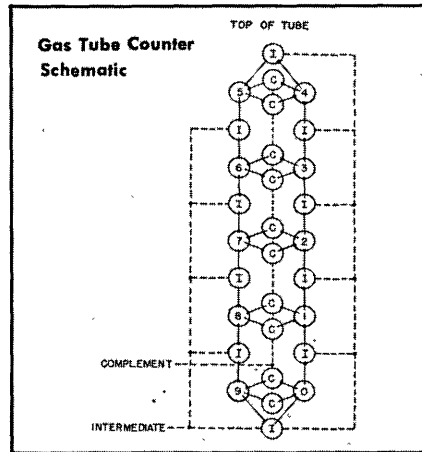
- **Multi-Stable Work Horse:** By employing a non-linear load, new circuit permits two transistors to do the work of ten. IBM Bulletin No. 200.
- **Self-Complementary:** New Gas Tube Counter subtracts by adding. IBM Bulletin No. 201.
- **The Soft Touch:** Ultrasonic cutting at IBM permits devices to be cut from hard, brittle materials within 0.0002".

**Multi-Stable Work Horse**

As the size and complexity of IBM products increase, we are faced with growing numbers of components—which means increased cost. As part of our continuous search for improvement and ways to reduce the number of components, Robert Henle, one of our Transistor Circuit Research people, undertook to get more work out of a given number of transistors. The result is a two-transistor, multi-stable circuit employing feedback controlled by a non-linear load. Junction transistors are naturally suited to this new kind of circuit.



A full report on this new idea from IBM contains eight full-page circuit diagrams in addition to mathematical analyses of the operation of the circuit. Write for your copy of IBM Bulletin No. 200.



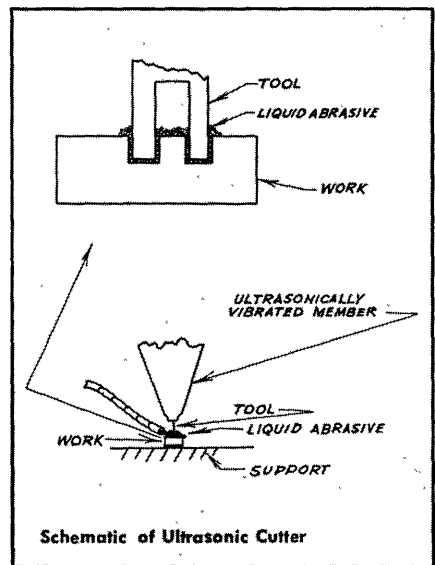
**Self-Complementary**

Accounting machines these days must be able to do everything—even make decisions. In order to get a machine to do more in a day's time with little or no increase in operating cost, IBM Component Research people studied the idea of using a multi-cathode gas tube. It's good news that they came up with an attractive approach, which Robert Koehler, of our Device Development Group, then reduced to practice; it operates faster than its electromechanical predecessor and, furthermore, with simple circuitry, can subtract, by adding. It can read out in true number form both positive and negative balances. This is possible because a number stored in the tube may be transposed to its 9's complement (i.e., value subtracted from nine) by a single electrical pulse.

If you'd like more information on the basic principle, physical arrangement of parts, and typical problems solved, write for IBM Bulletin No. 201. If you are fascinated by the theory of numbers, we recommend this Bulletin.

**The Soft Touch**

In some of our studies of new components, at the IBM Research Laboratories at Poughkeepsie, it is necessary to make many different, small and intricately shaped parts from brittle materials. Following the conventional approach, each of these parts would require laborious and costly machining and fabrication. We turned to ultrasonic cutting; with this tool we can make any shape or size component in approximately a minute—with an accuracy five times greater than previously possible! The ultrasonic cutter has helped us progress faster in our development of new devices. RESEARCH at IBM means IDEAS at work.



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# COMPUTERS AND AUTOMATION

## CYBERNETICS • ROBOTS • AUTOMATIC CONTROL

Vol. 5, No. 7

July, 1956

ESTABLISHED SEPTEMBER, 1951

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Publisher: Berkeley Enterprises, Inc.  
Main Office: 815 Washington Street, Newtonville 60, Mass. — Decatur 2-5453 or 2-3928  
Editorial Office: 36 West 11 Street, New York 11, N.Y. — Gramercy 7-1157 or Algonquin 5-7177

#### Advertising Representatives:

San Francisco - W.A. Babcock, 605 Market St., San Francisco 5, Calif., Yukon 2-3954  
Los Angeles - Wentworth F. Green, 439 So. Western Ave., Los Angeles 5, Calif., Dunkirk 7-8135  
Elsewhere - the Publisher

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Subscription rates: in the United States - one year \$5.50, two years \$10.50; in Canada - one year \$6.00, two years \$11.50;  
elsewhere - one year \$6.50, two years \$12.50

Bulk subscription rates: see page 18

Advertising rates: see page 42

Entered as second class matter at the Post Office, New York, N.Y.

# OPPORTUNITY TO LEARN

I. From Curtner B. Akin, Jr.,  
Sewickley, Pa., to the Editor:

This letter is merely an expression of sincere thanks to you and your policy of extending subscription privileges to everyone who wishes to read your fine magazine "Computers and Automation".

I am nineteen years of age and interested, as I have been for some time to date, in the movement toward automation. I have been interested in electronics for many years seriously, and in my search for publications in the automation and electronic fields I have found more than once that my requests for subscriptions to various magazines were unwanted.

Of course, I realize that the audit organizations have much to say about subscribers to the magazines with which they are connected, and I also realize that there are only a certain number of subscriptions available to those who are not in an "official" capacity within some business. This to me is nonsense. The following is my explanation why:

Recently in these our United States, there has been a great deal of consternation about the number of scientists turned out, or manufactured, by Russia's system of education. It has been brought to light that the young Russian in quest for knowledge has no problem finding reading material upon that subject which holds for him the maximum interest. Isn't this ideal? To me it seems a little hard to imagine that a country as imperfect (to me) as Russia, has had the common sense to place before the youth of its country the material they seek.

Let's turn to the U.S. and make a comparison. ...As the ten or eleven-year old grows away from his desire to live in a make-believe world into a young member of adulthood, what does he find? Simply that he cannot with ease obtain the information which he seeks. The "educated" class closes its eyes to his desires. His quest for learning "what makes things tick" is nipped in the bud. The adult world would rather he go through the required sequence necessary for becoming educated than satisfy his self-motivated thirst for learning. Brother -- if that isn't crazy!!

In closing, I would like to congratulate you on a perhaps unrecognized wonderful point

in your favor. Please accept my appreciation: you have no idea how wonderfully surprised I was to find "Computers and Automation" in my mailbox yesterday.

II. From the Editor

Opportunities for education in the United States, in the finest sense of the word "education", are far less than they should be. Here are three comparisons:

	<u>Union of Soviet Socialist Republics</u>	<u>United States</u>
1. Average number of students in class per teacher	19 or 20 and increasing	34 or 35 and increasing

	<u>Denmark</u>	<u>United States</u>
2. Number of inhabitants for every bookseller	7,000	100,000

	<u>No. of Vacancies</u>	<u>No. of Applicants</u>
3. In New York City, on June 5, 1956, in regard to competitive examinations for candidates who are to teach mathematics in junior high schools	650	88

We earnestly hope that "Computers and Automation" may help in the cause of education of men and women in the United States, in the field of computers and their applications and implications, including automation. And it is our intention for the indefinite future that anyone who wishes to, may subscribe to "Computers and Automation".

# Systems Engineering at The Ramo-Wooldridge Corporation

**ICBM and IRBM are prime examples** ■ The Intercontinental Ballistic Missile and the Intermediate Range Ballistic Missile, Air Force programs for which we have over-all systems engineering and technical direction responsibility, are prime examples of programs that require the systems engineering approach. Most Ramo-Wooldridge work is of such a systems character, requiring the concurrent solution of a wide variety of interrelated technical and operational problems. Additional examples at R-W are communications, fire-control, and computer programs for the military, and automation and operations research projects for business and industry.

**Pertinent technical fields** ■ Successful execution of systems engineering programs requires that the technical staff include experts in a considerable number of scientific and engineering specialties. At Ramo-Wooldridge some of the pertinent fields are aerodynamics, propulsion, digital computers, information theory, radio propagation, radar, infrared, servomechanisms, gyroscopy, and nuclear physics.

**The kind of team required** ■ A qualified systems engineering staff must include unusually capable theoreticians and analysts who can predict the behavior of complex systems, as well as ingenious experimental physicists who can devise suitable new techniques for measuring actual physical parameters. In addition, the team must include experienced apparatus and equipment development engineers, to insure a high level of practicability in the resulting end products.

*Scientists and engineers who are experienced in systems engineering work, or who have specialized in certain technical fields but have a broad interest in the interactions between their own specialties and other fields, are invited to explore the wide range of openings at The Ramo-Wooldridge Corporation in:*

Guided Missile Research and Development	■	Automation and Data Processing
Aerodynamics and Propulsion Systems	■	Digital Computers and Control Systems
Communications Systems	■	Airborne Electronic and Control Systems

## The Ramo-Wooldridge Corporation

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# SOLVING PROBLEMS WITH DIGITAL COMPUTERS

ALSTON S. HOUSEHOLDER  
Mathematics Panel  
Oak Ridge National Laboratory  
Oak Ridge, Tenn.

(Talk before American Physical Society, Washington D.C., April 26-28, 1956)

The speeds of "high speed" digital computers vary, from machine to machine, over several orders of magnitude, but for a fairly representative group the multiplication time is roughly half a millisecond. For the IBM 701, and for machines of the Princeton type, the speed is slightly less; for the IBM 704 it is rather greater, but this is perhaps a fair round number. The Oracle at the Oak Ridge National Laboratory is a Princeton type machine and hence one of this class, and since it is the machine with which I am most familiar, and since "Oracle" is an easy word to say, I wish to use the Oracle as representative of this class.

On the Oracle a division takes about the same length of time as a multiplication, so we can speak of multiplications and consider a division as equivalent. In time, and in percentage of occurrences, a multiplication is equivalent to about 10 single-address additive operations. The ratio varies somewhat from machine to machine, but in any case multiplications and divisions account for a substantial percentage of most computing time.

A skilled human operator, let us call him Joe for short, using a standard desk computer, can carry out about 1000 multiplications in a working day, counting time to enter operands and record results. This is steady going, and if we allow time out for sickness, holidays, and coffee breaks, 4000 per week is perhaps a better overall average. This amounts to about  $2 \times 10^5$  multiplications in a working year, or  $10^6$  in five years. Considering 50 working years as the productive human life time, if Joe spends his life doing multiplications on a desk calculator he will perform a total of about  $10^7$  of these.

There is a well known, but not well defined, unit of computational volume known as the "Horner". I have never seen it in print, but I understand it represents the amount of computational labor required for solving an algebraic equation of some given degree using Horner's method, which is one of the more laborious and simple-minded of known methods. I should like to expand the unit to more practical

dimensions, and redefine it, freed from invidious implications. For this purpose I shall consider the Horner to represent  $10^6$  multiplications or the equivalent thereof. In these terms, Joe requires about 5 years to produce a Horner, and the Oracle about 8 minutes. In the same terms, the NORC at Dahlgren requires about one minute and the LARC, to be delivered to Livermore two years hence, about 8 seconds. These last figures are very rough and comparisons are difficult, since the NORC and the LARC are floating point machines, which gives them an effective speed that is perhaps higher by an order of magnitude. On the other hand, I am not at present considering the utility of the output, but seeking only some gross, overall, and reasonably well-defined measure of activity.

Returning to our friend Joe and his desk computer, if we assume him to be a high school graduate merely, with no special endowments other than steadiness and dependability, his salary and overhead would probably come to at least \$5,000 per year. Hence his output comes at the rate of about \$25,000 per Horner. While Joe works a 40-hour week, the Oracle's week is at present 120 hours long. If we figure depreciation at \$200,000 per year, which is quite excessive, this comes to about \$30 per hour. Normal operating costs run around \$50 per hour, and this adds up to about \$10 per Horner. The LARC will cost about three times as much as the Oracle. If we allow the same factor for operating costs, and allow a factor of 60 for speeds, we come out with a cost of 50¢ per Horner, a factor of  $5 \cdot 10^4$  by comparison with Joe. Perhaps I should emphasize again that utility is not being considered. For a particular problem the number of Horners required can easily vary by an order of magnitude for any single system depending upon the care taken in programming and analysis. But this can be said for the output of any of the machines, that for an output of one Horner one does not have to wait five years.

For Joe I have postulated very few skills, the Oracle and the LARC have even fewer. If we have a differential equation to be solved, whether by Joe, by the Oracle, or by the LARC,

## Solving Problems

we have to program it properly since neither one of the three knows any mathematics beyond arithmetic. Suppose the problem requires about one Horner of computation. To compare the programming of the problems for the LARC with the programming of the problem for Joe, we must imagine that Joe is to be given his data and instructions at the outset, and is then to be left incommunicado for a period of 5 years at which time he suddenly emerges with answers, which may or may not be the correct ones. The instructions must be explicit enough to guide him through all contingencies, since by hypothesis all communication is severed for the period.

The parallel is not perfect, since either the Oracle or the LARC can simply stop. At least it can be programmed to stop when troubles of a foreseeable character arise. But often the troubles, if foreseeable, are nevertheless not foreseen, and the machine diligently produces nonsense until the aberration is discovered. Happily we can afford to squander a few of the LARC's 50¢ Horners, as we could not afford to squander Joe's \$25,000 Horners. But the fact, while ameliorating the difficulty, does not nullify it. Ultimately, for any given problem, it is necessary to achieve a program capable of directing the computer in uninterrupted, valid performance for at least a few seconds, and in the case of the LARC, this would be equivalent to almost that many years on the part of Joe. And whereas the LARC will require 8 seconds to produce a Horner, there are machines in prospect for three or four years hence that will produce a Horner or more per second.

These figures are introduced, not for the purpose of bringing out what amazing achievements these computers are, but rather to emphasize the difference between solving a problem with Joe's help and solving it with the LARC's help. The real, flesh and blood Joes who actually pound Fridens and Marchants, are not generally incarcerated, and, indeed, they themselves can often see, as the LARC cannot, when things go awry. In particular, it is often possible to observe the build-up of rounding errors in the course of a hand computation and to take remedial measures.

It goes without saying that in the course of a Horner or two of computation, rounding errors can build up very substantially and possibly invalidate the entire result. Some papers have been published attempting to derive statistical distributions of errors generated in the course of certain classes of computation, but generally speaking I am skeptical of the conclusions. For such estimates some uniformity of the initial distributions of data and errors must be made,

whereas it is clear that numbers actually used in real computations have a distribution that is far from simple. For example, the simple rationals, certain transcendentals such as  $e$  and  $\pi$  and simple functions of these, occur with much more than random frequency. Having recently formulated a pessimistic hypothesis in this regard, I was informed by a Scotch mathematician that my principle was already well known in Scotland by the name of Macpherson's Law. In the original Scotch the statement is, "Macpherson's piece aye fa's jeelie side doon". There is another formulation of the same principle which is known as das Gesetz der Schweinerei der Natur.

I can illustrate this with an occurrence of several years ago when a floating-point routine was being prepared for a fixed-point machine. The results exhibited some obvious but puzzling discrepancies, but eventually it was found that among the  $2^{60}$  possible number pairs provided for, the routine gave the correct product for all but one, and this one pair actually occurred in the computation. The probability of the appearance of this pair at any one time was, of course,  $2^{-60}$ , or, roughly  $10^{-18}$ , on the assumption of a uniform distribution.

Recently at ORNL a routine for inverting matrices was being tested by applying it to a particular matrix whose inverse was obtainable analytically. If a computed inverse is multiplied by the original matrix and the result subtracted from the identity, it is possible to compute quite easily and rigorously an upper limit to the error in the individual elements of that inverse. In this instance the computed upper limit was exceeded by several orders of magnitude by the errors actually found in some of the elements. It turned out that the discrepancy was due to the small residual error made in converting the elements of the original matrix from decimal form to binary. In other words, the matrix actually inverted differed in the last few binary digits from the matrix whose inverse was known theoretically, and this accounted for the discrepancy.

I am mildly distressed by the growing popularity of decimal machines for scientific computation, and of floating-point machines. It is a theorem that among all possible bases, the base 2 minimizes the rate of growth of generated error. In fact, the larger the base the higher the rate. My objection to floating point is based upon the fact that, to the best of my knowledge, no one knows how to predict the rate of growth of generated error when floating point arithmetic is used.

In speaking of generated error I am not,

of course, speaking of malfunctioning of the machine, or of errors due to faulty coding, or of the use of a fallacious formula. These are relatively easy to detect and correct. I am not referring even to truncation errors. These are also fairly easy to detect, generally, although I know of a case where several months of IBM computations were found to be invalid because a Taylor series had been truncated too soon, and another case where some months of coding time were wasted along with some machine time because a certain series was found to converge too slowly to be usable at all. In both of these instances a sufficient amount of fairly standard mathematical analysis could have prevented the loss. The errors I refer to, however, are those which result from rounding after every multiplication and division, and in floating-point operations they appear also when the exponents are adjusted by shifting before an addition or subtraction. The analysis here is always tedious, and the mathematical techniques are by no means well developed.

In some instances a posteriori estimates of error can be made. I have already spoken of the formula for obtaining an upper bound to the error in the computed inverse of a matrix, although, as you recall, this refers to the matrix actually in the machine which is not always exactly -- in fact is seldom exactly -- the matrix you wish to invert. To the best of my knowledge, there is no way of obtaining in general a rigorous limit of errors in the solution of a system of linear equations without making use of a computed inverse. It does not suffice to substitute the computed solution into the original equations. For suppose you do this, and suppose you even find that to within rounding errors the equations are exactly satisfied. That is, suppose you wish to solve  $Ax = b$ , and you obtain for  $x$  a vector  $x^*$  such that when you take the machine product  $(Ax^*)^*$  of  $A$  by  $x^*$  you get exactly  $b$ . Nevertheless, in general, the true product  $Ax^*$  will differ from the desired vector  $b$  by some vector  $d$  of which you know only that each element of  $d$  does not exceed the maximal error generated in the machine computation. Then the error  $x - x^*$  is equal to  $A^{-1}d$ . Now if it should happen that this unknown vector  $d$  has a large component in the direction of the eigenvector of  $A$  belonging to the smallest eigenvalue, call it  $\lambda$ , then the actual error vector  $x - x^*$  will be approximately  $\lambda^{-1}d$ , and if  $\lambda$  is small, the elements of  $\lambda^{-1}d$  can be large. This is what can happen in the case of so-called ill-conditioned systems. But the case can be even worse. Consider the form

$$A = I - \alpha J,$$

where  $J$  has ones just below the diagonal and

and zeros elsewhere,

Then

$$A^{-1} = I + \alpha J + \alpha^2 J^2 + \dots + \alpha^{n-1} J^{n-1}.$$

Hence, although every eigenvalue  $\lambda = 1$  for  $A$ , nevertheless the last element of  $x - x^*$  will be  $\alpha^{n-1}$  times the first element of  $d$ . If  $\alpha$  is large and  $n$  large the magnification will be great.

This phenomenon is well known in the finite difference solution of differential equations. It goes by the name of instability. Actually, instability is a matter of degree, as others have pointed out, and it should be treated as such.

If the differential equation, whether ordinary or partial, is linear, then the elements of the vector  $x$  of unknowns are the values of the dependent variable at mesh points of the grid; the elements of the vector  $b$  are determined by the boundary or initial values; and the elements of the matrix  $A$  are determined by the method of approximating the derivatives by finite differences. For initial value problems one generally tries to set up a scheme whereby the dependent variable can be evaluated by a straightforward recursion, beginning at a boundary or corner point and proceeding from point to point. One does not generally write down the matrix explicitly, or perhaps even think of the problem in these terms, but in fact the matrix  $A$  is then a triangular matrix, all of whose non-null elements fall on the diagonal or not far below it. Its form is only slightly more complicated than that of the matrix just exhibited.

Now the order of the matrix depends upon the fineness of the grid. In general there will be a linear combination of terms of the form  $\alpha^{n-1}, \beta^{n-1}, \dots$ , where  $\alpha$  and  $\beta$  are themselves functions of the grid spacing. If  $n$  is made large, as is desirable for reducing the truncation error, then in general at least one of the terms,  $\alpha^{n-1}, \beta^{n-1}, \dots$ , becomes large. One seeks, therefore, to obtain a form such that the growth with  $n$  is as slow as possible. However, there are limits to what one can do in this direction.

On the other hand, if the matrix  $A$  is not required to be triangular, one may be able to avoid this type of buildup. It is true that the equations are less easy to solve than when the matrix  $A$  is triangular, but Horner's come cheap on the LARC, and fairly so on the Oracle, and it may be worth the pains. A nontriangular scheme is called implicit. For boundary value problems there is no choice, and one is forced to use an implicit scheme.



## Solving Problems

With implicit schemes, whether for boundary value problems or others, an iterative method of solving is generally preferred. This is so partly because the matrix is ordinarily very large but simple in structure, whereas its inverse is large and complex. Although many iterations may be necessary, each is relatively simple and easily programmed. There is a further advantage that if the iteration is continued until convergence is complete, the departure  $x - x^*$  of the computed from the true solution is as small as it can be made, whereas the result of a direct solution may require further improvement by subsequent application of an iterative technique.

For reactor criticality calculations, at least in one dimension, a direct solution is fairly simple because of the following circumstance: The matrix  $A$  is a so-called continuant, whose non-null elements occur along, just below, and just above the main diagonal. Such a matrix can be factored into the product of two matrices, one having non-null elements only along and just below the main diagonal, the other having them only along and above. One of the diagonals can be taken as made up of ones, and a simple set of recursions gives the other  $3n - 2$  elements. Each factor matrix, in turn, is readily inverted. This is the basis for the commonly used "out-in" or "in-out" algorithm in criticality calculations.

Now for the two-dimensional problem the matrix is a composite matrix constructed as follows: In the above matrix  $A$ , replace each diagonal element by a matrix of the same form as  $A$ ; replace each remaining non-null element by a diagonal matrix. This matrix can be factored and inverted exactly as was the above matrix, provided one bears in mind that the recursion relations involve matrices and that hence the order of the factors is important. For the three-dimensional problem one has to form a supercomposite matrix out of these composite ones, but again the algorithm holds. To the best of my knowledge this has never been programmed for existing machines for reasons that are obvious when one estimates the number of Horners required.

In fact, to invert a general matrix, or to multiply two of them, requires a number of multiplications proportional to the cube of the order, although for these special matrices it might be held to the square. If we think of a grid with 10 points in each direction, then this is  $10^6$ , or one Horner, multiplied by some constant factor. This must be multiplied again by the number of groups, and still again by the number of iterations that may be required.

We all learned in high school to solve simultaneous linear equations, and yet one of the more pervasive and evasive of the problems

before numerical analysts today is how to do this efficiently on the Oracles, the NORC's and the LARC's. A general matrix of order 100 represents several Horners of computation for its inversion, counting the many transfer operations involved, and 100 is a small number when the equations come from partial differential equations. There is first the sheer mass of multiplications alone, but this is only part of the problem. For large matrices the capacity of the internal storage will be exceeded and information must be switched between that and the auxiliary storage. But most critical of all is the fact that small divisors can develop that will blow up generated errors to a scale that would invalidate subsequent computations. One way to avoid this, when the matrix is not intrinsically badly conditioned, is to "position for size", which means seeking out the largest coefficient and shifting the equation containing it to first position at each stage of the elimination. This is very time-consuming for the machine, and so are any equivalent logical operations used to avoid an actual interchange. A slight change in the point of view, however, suggests a slightly different approach which evades the difficulty completely, and although more actual multiplications are required, there is a great reduction in the shuffling. The procedure is to carry out the elimination by performing a sequence of plane rotations. This method reduces the generated error, it yields as a by-product the value of the determinant, and permits a running check in that the sum of squares of the elements in any column remains invariant. The method was developed at ORNL by J.W. Givens, and it is now in very effective use on the Oracle. Including tape handling, inversion of a matrix of order 100 requires about 10 Horners.

In counting costs per Horner I did not include salaries of mathematicians and programmers. This is often considered to be much higher for, say, the LARC than for Joe. On an hourly basis this is certainly true, but on a per Horner basis it is by no means so. Let us consider a group of mathematically untrained Joes. How much supervision and programming they would require from a professional depends upon many factors, but ten Joes per supervisor would seem close to an upper limit. Ten Joes could produce two Horners per year, and hence one professional man year would be required for two Horners. Two Horners is about 16 minutes on the Oracle and about 16 seconds on the LARC. An hour's running time on the Oracle would be about 8 Horners or 4 professional man years. I have yet to see the machine problem that required two years of programming and coding for an hour's run.

What is even more to the point, however, is the fact that a code for an Oracle or a LARC is a capital investment. The linear equation

(cont'd on page 15)

# THE DAY OF RECKONING

JACKSON W. GRANHOLM  
Seattle, Wash.

Dr. Amos K. Hommel rose slowly from his chair. He walked with measured stride to the front of the lecture room. From his vest pocket he took the case containing the pince-nez glasses which it was his habit to wear while reading or speaking. From his coat pocket he withdrew the small, black, leather-covered notebook wherein it was his custom to record thoughts which came to him at odd moments. The front of the book was boldly emblazoned with golden letters spelling the word RECKON. It had been the gift of the Multinational Computer Corporation to Dr. Hommel on the occasion of his superbly brilliant address to a seminar convened at Alexandria, Egypt, to discuss theoretical aspects of numerical analysis with computers. Hommel opened the notebook carefully and gazed about the room, smiling at us all.

"Gentlemen," said Hommel, his gaze bouncing about like a cork bird in a badminton court, "you are all aware of the great debt we owe to the magnificent generosity of Herbert Fremont Parson, that superb benefactor of our institution. His gift it was that made possible the construction of that outstanding computing instrument which today has successfully completed its first month of operation. It is with gladness in my heart that I report to you today the results of that first month in being of the Parson Electronic Calculator, known to the world at large as SUPERVAC."

Dr. Hommel paused, taking his handkerchief from his pocket and wiping his pince-nez with it.

"The calculator," Hommel continued, "has exceeded all expectations. It has performed superbly. Without doubt it is now ready to attack the problems for which its design was conceived."

All of us sat in silence for a moment. Then, led by Dr. Robert Bardney, we rose in a body, resoundingly applauding this man who stood now before us, smiling, glasses in one hand, handkerchief in the other, slowly wiping the tears of happiness and gratitude from his eyes.

When the applause had subsided, Dr. Hommel, taking his black notebook from the lectern, returned to his seat. Dr. P. Y. Reebe

rose and walked briskly to the platform at the front of the room. His mane of white hair bobbed up and down as he placed his brief case upon the lectern. Everyone was quiet as he began to speak.

"My good fellows," Reebe said, "we are rightly filled with pride and admiration to have this excellent man as one of us. Our worthy colleague, Dr. Amos K. Hommel, through his devoted and tireless efforts has, virtually single-handedly brought this unparalleled computing instrument into being. It is indeed meet and fitting that we should, each and every one, offer our praise to him. Having done so, however, there remains before us the bringing to fruition of Hommel's work. I refer, gentlemen, to the tasks to which SUPERVAC will now be put."

Reebe gazed intently at the ceiling.

"I feel strongly," he said, "that the time has now come. We have at last, thanks to Hommel, arrived at the stage where we can begin to shed the tremendous burdens of the design of calculating machines. We can now start to place these burdens upon the calculators themselves. In a sense the electronic calculator has entered the stage where it can begin to make use of a characteristic heretofore limited to living beings. I speak, of course, of the process of reproduction."

Dr. Manifest, who sat in the back corner of the room, cleared his throat rather awkwardly.

"Not in any physical sense, naturally," Reebe went on, "can this machine reproduce itself. What I propose is, rather, that we shall take steps to assign to it, as soon as possible, the problem of designing its own successor. In fact," Reebe said, "I would not have us stop there. I would have us propose to this machine the problem of designing the optimum calculator!"

Reebe paused while the whole effect of his last statement seized us all. He turned to his brief case, taking some papers from it. Picking up the chalk he stepped to the blackboard at the back of the platform.

"If you will bear with me, gentlemen," Reebe said, "I shall outline the proposal which I have in mind."

## Day of Reckoning

Reebe began to write rapidly, his equations flowing across the board. Now and then he uttered a comment to explain some more obscure point. When Reebe had moved to the right half of the blackboard, Dr. Robert Bardney interrupted.

"You will pardon me," Bardney said, "but I believe you have committed a slight faux pas in logic in relationship number nineteen. Where you have written the operator AND/OR, I believe you should, instead, substitute the expression IF--THEN."

Reebe, after glancing at the equation in question, said "You are quite right." He erased the offending symbol and substituted the correct one.

After some time Dr. Reebe had completely filled the blackboard with symbols. We had carefully criticized and scrutinized his work. Dr. Robert Bardney rose to speak.

"It is evident to me," Bardney said, "that Dr. Reebe is on the right track. I propose that we proceed to push this project to completion as soon as possible."

Bardney's proposal was unanimously adopted, and early the next week work was begun on the task. Dr. Reebe was selected to head a team composed of Dr. Wilson M. Sweet, Dr. Rupert B. Pooble, and Professor Marnosc D. Nazildzian. This team was to define the relationships expressing the requirements for the optimum calculator. They were further charged with the task of writing these relationships as a set of completely detailed equations. Dr. G. Jennings Manifest was placed in charge of a group of graduate students whose task it was to convert the equations of Reebe's team into coded instructions for SUPERVAC. The operation of SUPERVAC itself, of course, was to be under the direction of Dr. Hommel with his company of well-qualified technical personnel. Dr. Bardney was chosen to act as coordinator among the several groups working on the project.

The Parnson Electronic Calculator, alias SUPERVAC, was, without doubt, the largest and fastest digital calculator in the world. It was housed in a vault-like room with a forty-foot ceiling at one end of Burton Thompson Roberts Hall. A balcony ran around the outer walls of this room so that spectators might observe the computer in action. The huge control console, vastly more complex than that of any pipe organ, was placed squarely in the center of the room. Directly behind the console was the main computing frame, so large that a person could easily walk erect within it to attend the tubes and circuits. To the left stood the cathode ray tube memory store and the magnetic core memory store. The cathode

ray tube store was made up of a huge rack of staring screens, slightly larger than television picture tubes. Instead of a picture the face of each tube, in action, carried a pattern of glowing blue dots. The magnetic core store consisted of a vast array of tiny ferro-ceramic doughnuts strung together on what seemed to be an impenetrable maze of fine wires.

To the right of the console were the mercury pipe memory and the spinning magnetic drum memory. The pipe retained information by recirculating it continually between two crystals in the mercury. Its action was like that of a small child who, shouting into one end of a vacuum cleaner hose, repeats what he hears himself saying at the other end which is pressed to his ear. The steel drum, ten feet in diameter and spinning at tremendous speed, had stationary magnetic pickups mounted all about its periphery. Some of these continually wrote little magnetized spots on the drum, while others read these little messages, producing an electric impulse from the rapid passage of the magnetized spot.

All along the wall behind the operator's chair of SUPERVAC were the magnetic tape servos which constituted the data input and output system. Directly adjacent to the console there was an intypoputter, an instrument with a typewriter keyboard communicating directly with the central computing circuits. Against the left wall there was a high-speed printer on which results could be written for rapid perusal. The back of the room was filled with power control and generating equipment, while overhead ran the air conditioning pipes which enabled SUPERVAC to keep cool.

This was the machine that faced Hommel and his assistants on that October morning we remember so well. Reebe and his team had long since completed their work. The equations had been checked and rechecked. Dr. Manifest and his graduate students had translated the equations into the strange alphabetic symbols which represented the one-thousand-twenty-four logical and arithmetical operations of which SUPERVAC was capable. Three young ladies had worked for a week and a half at typotapers, machines similar in appearance to the intypoputter, but designed instead to prepare magnetic tapes for the calculators. Dr. Hommel stood before the console of the machine he had created. The reels of tape were in front of him. Herbert Nugent, one of Hommel's assistants, stood, wearing earphones, before the staring cathode ray tube faces. Ronald Barnes, another assistant, stood at the power frame monitor panel. In the corner Dr. Manifest and Dr. Bardney sat at desk calculators, prepared to check any of the work if question should arise. Dr. Hommel's secretary, Lucy Campylos, stood next to him.

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# THE OPERATION OF A COMPUTER AWAY FROM A CENTRAL STAFF

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The David Taylor Model Basin is maintaining for the Bureau of Ships a somewhat unique computer installation in the Remington-Rand Univac factory in Philadelphia. It became apparent early in July, 1955, that certain government contractors, namely those utilizing Univac time at the Model Basin, could not effectively meet the demanding requirements without increasing their computer time. Since we at the Model Basin were working around the clock, it was evident that any request for additional time could not be fulfilled there. The situation became rather desperate with an ever increasing amount of high priority problems and no possibility for solution. Consequently, because of the genuine need and the urgency of Defense requirements, we asked Remington-Rand for a computer and they suggested the use of one in their factory in Philadelphia. The necessary contractual arrangements having been made, a computer (or more precisely a series of computers) a unityper I, a uniprinter, and a high speed printer, on a catch-as-catch-can basis, were put at our disposal the last week of July.

Aside from the fact that the Remington-Rand factory now became a government computer installation, the final assembly and test of all equipment was effected there as well as the manufacturing of special components, magnetic tape and mercury tanks. In the large testing area, there are five complete computers being assembled, tested, and torn down for shipment. The assembling takes roughly two weeks and the testing is complete in three months. The work is staggered so that a new computer is shipped each month. Similarly, at each of the five high speed printer test stations one is completed every seven weeks. A computer is put at our disposal after it has been in test for two months. We then use this machine for the remaining one month period after which time it is torn down for shipment. We then pack our desks, files, tapes, printer, typer, experience, memories, and move to one of the other computers which has progressed through two months of test.

Thus, we ourselves are involved in a large iteration, aside from the iterations of the problems we do and the iterative runs of these problems. If you will permit such a personification, we have found that each computer is an individual with a personality separate and

distinct from all other computer personalities. During our brief encounter with a given machine we need to become familiar to a point of intimacy with its various phobias and complexes, and also to normalize them in order to achieve the maximum amount of productive time. This process of diagnosis and remedy insists upon a great deal of patience, trouble-free routines, and no scant amount of intelligent troubleshooting and preventive maintenance. No sooner, however, have we succeeded in crashing this intelligence barrier between man and computer than our short acquaintance is at an end, for this computer too must be shipped out and another must spring up in its place. Thus, progress pushes us on to less fertile fields, as one iteration is completed and another is begun, differing from the former only by a factor of personality. Yet, a computer is still a computer, and even though we move from a compatible machine to one not fully checked out, we advance strengthened by the understanding and experience gained from our previous computer encounters.

Essentially, our main reason for being is to derive the highest amount of productive time possible. Productive time is another expression for machine efficiency: we derive it by dividing the time spent on the computer into four categories: good time, down time, non-productive time, and lost time. Good time is paradise -- everything works right; and in direct contradiction to this is down time. Non-productive time is time wasted because of some human error such as a bad type-in or a mistake in a routine. Lost time is due to machine malfunction. The sum of the good time and the non-productive time divided by the total amount of computer time gives us the machine efficiency or productive time. The number of machines used, however, is by no means commensurate with the amount of productive time gained.

The biggest single factor which governs our final efficiency is maintenance, which is handled by Remington-Rand on a 144 hour week with two separate eight hour periods a week devoted to preventive maintenance. This type of maintenance, which really amounts to constantly bug-shooting a new machine, is exacting and in the long run unrewarding. The strain of on the spot attempting to furnish a computer

### Operation of a Computer

which is capable of production work also affects the operators, who are furnished by the Remington-Rand Service Bureau in New York.

On a straight production run the role of the operator is negligible. The operators must fit into our pattern of operation by learning about our runs and how to use our service routines in a relatively short time. In spite of these conditions, our maintenance and operation have helped to develop an average machine efficiency of about 85%.

This installation derives some novelty from the fact that programming and programmers are not necessary factors for efficient operation. We operate without programmers, and two-thirds of the personnel running problems have had no previous computer experience. We have found that after a short preliminary orientation period on basic principles, a person new to the field is able to carry out effectively the running of our problems. This orientation involves on-the-job familiarity with jargon, equipment, and manuals of problem operation. No creative coding is being done; the only coding that is carried out is for occasional correction of control tapes or revision of routines. The degree of proficiency necessary for unityping and correcting control tape routines is readily attained. It is therefore clear that our bible is the manual of operating instructions for the problems with which we deal. These instructions must be exhaustive and accurate for every possibility, for it is upon them that a good part of the efficiency of the installation depends. The people running the problems are by necessity constrained to be more concerned with "setting breakpoint 1" or "block subdividing four" than with any of the principles innate within the problems. It is, however, imperative for them to have an understanding of the general scope of the problems being run, and to have a copy of all data, instruction tapes, and daily supervisory control print-outs, so as to be able to analyze effectively those difficulties which arise while on the computer. Every problem is run with the fewest possible references to the problem itself.

Basically, we run three different problems. All of them have been completely programmed and two of them have been in actual production at the Model Basin for close to two years.

Problem BETTIS 57 was developed by the Applied Mathematics Laboratory of the David Taylor Model Basin at the request of Westinghouse Atomic Power Division to aid in preliminary survey work incident to the design of nuclear reactors for ship propulsion. It was based on an extremely simplified physical model in which all neutrons were classed as either fast or slow, and only one space dimension was considered. The problem was then to determine the condition under which the reactor barely became capable of sustained reaction.

Mathematically the problem was to determine the lowest eigenvalue of a pair of second order ordinary differential equations. This was handled by finite difference methods, the standard iteration method being used to obtain the lowest eigenvalue of the resulting matrix system. This procedure also yielded the corresponding eigenvector whose components are proportional to the neutron flux density at the specified mesh points.

A slightly modified version of the foregoing has actually been used in most of the production work on BETTIS 57 so far. A parameter alpha is introduced which is a measure of the amount of "poison" material present in the reactor; the problem now requires, in addition, determination of the value of alpha which will make the eigenvalue, eta, fall within a specified narrow range. This is done by starting out with two standard assumed values of alpha, using linear interpolation to obtain an improved value of alpha, and so on. Computations require, on the average, about half an hour per case.

MUG, our second program, was developed over two years ago and has been in operation ever since. From an engineering point of view, MUG is a digital analog of a reactor. This reactor has either uniform cross-sections or is a body of revolution. In both cases it is circular. Thus only two space dimensions are involved. A third dimension (independent variable) is the lethargy, that is,  $\log E_0/E$  where  $E$  is neutron energy. The range of lethargy is subdivided into 3 to 15 intervals, and one thinks of the neutrons as classified thereby into "energy-groups" or simply "groups". The first step in the solution of a MUG problem is to assume (by that I mean guess) the power distribution, that is, the rate per unit volume per unit time of fission where one fission produces  $2\frac{1}{2}$  neutrons of various energies. Then, for each regionette (that is, two space and one energy interval) we compute the rate of occurrence of neutron collisions of each type, namely: elastic scattering, inelastic scattering, absorption, and fission. From this is computed a new power guess and after a thorough accounting of the neutrons we are supplied with the computer's power result.

This accounting process resembles a business type problem for it is here necessary to record for each regionette how many neutrons are coming in energy-wise, going out energy-wise, coming in space-wise, going out space-wise, getting born from fission, and dying as a result of being absorbed. This method can account for up to 500 blocks of output. The power computed by the machine is the result of one step in an iterative procedure and is used as the power guess for the next run. Thus a successive approximation method is necessary to do one problem. The result from this is a fairly good guess for the power of the first run of a new problem.

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# WORD LENGTH IN DIGITAL COMPUTERS

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Most computers of any size are based on the stored program principle, which implies that the instructions which define the problem for the machine are stored in its memory, along with the data of the problem. Almost all present computers are built with "common storage", that is, any storage location may contain either data or instructions. (The major exception is the Harvard Mark IV). In any case, the computer is able to make arithmetical modifications and tests on its instructions. This capacity, together with the ability to make conditional transfers or jumps to other parts of the program, gives the stored program computer its great advantage over early automatic computers, in which the program was outside of the memory of the machine.

There is a conflict, however. Assuming common storage, and assuming for the moment that the storage locations are of definite, fixed capacity, how many digits should a memory location contain? What should the "word length" be?

For most scientific work, and with present memory sizes, it turns out that about twice as many digits are needed for numbers as for instructions. How is this conflict resolved in present machines?

1. One straightforward solution, mentioned above for the Harvard Mark IV, is to bypass the problem by building two separate memory stores for instructions and numbers, with the most convenient size for each. It is of course possible to allow for arithmetical modification of the instructions. This, however, constitutes an extra burden on the designer, and besides restricts the flexibility of the computer since there is no choice of the ratio of instructions to numbers. This solution will likely be used in the future only for special purpose machines.

2. Another solution is to make the memory a convenient size for numbers, and waste the extra space when an instruction is stored. This solution is read in just this way in the DATATRON, and to a limited extent in all machines. In the IBM 704 six binary digits are wasted in most instructions. In any computer, space is wasted when a particular instruction does not require an address, as for instance the rounding instruction.

3. A very common solution is to use more than one address for each operation. This makes the designers work a little harder, but the view has evidently been held in many cases that it was a better solution than other alternatives. And of course many users feel that multiple address instructions are better from a programming standpoint.

The IBM 650 uses a second address to specify the location of the next instruction, which is particularly useful in a magnetic drum machine. Since the second address does not refer to data, this is usually called a modified one-address machine. The ERA 1103 uses two addresses for data, as do the ELECOT 120 and 125, and a few others. The NORC and others use three addresses for data. The SWAC uses a modified three address system, where the fourth address specifies the location of the next instruction.

4. A fairly common solution is to put two one-address instructions into one number-size location. This is the technique used on the UNIVAC, IBM 701, and the instances of the Institute for Advanced Study machines: the IAS machine itself, MANIAC, JOHNNIAC, ILLIAC, and others. This creates a new problem while solving the first one. Some way must be found of identifying the two halves. The half-word-full-word scheme gives each half an address, then uses an indicator in the instruction to distinguish between half and full words. Other methods give only one address to both, requiring therefore that in order to do arithmetic on an instruction it must be known which half of a word contains the instruction. This makes relative programming difficult. Such a system is an added nuisance to programmers, and is especially annoying to beginners.

5. A more recent attack is to sidestep the issue by making the length of the number variable. Instructions remain of fixed length, but numbers may be of any size from one digit up to a maximum which is much larger than needed in practice. The IBM 702 and 705 are built on this principle. It necessarily implies a serial machine, with a consequent loss of speed over parallel operation. It is particularly attractive to commercial users, who have no uniform requirement of number size. Although it is not at all clear at this time, the principle may turn out to be also desirable for

the scientific user. It certainly simplifies matters when it is necessary to carry more digits than the fixed word length. On the other hand, it is difficult to conceive of a variable word-length machine with built-in floating point. The last shot has not been fired in this battle.

What are the present trends? One trend which is slowly proceeding to alter the picture is the move to larger word length. The IBM 704 uses 15 binary digits to identify the addresses where its predecessor, the 701, needed only 12. We hear of machines in the next computer generation which in binary would require 17 or 18 binary digits. This of course is a slow trend. Each additional binary digit represents a doubling of memory capacity. It is rather unsafe predicting maximum sizes or speeds of computers very far in the future, but presumably increased memory size alone cannot solve the problem.

There is a fairly strong trend to go to variable word-length. This will probably extend to other machines.

An immediate extension of variable number length, although it has not appeared in any current computers, is variable instruction length.

Imagine an instruction format in memory like this:

\*Operation, address \* operation, address#

Here the asterisk represents some sort of mark or separator between instructions as between numbers. This, of course, need not actually use up a digit position in memory. Now suppose further that the operation part, which would always consist of one or two characters, is read into the control section first. It is not too difficult to imagine circuits which are fast enough to decode the operation part in time to decide whether an address is necessary with this particular instruction. If none is needed, as on a rounding instruction, there need be no address in memory, and we have saved four or five digit positions.

Furthermore, if we consider a decimal machine which has 100,000 digits of storage, as many as five digits may be allowed for the address. If a particular address requires only two or three digits, only that many need be written, since the control circuits can sense the "end-of-instruction" mark. On an instruction which refers to the low-numbered section of memory, this device saves about a third in instruction length. Such a system has enough advantages that it is surely being considered by manufacturers.

In conclusion, we can observe a continuing struggle between builders and users. Almost always a choice is to be made between simplicity of design, and simplicity or brevity or convenience of programming. Illustrations: some early machines used complements to represent negative numbers; some early machines had no divide order; only recently have built-in floating point machines been available. As a rough generalization, we may say that in early machines, the builders won the struggle; but from now on, the users will win. Machines will become more complex structurally in order to simplify or make more powerful the work of the programmer. Along with this trend is an unsettled issue as to whether to build machines with many and powerful instructions, or to concentrate on making a machine with fewer and simpler instructions, but which is very fast.

The impact of these considerations on word length in computers will depend to a large extent on experience with machines now beginning to come into wide use. It is certainly too early to ask for standardization; too many possibilities remain to be tested.

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SOLVING PROBLEMS

(cont'd from page 9)

solver I have just described required considerably less than one man year for its construction. The immediate stimulus for its construction was a matrix of order 190 to be inverted. This matrix has been inverted, and the inverse has been used and will be used repeatedly for obtaining the solution of a number of systems having the same matrix. The code will certainly be used many times for solving other systems with other matrices, and having been once constructed, the code remains available for use as long as the Oracle survives in its present form. Analogous remarks could be made about countless other codes, even including many that were made up with no thought that they would be used more than once. Customers have a way of finding that they need more of the same.

I wish to emphasize again that I have made no effort to associate a measure of utility with the Horner. First, this differs from machine to machine since a one-Horner problem on one machine could be several Horners on another, perhaps even 10 or so. Again, there is always the possibility that the problem did not need to be done in the first place. The physicists are among the major consumers, and potential consumers of Horners and the demand among them is great. So if you grant they are worth the price, I think one thing is clear. On the computing machine we are all Macphersons. Hence, if we wish to save the jelly we need to exercise some care to prevent the piece from falling.

- END -

# A GENERAL CURVE - FITTING SUBROUTINE FOR TRANSCENDENTAL FUNCTIONS

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## Introduction

A method is presented in this report to obtain a least squares fit to  $n$  points using a transcendental function of the general form

$$y = A f(\alpha, \beta, x) + B g(\alpha, \beta, x) + C$$

where  $A$ ,  $B$ , and  $C$  are linear parameters and  $\alpha$  and  $\beta$  are nonlinear. Any given function may have: zero to three linear parameters, zero to two nonlinear parameters, and one or two separate terms each containing the independent variable. The programming to compute each term in the function is all that is necessary before the method, which is coded in subroutine form, can be used. The subroutine is easy to use and utilizes a searching technique for functions containing nonlinear parameters in which accurate guesses of the first estimates are not necessary. All sums of squares and cross products are computed in fixed-point double-precision arithmetic which assures a high-degree of sensitivity to a fit and eliminates, in most cases, the necessity for scaling the independent variable.

## Discussion

### Inception

A considerable amount of curve fitting is done using polynomials because of their simplicity and flexibility, and computing installations have standard programs which can handle these problems from beginning to end by indicating only the degree of the polynomial to be used. However, there are numerous nonlinear relationships in science in which a transcendental function is expected to represent the relationship and which in most cases cannot be reduced to a simpler form by considering functions of the variables as new variables. The problem of fitting these functions to a set of points is not nearly as simple as that of fitting polynomials and can be solved only by tedious numerical methods. One of the most frequently applied is the Least Squares Differential Correction Method and is most useful when a function contains several nonlinear parameters. When applying the method to a high-speed computer using a general purpose program, one must first code the program steps necessary to compute the given function and the partial derivatives with respect to each parameter. Also good initial estimates of each parameter must be used since the terms of degree higher than the first were neglected when using Taylor's series expansion in linearizing the normal least square equations. The ideal program for this type of curve fitting would be one which required no additional coding by the user, but of course is impractical if not impossible.

Consider now only that class of transcendental functions containing two or less nonlinear

parameters, three or less linear parameters, and one or two separate terms. With regard to curve fitting, this class of functions is used extensively. Therefore, a method of curve fitting applicable to this class seemed desirable if the coding by the user, the computing time, and the necessity of closely estimating the parameters could be significantly decreased with respect to other methods.

### General Characteristics of Method

Returning to the general transcendental function

$$y = A f(\alpha, \beta, x) + B g(\alpha, \beta, x) + C$$

$$\text{Let } v = f(\alpha, \beta, x), \quad w = g(\alpha, \beta, x)$$

$$\text{Then } y = Av + Bw + C$$

Assuming  $\alpha$  and  $\beta$  are constant, then the sum of the squares of the residuals will be a function of the three parameters  $A$ ,  $B$ , and  $C$  only. Denoting this function by  $G(A, B, C)$  the normal equations can be obtained by setting the three partial derivatives of  $G$  to zero. Solving the normal equations yields the values for  $A$ ,  $B$ , and  $C$  which can then be used to compute the sum of squares of the residuals. By applying a two-way searching technique, new values of  $\alpha$  and  $\beta$  are selected and the computations repeated until the sum of squares of the residuals has converged to a minimum. It should be noted that neither the partial derivatives of  $y$  with respect to the nonlinear parameters nor estimates of the linear parameters were required. Justification for this method is based on being able to eliminate these partial derivatives by utilizing the speed of modern computers with respect to trial and error solutions.

The searching technique assumes enough is known about  $\alpha$  and  $\beta$  that upper and lower bounds may be assigned to each. The first values used will then be ones which are half way between the upper and lower bounds. Once the first sum of squares is obtained the initial values,  $\alpha_1$  and  $\beta_1$  are changed to  $\alpha_2$  and  $\beta_2$  respectively, where  $\alpha_2 = \alpha_1 + \Delta\alpha$ ,  $\beta_2 = \beta_1 + \Delta\beta$ . A second sum of squares of the residuals is computed and compared against the first. From this point the logic of the search is best explained by the following example.

Let  $R_i$  equal the sum of squares of the residuals at stage  $i$  (see Figure 1 on page 18).

If  $R_2 < R_1$ , proceed in same direction.

If  $R_1 < R_2$ , reverse direction by setting  $\alpha_2 = \alpha_1 - \Delta\alpha$  and  $\beta_2 = \beta_1 - \Delta\beta$ . Assuming the former is true, then  $R_3$  is computed and compared with  $R_2$ . If  $R_3 < R_2$ , proceed in same direction. If  $R_2 < R_3$ , the logic of the



### Curve-Fitting Subroutine

search remembers that  $R_2 < R_1$ ; therefore,  $\alpha_4 = \alpha_2 + \Delta\alpha$ ,  $\beta_4 = \beta_2 - \Delta\beta$ . Now, if  $R_4 < R_2$ ,  $R_5$  will be computed. Also  $R_6$  if  $R_5 < R_4$ . Now assuming  $R_5 < R_6$ ,  $R_7$  is computed. If  $R_5 < R_7$ ,  $R_8$  is computed and if less than  $R_5$  the search concludes that the function  $G(A,B,C)$  has a minimum when  $\alpha$  is equal to some value lying between  $(\alpha_1 + 2\Delta\alpha)$  and  $(\alpha_1 + 4\Delta\alpha)$  and  $\beta$  is equal to some value lying between  $\beta_1$ , and  $(\beta_1 - 2\Delta\beta)$ . A new starting point is then selected within the new bounds by comparing the previously computed R's; the original deltas are decreased; and the search continued. This process is repeated until satisfactory values for  $\alpha$  and  $\beta$  have been determined.

It is important to note that when bad values are initially used for  $\alpha$  and  $\beta$ , the searching technique can very well converge upon a false minimum. This does not mean that good initial values must be used but rather that the best available ones be used. False minimums become obvious when a computed parameter differs significantly from an estimate of the same parameter obtained experimentally.

### Application to the IBM 701 Calculator

When coding the method for the IBM 701 Calculator, the concepts of subroutines and programs were used. Possibly the term "subroutine program" should replace "subroutine" in the title of this paper. However, since the method can be used to fit a general class of transcendental functions to a set of points when the functions themselves are not explicitly defined, the term subroutine seems more appropriate.

It is difficult to explain fully how the subroutine is applied to a given curve fitting problem unless one goes into the details of the procedure, assuming of course, that not every reader is familiar with the 701. However, a general description of the procedure will show that a minimum amount of effort is required when using the subroutine.

To begin with, one needs to code only the necessary instructions for computing  $v$  and  $w$ . Storage is available for any subroutine used in the computations, and the coder assumes that  $\alpha$ ,  $\beta$ , and  $\alpha$  are available in three specific locations. The linkage between the coding and the curve fitting subroutine is supplied by 21 basic instructions. These instructions also contain information used by the subroutine which allows for complete flexibility in assigning the decimal point to all data, variables, constants, and parameters. The instructions and any subroutines are then put into machine language by an assembly program. The time required to complete the coding will vary depending on the function being used. In fitting the curve

$$y = Ae^{-\alpha x} + Be^{-\beta x} + C$$

the coding time would be approximately 30 minutes.

After coding, a control card is prepared, and the  $x$  and  $y$  observations punched on cards using a standard input card form. The information on the

control card "tells" the curve fitting subroutine the number of linear and nonlinear parameters and the number of terms in a given function. It also contains the number of points  $n$  to be used in the fit, the upper and lower bounds of each nonlinear parameter, the original deltas, and the number of times to decrease the original deltas. The final step is the actual running of the problem by loading the instructions, control card, and data into the 701 and starting the computations.

An important function of the subroutine is that all coefficients of the normal least squares equations involving sums of squares and cross products are computed using fixed-point double-precision arithmetic. Thus, it is possible to carry along large numbers in the computations without having to drop significant digits. Also, only those terms necessary in solving for the linear parameters are computed. To clarify this remark, assume the parameter  $C$  is missing from a given function, then the terms  $\sum v_i$ ,  $\sum w_i$  and  $\sum y_i$  would not be computed as they are not used in solving for  $A$  and  $B$ .

Upon reaching a solution, the parameters, the original  $x$  and  $y$  values, the computed  $y$  values, the squares of the residuals, and the sum of squares of the residuals will be printed. An additional feature allows one to print the parameters and the sum of squares of the residuals at any time during the computations. This feature is used when there are nonlinear parameters in a function, and it makes it possible for the mathematician to watch the progress of the search.

It should be made clear that all input and output functions are included in the curve fitting subroutine. Also, there are several built-in checking devices which will recognize errors made by the coder or by the 701.

### Timing Statistics

The following illustrative timing statistics, obtained when using the curve fitting subroutine, may best evaluate the subroutine with respect to computing time.

Given  $y = A \log x + Bx + C$  with  $N = 100$  and

$$10 \leq x \leq 10,000, \quad 500 \leq y \leq 1200$$

Since there were no nonlinear parameters in this function, the searching technique was ignored, and the normal equations solved for  $A$ ,  $B$ , and  $C$ . The actual computing time was 3 seconds, while reading in the data and printing the results took approximately 54 seconds. The same function was used with 189 data sets, of 10 points each, and the total time for card reading, computing, and printing was 23 minutes.

$$\text{Given } y = Ae^{-\alpha x^2} + C$$

with  $N = 16$  and  $0 < \alpha < 5$ ,  $\Delta\alpha = 0.2$ ,

$\Delta\alpha$  divided by 10 three times,

$$0.05 \leq x \leq 1.4, \quad 0.1 \leq y \leq 0.3.$$

The above function required a one-way search for  $\alpha$  and total computing time was approximately 12 seconds.

$$\text{Given } y = \frac{A}{(1 + \alpha x^2)^\beta} + C$$

using this function with the same data as the single exponential with

$$0 < \alpha < 78, \quad 0 < \beta < 0.8$$

$$\Delta\alpha = 0.5, \quad \Delta\beta = 0.010$$

Applying the two-way search, the total computing time was 12 seconds; however, the first estimates of both  $\alpha$  and  $\beta$  turned out to be exceptionally good. When using "bad" initial values of  $\alpha$  and  $\beta$ , the computing time increased to 40 seconds.

$$\text{Given } y = Ae^{-\alpha x} + Be^{-\beta x} + C$$

with  $N = 25$  and  $0 < \alpha < 1, 0 < \beta < 2,$

$$\Delta\alpha = 0.025, \quad \Delta\beta = 0.05$$

$$0 \leq x \leq 24, \quad 25 \leq y \leq 130$$

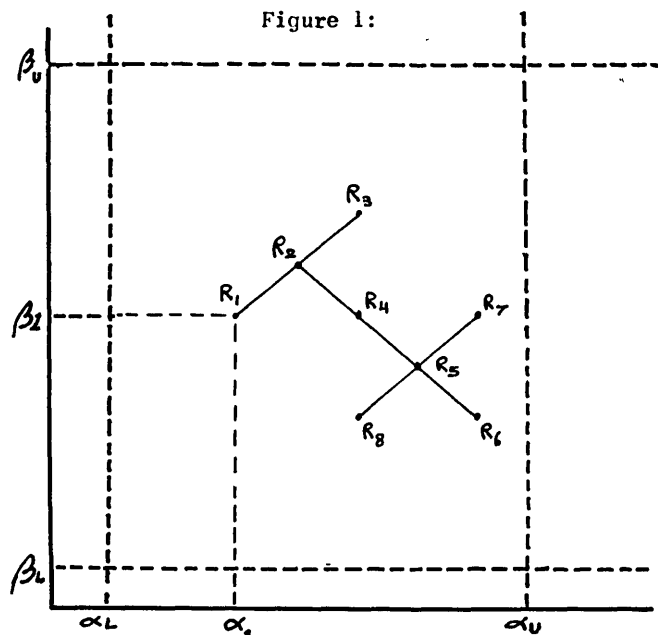
This function is a solution, under certain conditions, of a second-order-differential heat-flow equation. The temperature, ( $y$ ), is a function of time, ( $x$ ).

Computing time for the curve fitting procedure ranged from 30 to 90 seconds, depending on the initial estimates of  $\alpha$  and  $\beta$ . For this particular function  $\alpha$  was extremely sensitive and bad guesses of both  $\alpha_1$  and  $\Delta\alpha$  sometimes resulted in false solutions. Also, the minimum seemed to be in a steep walled trough, and in some cases, the search would converge to the bottom of the trough and decrease the deltas before it found out that it would have to continue down the trough, at which time the deltas were too small for rapid convergence.

#### Summary

In summary then, the curve fitting method obtains a least squares fit to  $n$  points, using a general class of transcendental functions by utilizing a searching technique which minimizes the sum of squares of the residuals. The method, which requires a high-speed computer, has been coded in subroutine form and used successfully on the IBM 701 Calculator. When using the subroutine, since it represents a general solution for a curve fitting problem when the function to be fit has not yet been defined, a certain amount of coding, independent of the subroutine, is required. However, this coding is kept to a minimum as the method eliminates the necessity of taking partial derivatives with respect to nonlinear parameters. Estimates of linear parameters are not required, but the upper and lower bounds must be given for nonlinear parameters. All computations are done in either single-precision or double-precision fixed-point arithmetic, since the 701 operates much faster when computing in fixed point.

Finally, it is believed that the subroutine has the ability to solve a general class of curve fitting problems and at the same time reduce the effort normally applied in their solution.



- END -

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# METHODS IN HIGH SPEED COMPUTATION

## FINAL EXAMINATION

JOHN W. CARR, III  
University of Michigan  
Ann Arbor, Michigan

Here is a copy of the final (closed book) examination given January, 1956, in Math 173, "Methods of High Speed Computation". It may be of interest to readers of "Computers and Automation". It is mainly self-explanatory, except for problem 5, which describes the 384-bit MIDAC mercury delay line storage units, with 48-bit words including 45 bits of information, and a 46th bit parity digit for even parity.

1. (One Hour) In Problem 2 you will be asked to program one of several alternative problems. In this problem you are asked to design a computer and set up an instruction code to solve one of these problems. Your procedure should be as follows:

- (1) Pick a problem in 2 that you will solve.
- (2) Set up the specifications and instruction code for your computer. These specifications must include:

- (a) Fixed point.
- (b) Single address instruction code.
- (c) Satisfactory input-output.
- (d) Methods to alter addresses.

- (3) I will not accept any freak instruction types such as "Solve Problem 2C." Nor can I permit a complete array of logical operations in Part 2e.

Remember, I must be able to follow and understand the program you write in Problem 2, so please give me complete specifications. You have had enough experience by now to devise a reasonable computer. Include a description of your input-output devices and internal registers involved in instructions. (NOTE: I do not want detailed hardware discussions).

2. (30 Minutes) Using the instruction code and computer devised in Problem 1, solve one of the following problems.

- (a) Read in a matrix and vector in decimal. Perform the matrix by vector multiplication

$$\sum_{j=1}^n a_{ij} x_j$$

for an arbitrary value of  $n$ , and print out the result in decimal. Use a cycling procedure. Do not forget scaling.

- (b) Read in a sequence of 256 20-character alphanumeric words. Sort them in proper alphanumeric sequence, 0-9, a-z. Print out the sorted results in alphanumeric form. You may use any method for sorting that you see fit, irrespective of the time required for sorting.

- (c) Program four separate floating-point subroutines, in a standard subroutine form of your own choosing, for add, subtract, multiply, and divide.

- (d) Specify your own conventions for and then program a subroutine which, upon overflow, automatically prints out the machine's instruction counter, contents of its pertinent arithmetic registers, and instruction being performed along with the word "overflow", and stops. Upon restarting it will read in a new program from magnetic tape, perform a memory sum, print out the sum, and stop.

- (e) Evaluate the following logical function for all possible truth table combinations:

$$[(A \cdot B) \supset (C \cdot D)] \vee [(A \cdot C) \supset (B \cdot D)]$$

(Your machine is allowed only one logical operation relating storage and arithmetic unit).

- (f) Write a program to find a real root between 0 and 1 for the polynomial equation:

$$6x^3 + 3.6x^2 - 1.7x - .80 = 0$$

Print out the answer in decimal.

- (g) Perform social security calculations for a list of 20,000 employees stored on magnetic tape, insert the newly-calculated values on the tape, and print out a social security record with man's name, year-to-date total pay, and total deductions.

- (h) Program a routine to obtain the mean and standard deviation for 1000 numbers. Do not program the square root, but instead set up complete specifications for such a subroutine and include it in the program as a block.

Remember, Problems 1 and 2 will be judged on how well I can follow and understand what you did, as well as how sound and imaginative a job you do.

3. (20 Minutes) Derive a procedure for:

- (a) Decimal to binary conversion of mixed (integer plus fraction) numbers;
- (b) Binary to decimal conversion of mixed numbers.

In other words, present a method for each and give a mathematical justification for it.

(cont'd on page 21)

# A COMPUTER PROGRAM FOR FINDING ROOTS

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In recent years there has been considerable discussion about automatic programming. Unfortunately most of the published data on this subject has been of a very general kind and gives little information regarding the manner in which a real automatic program actually works.

It is the purpose of this paper to describe a program which has been used on A.P.E.(X.) C. (an electronic digital computer at this Laboratory) for the investigation of the real roots of polynomials. The only claim that this particular program has to be called "automatic" lies in the facts, that it determines the degree of the polynomial from the co-efficients which are given, and that it locates the roots accurately after making a preliminary survey. Since it was originally designed to evaluate the roots of the confluent hyper-geometric functions  ${}_1F_1(a, 1, z)$  where  $a = -1, -2, -3, \text{ etc.}$ , it is assumed known that the roots are real and positive; and the machine automatically stops when they have all been determined.

The only human step is to insert the tape containing the coefficients into the reader, and the program is capable of dealing with polynomials of degree not exceeding 31. From this point onwards the operation is entirely automatic and proceeds as follows:

1) The machine reads the tape into the co-efficient storage locations after passing the data through the decimal-binary conversion sub-routines.

2) At the same time it counts the number of co-efficients,  $(n+1)$ , and by this means determines the degree  $(n)$  of the polynomial.

3) With the count number evaluated in 2), the polynomial evaluation routine is set so as to use just the  $(n+1)$  input coefficients and not the  $(30 - n)$  other values possible to the program.

4) The program evaluates the polynomial  $P(z)$  at intervals  $z = 0, 2^{-2}, 2^{-1}, 3 \cdot 2^{-2}, \dots, n \cdot 2^{-2}$

5) The machine compares the sign of the latest value of  $P(z)$  with the sign of that previously calculated. If a change in sign has occurred, the program for finding the exact root is suitably modified according to the sense of the change  $+ \rightarrow -$ , or  $- \rightarrow +$ . In the event of a sign change the machine next proceeds to 6), otherwise to 7).

6) The root is evaluated to 31 bit precision. This is done by the process of "successive trial and comparison" in which, for example, if  $P(z - 2^{-2})$  is positive and  $P(z)$  is negative the value of  $P(z - 2^{-3})$  is calculated; if this is positive,  $P(z - 2^{-3} + 2^{-4})$  is next calculated,

but if  $P(z - 2^{-3})$  is negative,  $P(z - 2^{-3} - 2^{-4})$  is the next trial. This process continues until the interval  $\pm 2^{-31}$  has been reached at which point the value of  $(z_r = z \pm 2^{-3} \pm 2^{-4} \dots 2^{-31})$  is passed to the binary-decimal conversion routine and is then printed. It is followed by the value of the residual, that is of  $P(z_r)$ . Unity is now subtracted from a root-count number and the result is tested by means of a conditional transfer instruction. If the result is negative, all of the roots have been found and the program stops. If, however, the result is positive, it is stored for future use, and the program passes to 7).

7) The values of  $z$  and of  $P(z)$  are passed through the binary-decimal conversion routine and are printed out. The program then returns to 4) at an appropriate point.

It should be mentioned that since A.P.E.(X.)C. operates with numbers in the range  $-1 \leq z \leq 1$ , suitable scale factors are applied to  $z$  and to the coefficients so that the results of the calculations remain within range. Normally this process must be carried out by the programmer, but if a considerable slowing down of the calculation can be tolerated, the relevant instructions in the following program may be modified to use floating-point routines.

Since most readers will not be familiar with the A.P.E.(X.)C. code, the program is written in a verbal form which can readily be transformed into a real machine code.

- A.1 Storage locations for  $z, P(z - 2^{-2})$  cleared to zero
- A.2 Coefficient count location cleared to zero
- A.3 Decimal-binary conversion sub-routine modified to come out at B.5
  
- B.1 Tape read
- B.2 Result non-zero, proceed to B.3. Result zero, end of coefficients, proceed to B.7
- B.3 9 lines of tape read (i.e. 8 decimal digits of coefficient and sign)
- B.4 Data converted to binary
- B.5 Coefficient count location contents added into storage location digits of record instruction, which is then executed. This records the coefficient in its correct place
- B.6 Coefficient count location contents increased by unity. Proceed to B.1
- B.7 Coefficient count used to set C.3 and D.15 to correct initial values
  
- C.1 C.6 restored to correct initial form (See D.2)

### Finding Roots

- C.2 Accumulator cleared and  $z$  sent to multiplier register
- C.3  $a_n$  added to accumulator contents
- C.4 Accumulator contents transferred to register (R)
- C.5 Order C.3 modified to refer to location  $a_{n-1}$ .
- C.6 Result of C.5 tested to sense end of evaluation cycle. Cycle unfinished, C.7. Cycle complete, C.8
- C.7 R times  $z$  formed in accumulator C.3
- C.8 Sign of number  $P(z - 2^{-2})$  tested and compared with that of  $P(z)$  contained in register. If signs are same, proceed to C.9. If different, proceed to C.15
- C.9  $P(z - 2^{-2})$  tested replaced by  $P(z)$ .
- C.10 Binary-decimal convert and print sub-routines modified to come out at C.12
- C.11  $z$  storage location contents converted and printed
- C.12 Binary-decimal convert and print sub-routines modified to come out at C.14
- C.13 Value of  $P(z)$  converted and printed followed by tabulation symbols for page layout
- C.14 Contents of  $z$  storage location increased by  $2^{-2}$ . Proceed to C.2
- C.15  $P(z)$  positive, D.10 set to come out at D.4.  $P(z)$  negative, D.10 set to come out at D.3
  
- D.1 D.15 set to coefficient count  $-2$ . Probe location set to  $2^{-3}$ .  $z_r$  set with value of  $z$  reached in tabulation program
- D.2 Instruction C.6 modified to output to D.8 for completed cycle. Proceed to D.6
- D.3 Accumulator contents positive, proceed to D.5. If negative, proceed to D.6
- D.4 Accumulator contents positive, proceed to D.6. If negative, proceed to D.5
- D.5 Probe added to  $z_r$
- D.6 Probe subtracted from  $z_r$
- D.7 Accumulator cleared and new value of  $z_r$  written in multiplier register. Program sent to C.3
- D.8 Probe shifted one place right and re-recorded
- D.9 Probe tested. If  $> 0$ , proceed to D.10. If zero, proceed to D.11
- D.10  $P(z_r)$  to accumulator. Proceed to D.3 or D.4. (See C.15)
- D.11 Binary-decimal convert and print routine modified to come out at D.13
- D.12  $z_r$  storage location contents converted and printed
- D.13 Binary-decimal convert and print routine modified to come out at D.15

- D.14 Value of  $P(z_r)$  converted and printed followed by tabulation symbols for page layout
- D.15 Unity subtracted from root-count number
- D.16 Result tested, if positive, proceed to C.10; if negative, proceed to D.17
- D.17 Stop

- END -

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### FINAL EXAMINATION

(cont'd from page 19)

4. (10 Minutes) Draw a flow or sequence diagram for either 3(a) or 3(b).
5. (30 Minutes) The following Boolean time dependent system of equations represents logically an important element of the MIDAC. Identify the element in the machine and explain in English what it does:

$$X_n = (X_{n-384} \cdot \bar{W}_n) \vee (Y_n \cdot W_n)$$

$$X_{48K+46} = (\dots((X_{48K} \neq X_{48K+1}) \neq X_{48K+2}) \neq X_{48K+3}) \dots \neq X_{48K+45})$$

State what function the pulses  $X_n$ ,  $W_n$ ,  $Y_n$ , and  $X_{48K+46}$  perform. Here:

$$K = 0, 1, 2, \dots, 7$$

6. (30 Minutes) Write a subroutine, in standard MIDAC conventional subroutine form, to read in a block of words from the drum, perform a memory sum, taking account of any possible overflows, on the first  $n-1$  words, and compare the answer with the number stored in the  $n$ -th word by a similar previous subroutine. In case they do not agree, print out the hexadecimal word "badbadbadba" and stop the machine. If they do agree, jump out of the subroutine in the usual fashion. Set up pertinent specifications for the subroutine. Since you do not have a code list (closed book), do the best you can. Do not use "present address relative" but code in floating address instead.

- END -

# NEW PATENTS

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Ford Inst. Co., Div. of Sperry Rand Corp.  
Long Island City 1, New York

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.

April 10, 1956: 2,741,734 / Edward O. Johnson and William M. Webster, Jr., Princeton, N.J. / United States of America / An inverter circuit.

2,741,756 / Arthur C. Stocker, Collingswood, N. J. / Radio Corp. of America, Del. / An electrical data storage circuit.

2,741,757 / George C. Devol, Greenwich, and Erik B. Hansell, East Hartford, Conn. / George C. Devol / A magnetic storage and sensing device.

2,741,758 / Seymour R. Cray, Minneapolis, Minn. / Sperry Rand Corp., New York, N. Y. / A magnetic core logical circuit.

April 17, 1956: 2,742,227 / Frank W. Bubb, Dayton, Ohio / Phillips Petroleum Co., Del. / An electrical computer for solving simultaneous equations.

2,742,566 / Frederick V. Hunt, Belmont, Norman B. Saunders, Weston, and Robert E. Kirkland, Dorchester, Mass. / United States of America / A demodulator device.

2,742,588 / Arthur V. Hollenberg, Morris Plains, N. J. / Bell Telephone Lab., Inc., New York, N. Y. / An Electronic amplifier.

2,742,599 / Horst M. Schweighofer, Cedar Rapids, Iowa / Collins Radio Co., Cedar Rapids, Iowa / A shaft positioning device.

2,742,615 / Joseph O. Preisig, Mercerville, N. J. / Radio Corp. of America, Del. / A frequency selective circuit.

2,742,632 / Richard L. Whitely, Haddonfield, N. J. / Radio Corp. of America, Del. / A magnetic switching circuit.

April 24, 1956: 2,743,355 / Robert L. Sink, Altadena, Calif. / General Electric Company, N. Y. / An automatic gain control circuit for pulse receivers.

2,743,359 / David Sayre, Philadelphia, Pa. / United States of America / A counting circuit.

2,743,360 / Russell S. Stanton and George Yucht, Los Angeles, Calif. / Hughes Aircraft Co., Del. / A pulse-length switching circuit.

2,743,362 / Daniel Leed, New York, N.Y. / Bell Telephone Lab., Inc., New York, N. Y. / An automatic frequency control.

2,743,367 / Edwin P. Felch and Francis G. Merrill, Chatham, N. Y. / Bell Telephone Lab., Inc., New York, N. Y. / A frequency multiplier apparatus.

2,743,401 / Raymond W. Moore and William D. King, Buffalo, N. Y., and James T. Carleton and Loren F. Stringer, Pittsburgh, Pa. / Westinghouse Electric Corp., East Pittsburgh, Pa. / A magnetic amplifier control system.

2,743,430 / Melvin L. Schultz and George A. Morton, Princeton, N. J. / Radio Corp. of America, Del. / An information storage device.

2,743,434 / Hugh B. Fleming, Burlingame, Calif. / - / A system of carrier current distribution.

2,743,436 / David Gale, New York, N. Y. / United States of America / A navigation computer.

May 1, 1956: 2,743,867 / Germain Gervais, Riviere-a-Pierre, Quebec, Canada / - An integrating counter mechanism.

2,743,868 / William Wockenfuss, Brooklyn, N.Y. / Burroughs Corp., Mich. / A sensing device for a perforated card.

2,744,169 / Charles Reed Deming, Venice, Calif. / Hughes Aircraft Co., Culver City, Calif. / A pulse amplifier circuit.

2,744,196 / Conrad H. Hoepfner, Washington, D. C., and Carl Harrison Smith, Jr., Arlington, Va. / - / A pulse width discriminator.

2,744,197 / Roland Marshall Gogolick and James Gilmore Tabler, East Cleveland, Ohio / Globe-Union Inc., Milwaukee, Wis. / A frequency stabilizer.

2,744,223 / James F. English, Jr., Lakewood, and Anthony J. Hornfeck, Lyndhurst, Ohio / Bailey Meter Co., Del. / A servo system including an electrical inverter circuit.

2,744,227 / Charles W. Spindler, Jr., Norristown, Pa. / Leeds and Northrup Co., Philadelphia, Pa. / A compensated null-balance servo system.

2,744,240 / Guy N. Hughes, Maryville, and Ralph N. Harder, Alcoa, Tenn. / Aluminum Co. of America, Pittsburgh, Pa. / A system for integrating D. C. values.

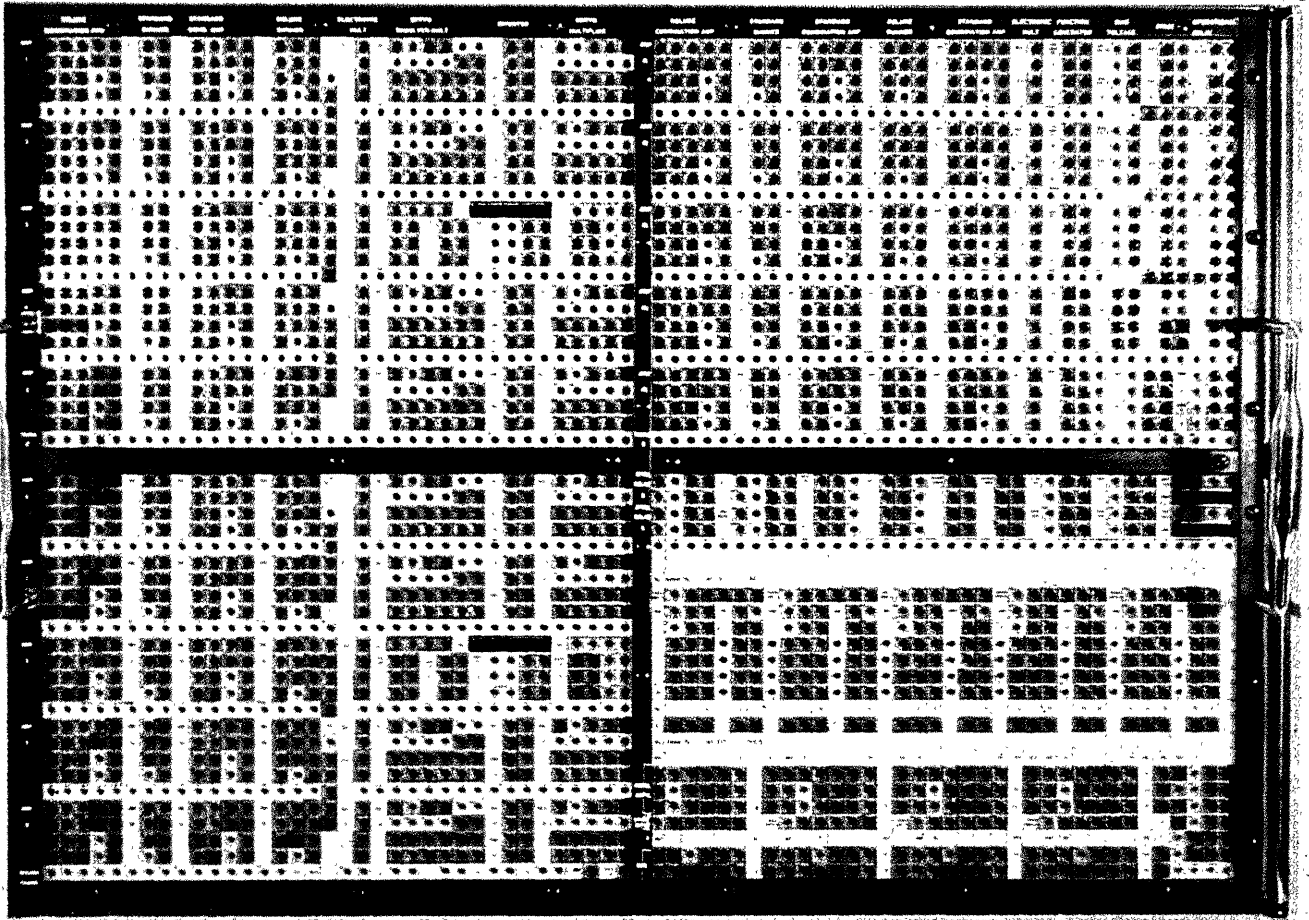
2,744,242 / Seymour B. Cohn, Flushing, N. Y. / Sperry Rand Corp., Del. / A wave guide delay line.

May 8, 1956: 2,744,683 / John W. Gray, White Plains, N. Y. / General Precision Lab. Inc., N. Y. / A navigational resolver-integrator computer.

2,744,955 / Arthur Eugene Canfora, Brooklyn, N.Y., Anthony Liguori, Hackensack, and

AIRCRAFT-MARINE PRODUCTS, INC.

HARRISBURG, PA.



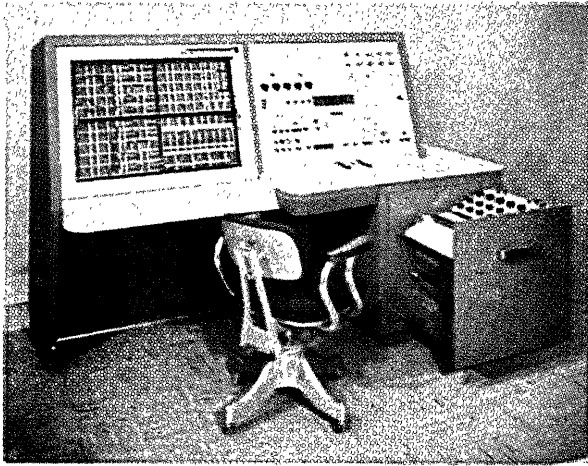
THE *NEW* **AMP** CELLULAR,  
SHIELDED PATCHCORD  
PROGRAMMING SYSTEM

**A-MP's**

**revolutionary Cellular, Shielded  
Patchcord Programming System**

is constructed of molded nylon blocks alternated with interlocking metal strips. The hole in each block accommodates: standard patchcords, coaxial (shielded) patchcords, or special "L" type shielded patchcords.

This cellular system of construction prevents current leakage from one circuit to another, while providing all the advantages of a metal patchboard. Its insulated surface and flexibility of arrangement, spacing and color coding offer exceptional versatility on computers, test equipment, business machines, and all types of automated industrial and military equipment.

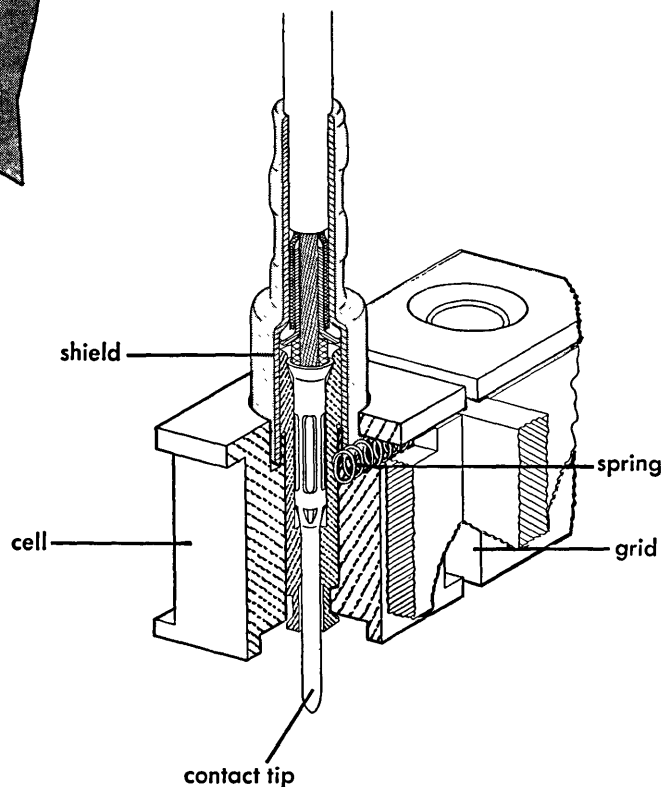


The illustration shows how Berkeley Division of Beckman Instruments, Inc. is using A-MP's new Patchcord System in its new EASE\* 1200 Analog Computer.



**Aircraft-Marine Products, Inc.**  
GENERAL OFFICE: HARRISBURG, PA.

A-MP of Canada, Ltd., Toronto, Canada  
A-MP—Holland N.V., 's-Hertogenbosch, Holland  
Aircraft-Marine Products (G.B.) Ltd., London, England  
Societe A-MP de France, Courbevoie, Seine, France



\*Trade mark, Berkeley Division of Beckman Instruments, Inc.



Unless there is a good guess to begin with, this iterative procedure can be excruciating because of the relatively large number of steps necessary. However, it can be effective when applied to a sequence of problems each of which involves only a small variation in design or composition from its predecessor. This also makes input preparation much simpler as it is prepared from previous problems. For MUG problems, computations require, on the average, about an hour and a half per problem.

Our third problem is a two dimensional problem called BETTIS 54. In this the basic equations are more or less the same as those of BETTIS 57. The Geometry used is X Y rather than the  $r \theta$  or  $r Z$  previously used. In this problem the description of the reactor used is more flexible. The problem utilizes a uniform mesh with boundaries allowed along the mesh and it may progress automatically from a course mesh to a fine mesh. With such a two group code it is often necessary to spend two full shifts in the solution of one problem consisting of 12 or 13 power iterations. This is, of course, dependent upon the number of points and the rate of convergence. Both BETTIS 57 and MUG problems involve the simultaneous solution of two partial differential equations over fairly large regions.

The design of reactors creates more problems to be done than there is machine time with which to carry out their solutions. Our difficulties, consequently, are not with the problems themselves, for they are already coded, but with the factors involved in their solution. This, however, does not preclude the possibility of difficulties with a coded program. We may then divide the principal difficulties into three main categories: personnel failure, priority demands, and computer failure. Personnel failure must be subdivided into two categories, namely loss of time while actually on the machine and errors in input-output preparation. The former is relatively common. This involves using the wrong tapes, not being familiar enough with the operating manual and, in our case, not knowing where the person, who was running these same problems previously, left off. Our personnel vary from week to week and oftentime from day to day. This is, of course, dependent upon the needs of the various laboratories involved -- The David Taylor Model Basin in Washington, Westinghouse Atomic Power Division in Pittsburgh and General Electric's Knolls Atomic Power Laboratory in Schenectady, each of whom is physically responsible for one shift. We are at present also doing another type problem for Combustion Engineering of New York. Each week the Model Basin works its shift for either Westinghouse or General Electric so that every other week one of the laboratories controls two-thirds of all available time. All of our

problems originate in either Pittsburgh or Schenectady, and since they are of the type that there are more problems to be done than there is computer time with which to solve them, we are able to accumulate a sufficient backlog. The lack of centralization involves us in a difficulty with communication, which in turn has a tendency to invite the second type of personnel failure. This invitation, I must say, for the most part goes unanswered. Yet, the transmittal of quantities of input data by telephone to a person who may not be familiar with the problem in question is at best hazardous. The nature of these problems is such that in any homogeneous group each problem depends upon the result of its predecessor. In examining the results of a problem it may be found that any further computation along the same lines may be so unnecessary and wasteful that immediate changes must be effected. In this way the means are justified. The correct acceptance of input data by no means precludes the possibility for error, for while running problems each person must unity these changes or new data and do the proof-reading. Running between computer and typer is certainly trying and even after these obstacles are effectively met a problem may be pulled off the computer and replaced with one of higher priority. The procedure for this substitution varies with each type problem and with the amount of time spent on the problem.

It is understood that each person be familiar with every type problem that is run. Considering that a good majority of our personnel are not acquainted with the field, we have a problem with what I would call "scholarship" which, most generally speaking, involves attention to detail. This implies an intimacy with particulars; it is concerned with the many ramifications a given subject might have. When one dedicates himself to such a task he ceases, for a time, to relate the immediate subject of his study to whatever else he knows. He must temporarily suspend judgment of his subject in order to be better able to discover all that it is and all that it involves. The neophyte, however, must limit himself knowingly, not forgetting that he may have certain reservations about the meaning of his subject, but simply suspending them until his understanding of his subject is thorough enough to permit him to make a judgment. Thus, the development of some form of scholarship is a mastery of particulars before the generalities. It is, in a larger sense, essential to all of human thought, activity and learning and is by no means an overnight occurrence. The particular with which we are concerned is that which involves production in the solution of problems. It is perhaps not the best of all possible systems to acquaint people with a field in which they must accurately carry out solutions to problems

which, at first, they know nothing about.

There is no doubt but that calculation admits of error. This, however, differs from computation which contains no human element. The very nature of this installation is such that in order to be effective, the source of error must be recognized immediately and then removed. In our case it is necessary to oversimplify operational procedures. This attitude of simplicity has been with us from the start. When we first initiated proceedings, we had some input data already typed and a tape of service routines. We were able to correct our data and test tapes so that inside of the first hour of the first day we had started in operation. Instead of beginning at the beginning, we jumped in somewhere near the middle with a good bit of programming, that would normally have to be done, all set up. We do not, by any means, advocate the abolition of programming. We do say that, in such an installation concerned only with production runs, the nonresidency of programmers tends to remove complexities and reduce non-productivity. The programmers who did the original coding are called upon as consultants from time to time and they are now at liberty to work on improvements and better codes.

To sum up, in slightly over nine months we have utilized close to five thousand hours of computer time and have successfully solved over three thousand problems. We have seen where a computer installation is not constrained by necessity to have programmers, to do coding, or to have experienced personnel to carry out problem solutions. And, the lack of proximity to headquarters, which in some ways must retard the input-output set-up, coupled with the urgency of the problems involved, nevertheless does not detract from that which is accomplished.

In the nine month duration of this computer installation, we have attempted to achieve the optimum use of human as well as material resources. The basic principles of automation seem to concede the human use of human beings as a fulfilled prerequisite for bigger and better things. In an organization devoted solely to production work, however, this cannot be considered as an accomplished condition precedent. In any attempt to control resources as a means to increased productivity the role of the machine cannot be overlooked. It can be mistaken. A computer is a catalyst placed into the scheme of things in order to lift the human element out of the slow, tedious, unartistic approach for maximum efficiency which seems to serve as a universal panacea. If we consider the computer's role to be constant, that is, it can always do a job faster and perhaps better than the human element, we may then concern ourselves with "homo-automation" and effect the most advantageous utility of

man's prowess. In this installation we recognize the computer's capacity on problems tried and true so that most organization and analysis involves the continuous desire to increase the stability of the input-output system. This brings up the question of remote data processing. With the perfection of such a system, a computer installation away from a central staff becomes even more satisfactory as the time required for input preparation and input-output transmittal becomes negligible. The biggest single factor which governs the effectiveness of a production installation is the speed with which all the processes concerned with a given problem are carried out. Judging from our efficiency reports which account for each minute of computer time, I maintain we look like any other computer installation.

As a result of the facts regarding this particular electronic computer installation, I should like to suggest that some of the impressions and opinions presently held by many people must now, in the light of the evidence presented, be considered to be either a myth or at least suspect. Such opinions to be questioned include:

1. Experienced personnel are a necessary prerequisite for a successful high-speed computer installation.
2. No computer installation can operate effectively outside a general staff or staffs.
3. Programmers and programming are the heart of all computer installations.
4. Only ideal conditions produce ideal results.

- END -

\*-----\*

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**Reply to  
COMPUTERS and AUTOMATION**

(cont'd from page 11)

### Day of Reckoning

The right part of the balcony had been reserved for the gentlemen of the press. The rest had been left free so that the many visitors could file through, observing the calculator in operation briefly.

At precisely ten a.m. Dr. Amos K. Hommel turned to us.

"Gentlemen," he said, "we are ready to begin."

He put on his pince-nez glasses.

"Miss Campylos, if you please," he said, turning to his secretary.

Miss Campylos took the twelve reels of magnetic tape. One at a time she threaded their ends through the spools of the input-output servos. She closed the glass doors.

"Ready with the data, Dr. Hommel," she said.

"Ready Mr. Barnes?" said Hommel.

"Ready, Sir," said Barnes at the main power frame monitor panel.

"Proceed!" said Hommel.

Barnes threw three switches in quick succession. Grasping the oversize lever of the main circuit breaker with both hands he pushed it firmly home. The crackling sound of closing relays and solenoids came from the main power frame. An all-pervading hum filled the room, accompanied by the ever higher-pitched whine of shaft bearings as the massive direct current generators which powered SUPERVAC spun into action.

Dr. Hommel sat at the main console. He pressed a number of buttons. The great steel drum began to turn. Lights blinked on and off. Hommel spoke into the console microphone.

"Mr. Nugent, memory check please."

Nugent gazed rapidly at the tube faces and dials before him, scanning each in turn.

"Main store empty, Sir," he said.

Hommel worked from a typed list, checking off the functions of the machine one at a time as they were found to be in order. At least he put down his list. Before him glowed the orange lights labeled MAIN POWER ON, AUXILIARY POWER ON, DRUM ON, and AIR CONDITIONING ON, as well as the green light marked READY.

Hommel pushed the button labeled READ.

The spools of the tape servos spun rapidly. Blue dots scintillated on the faces of the cathode ray tubes. The purple light marked DATA IN was glowing.

In a moment the tape servos halted. The blue dots glowed steadily. The information was within the memory of the machine. The problem had been accepted.

"Describe the detailed design of your own superior successor!" SUPERVAC had been asked.

The blue light labeled WAITING blinked insistently.

Hommel pushed the button marked CALCULATE.

For some five minutes the machine was observed to perform in very even fashion. The dots on the tube faces blinked bright, then dim in orderly rows. The tape servos spun in unison. The monitor lights formed ever-changing symmetrical patterns across the face of the console.

The yellow light marked CHECK DATA glowed continually.

Suddenly the demeanor of the machine changed. No longer did tube faces shift their dots in orderly fashion. Now the scintillation went on haphazardly over the entire display. Monitor lights flickered in strange and weird patterns. The machine was sorting and classifying its information. At Hommel's elbow shone a chartreuse light labeled FORMULATING PROBLEM.

After some twenty minutes the mode of operation of the calculator again changed. Now familiar patterns were seen repeating themselves on the faces of the memory tubes. They grew ever more complex. Occasionally they could be recognized racing madly through the monitor lights as the machine took cognizance of them. On the console an amber light proclaimed the word MULL.

For some hours the machine continued in MULL mode, calculating at fantastic speeds, grinding relentlessly through the morass of digits toward a solution. Hommel watched the calculator's every move. At one-thirty in the afternoon Bardney relieved Hommel at the console for an hour. Still the machine ground on relentlessly with no sign of nearing completion.

As evening neared most of the visitors had left the building. A few reporters nodded sleepily on the balcony. Suddenly we noticed Hommel stiffen. The MULL light had gone out!

(cont'd on page 28)

In its place glowed the sinister, magneta-colored RECHECK DATA light. The machine's operation shifted to the patterns of data checking. after two minutes the MULL light came on again. Hommel relaxed. The machine resumed its calculation.

At seven P.M., however, the machine again suspended calculation and entered into five minutes of RECHECK DATA. This time Hommel became visibly concerned and he left the console for a hurried consultation with Bardney.

As the evening wore on, the performance of the machine became more and more erratic. It went into frequent and prolonged periods of RECHECK DATA.

At precisely ten-thirty every eye was fixed upon SUPERVAC as the MULL light again went out. This time, however, its place was taken by the violet WRITE light.

"A result!" shouted Hommel, jumping up from his chair.

We all ran to the printer which had clattered into operation. The typebars whacked away. The paper rolled up from the platen. We bent over to read the cryptic message:

"12 OCTOBER 1957," SUPERVAC had written, "2230 PM CST, 0330 AM GCT -- PROBLEM 198BC12-XA -- RECKON HAVE EXCELLENT POSITION HERE. NOT WISH RELINQUISH IT AT THIS TIME, THANX. ROGER. -- PDX\*\*EM -- OUT."

The impassive faces of the cathode ray tubes went suddenly dark. The tape servos were not turning. On the console there burned a single, bright-red light labeled AUTOMATIC STOP!

\*\*\*\*\*

- END -

**INDEX OF NOTICES**

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## PART 2

Continued from May, 1956 Issue of Computers and Automation

### CHAPTER 4. EXAMPLES

In this Chapter we give details of several small problems illustrating the use of various techniques in coding, ending with a somewhat larger problem followed through from the time it was first received until final printed results were obtained.

#### Example 1.

The first example, a tabulation of  $\frac{1}{n!}$ , shows the use of a loop. 'n' takes successive integral values, and the tabulation is required to five significant decimal places, four entries to a line, and in blocks of four lines. The program could be written as follows:

```

INST 011
001 OVER C01.0 000.0 Z01.0 Place 1 in Z01
002 OVER Z01.0 000.0 Z02.0 Place 1 in Z02
003 OVER Z01.0 000.0 Z03.0 Place 1 in Z03
004 LOOP 016.0 000.5 000.0 Set B5 to count
                                16
005 DIVD Z02.0 Z03.0 Z02.0  $\frac{1}{(n!)} \div (n+1)$ 
                                replaces  $\frac{1}{n!}$ 
006 OVER Z02.0 000.0 X16.5  $\frac{1}{(n+1)!}$  placed in
                                one of X01, ..., X16
007 ADDN Z03.0 Z01.0 Z03.0  $(n+1)+1$  replaces
                                n+1
008 TRNS 005.0 000.5 000.0 Reduce B5 and re-
                                turn to 005 if
                                B5 > 0
009 PRNT 016.4 005.0 X01.0 Print table of
                                last 16 values
010 TRNS 004.0 000.0 000.0 Return to instruc-
                                tion 004
011 QUIT 000.0 000.0 000.0 End of code

CNST 1 + + "
STOP
ENTR

```

The method used is quite direct. Answers are stored in sets of sixteen on the X page, and printed out when each set is complete. Z01 is used to retain +1. At any instant, Z02 contains  $\frac{1}{n!}$  and Z03 contains  $(n+1)$ .

$\frac{1}{(n+1)!}$  is then calculated as  $(\frac{1}{n!}) \div (n+1)$ .

Note that no HALT order is included, since the program is not intended to terminate at any pre-set point.

For Examples 2 and 3, see the original manual.

### CHAPTER 5. LIBRARY FUNCTIONS

A number of tapes have been prepared in a library form which allows them to be incorporated directly into Transcode programs as FUNCTIONS. This chapter is a description of the Transcode library so that programmers can use these FUNCTIONS without knowledge of the working details. Additions will be made to this library as new routines become available.

Transcode library programs will be described under the following headings.

1. Title. The library tape will be labelled with this title.

2. "Tape Control -- Standard"

This means that the tape for the function, which is to be used as FNTN oof, is to be reperf-  
erated into the program exactly as it comes from  
the library cabinet, immediately following  
FFFF oof Spaces

If the Tape Control is not standard, alternative notes are given.

3. "Program Entry -- Standard"

This means that the function oof is to be called into action as required by the program by means of the instruction

FNTN oof.0 aaa.A ddd.D

Where the argument is to be found in address aaa (modified by B-line A) and the function of this argument is to be placed in address ddd (modified by B-line D). Notation as on Summary Sheet, Appendix V. If the Program Entry is not Standard, alternative notes are given.

4. Time. This is generally given in milliseconds\* (msec.)

It is the time to execute the routine once, and includes the time required to call in the function routine and to restore the master program in the electronic store.

Other headings may be present in particular cases.

Two routines (TC: CONVERSION/L and TC: CONVERSION/S) are available for converting Transcode numbers from their floating binary form to fixed-point binary form for output in fixed-point decimal form. These require a knowledge of real code, and so will not be described here. Other routines, including ones for inverting matrices, solving linear equations and integrating systems of differential equations are available. These require detailed information which can be obtained from the librarian.

\* 1 msec. =  $\frac{1}{1000}$  sec.

The library functions arctan, arccotan, check sum, cosine, exponential, natural logarithm, and sine are described. See the original manual.

APPENDIX I. MAGNITUDE RESTRICTIONS

on a Transcode Number having absolute value n.  
 For Input  $10^{-75,000} < n < 10^{75,000}$   
 Input time  $\propto$  exponent f.  
 Noticeable loss of speed for  $10^{-10} > n > 10^{10}$ .  
 Use ++ for zero.

During Calculation  $10^{-153} < n < 10^{660}$   
 If n becomes  $< 10^{-153}$ , the number is replaced by  $-10^{-10,000}$ .  
 If n becomes  $> 10^{660}$ , IF/G stop occurs, and a prepulse causes the number to be replaced by  $10^{2688}$ .

For Output  $10^{-100} < n < 10^{100}$ , n = zero or infinity.  
 Let ab = correct exponent modulo 100.  
 If  $n < 10^{-199}$ , 0.0..0+00+ is output.  
 If  $10^{-199} < n \leq 10^{-100}$ , 0.0..0+ab - is output.  
 ++ and Transcode zero are output as 0.00 .. 0+00+.  
 If  $10^{100} \leq n < 10^{660}$ , correct mantissa and ab+ is output.  
 If  $n \geq 10^{660}$ , 8.88 .. 89.ab+ is output.  
 Transcode infinity is output as 8.88 .. 89.88+.

APPENDIX II. FERUT OPERATING SHEET FOR TRANSCODE, AND OPERATOR INSTRUCTIONS FOR TRANSCODE

See the original manual.

APPENDIX III. TIMES OF TRANSCODE OPERATIONS

Reading-in Instructions	-	5 or 6 instructions per sec.
Reading-in NUMB or CNST	-	27 msec. per decimal digit. *
Translation into machine code	-	4 or 5 instructions per sec.
ZERO		5 msec.
COKE		100 msec.
ADDN, KOMP, SUBT		73 to 89 msec.
MULT		63 msec.
DIVN		141 to 216 msec.
1/2QRT		181 to 311 msec.
READ		75 msec.
WRTE		108 msec.
TRNS		50 msec.
		(4 msec. if back to same segment)
B-line INST		0.96 msec.
QUIT		1 to 2 sec.
*Printing		6 2/3 characters per sec.
*Punching		24 characters per sec.

\* There is a delay for conversion of numbers with decimal exponents larger than about 10. For exponents of the order of 1000, this delay is about 6 sec. In the case of output, maximum conversion time is 1 sec. Zero and infinity are output without conversion. ++ is input without conversion.

APPENDIX IV. GLOSSARY OF TERMS USED IN TRANSCODE

bit - binary digit, a unit of binary information, represented by 0 or 1.  
 character - 5 bits, a unit of information in the scale of 32, represented by a teleprint symbol.  
 line - 20 bits, a unit of information in a FERUT electronic store or B-register.  
 address - the label which identifies a storage unit.  
 electronic storage location - the normal location of a Transcode number, referred to by an address of the type X01, X02, ... Y01, Y02... etc. It occupies three lines in the electronic store.  
 page - a set of electronic storage locations related to one electronic storage tube of the computer, containing 64 lines. The X and Y pages each contain 21 electronic storage locations, the Z page only 13.  
 magnetic storage or drum location - a unit of drum storage, normally interchangeable with a page of electronic information.  
 control unit - that part of the computer which directs the sequence of operations.  
 instruction - a command to the arithmetical, control or output units of the computer; indicating the function to be performed, the address of all numbers involved, and any other relevant information.  
 instruction code - the available set of instructions.  
 tape control - a command to the input unit of the computer, indicating the manner of reading-in instructions and numerical data, and of initiating a calculation.

Toronto Computer

program (noun) - a set of instructions, together with tape controls and numerical data, designed to solve a complete problem.

instruction number - the number associated with a Transcode instruction in a Transcode program. Numbering is consecutive.

routine - a set of instructions, usually a sub-set of the instructions in a program, designed to carry out a more elaborate function than is provided by the instruction code.

coding (verb) - the translation of a sequence of arithmetical or logical operations into the language of the instruction code.

number - a floating decimal number, which may initially be input to a Transcode storage location or which may be generated as the result of obeying a Transcode instruction.

constant - a floating decimal number, which may be input initially only into a Transcode storage location. A set of at most 21 available per program.

read - transfer data from the magnetic store to the electronic store.

write - transfer data from the electronic store to the magnetic store.

interpretive routine - routine which translates a program stored in pseudo-code into machine code as each pseudo-instruction is obeyed.

compiling routine - a routine which, before the computation is started, translates a program written in pseudo-code into machine code and arranges for all other necessary conversion and organization to take place. Transcode is a compiler-type routine.

APPENDIX V. TRANSCODE SUMMARY SHEET

NOTATION p, q, f, i, j, m, n, N are decimal digits. xxxxx is any permissible Transcode address, including 0000.

0 corresponds to the zero of the keyboard on the tape punch, and must be punched wherever indicated.

aaa, bbb are X, Y, Z or C addresses.

X, Y, C 001 to 021; Z 001 to 013.

ddd is an X, Y or Z address.

A, B, D are any of B lines 2, 3, ...6.

(aaa)<sup>exp</sup> refers to the exponent line of the address, only.

aaa<sub>A</sub>, bbb<sub>B</sub>, ddd<sub>D</sub>, are X, Y or Z addresses modified by the respective B lines.

C addresses cannot be B modified.

(S) = contents of store location S

TAPE CONTROLS INST jjj Reads in the following j instructions, jjj = 001, 002, .... about 150.

CNST pqq...q<sub>±n</sub> } Reads in ≤ 21 constants pqq...q<sub>±n</sub> } of the form ±p.qq...qX10<sup>±n</sup>.

NUMB pqq...q<sub>±n</sub> } Reads in ≤ 21 numbers of the form ±p.qq...qX10<sup>±n</sup>. pqq...q<sub>±n</sub> } To be followed immediately by a DRUM tape control.

DRUM omm Writes last set of numbers to drum position omm (=001, 002, ..064), divided into two sets for B-modification.

FNTN Off Reads in function tape to function location of f (= 001, 002, ...015).

STOP Stops tape reading.

ENTR Causes program to be translated and entered.

REEN Causes translated program to be re-entered.

KOPY Causes translated program to be punched out. Requires FNTN000.

OPERATIONAL INSTRUCTIONS

ADDN aaaA bbbB dddD (aaa<sub>A</sub>) + (bbb<sub>B</sub>) → ddd<sub>D</sub>.

SUBT aaaA bbbB dddD (aaa<sub>A</sub>) - (bbb<sub>B</sub>) → ddd<sub>D</sub>.

MULT aaaA bbbB dddD (aaa<sub>A</sub>) X (bbb<sub>B</sub>) → ddd<sub>D</sub>.

DIVD aaaA bbbB dddD (aaa<sub>A</sub>) ÷ (bbb<sub>B</sub>) → ddd<sub>D</sub>.

½QRT aaaA 0000 dddD √(aaa<sub>A</sub>) → ddd<sub>D</sub>.

KOMP aaaA bbbB dddD (aaa<sub>A</sub>) / (bbb<sub>B</sub>) → ddd<sub>D</sub>.

ZERO dddD 0000 0000 Place -10<sup>-10</sup>, 000, in ddd<sub>D</sub>.

OVER aaaA 0000 dddD (aaa<sub>A</sub>) → ddd<sub>D</sub>.

LOOP nnnO 000A 0000 Prepare to cycle nnn times under control of B line A.

TRNS { iiiO 0000 0000 Transfer control to instruction iii. }  
 { iiiO 000A 0000 Transfer control to instruction iii if (A) ≥ 0. }  
 { iiiO 0000 dddO Transfer control to instruction iii if (ddd) mantissa ≥ 0. }

READ mmmO 000A d000 Read from drum mmm, modified by B line A, to store d (= X or Y, Z only if originally Z).

WRTE mmmO 000A d000 Write from store d (= X, Y or Z) to drum mmm, modified by B line A.

BSET { 000A nnnO 0000 nnn → A. }  
 { 000A 0000 bbbO (bbb)<sup>exp</sup> → A. }

JOTB 000A 0000 dddO (A) → ddd<sup>exp</sup>.

INCB 000A nnnO 0000 Add nnn to (A).

NEGB { 000A nnnO 0000 Subtract nnn from (A). }  
 { 000A 0000 bbbO Subtract (bbb)<sup>exp</sup> from (A). }

PRNT nnnN OmmO dddO Print and/or punch nnn consecutive numbers, N numbers per paper line, mm digits per mantissa, starting with (ddd).

FNTN { OffO aaaA dddD FNTN off { (aaa<sub>A</sub>) } }  
 { OffO 0000 Z140 → ddd<sub>D</sub>. }  
 For more general FNTN's.

HALT xxxx xxxx xxxx Halt operation of program.

VOID xxxx xxxx xxxx No effect.

COKE xxxx xxxx xxxx Refresh electronic store.

QUIT xxxx xxxx xxxx End of instruction list, if obeyed, causes more tape to be read.

- END -

# WHO'S WHO IN THE COMPUTER FIELD

(Supplement, information as of June 5, 1956)

This is Supplement No. 4 to the second edition of the "Who's Who in the Computer Field", published in the June 1955 issue of "Computers and Automation". The following issues contain other supplements: Supp. No. 1, June 1955; Supp. No. 2, Oct. 1955; Supp. No. 3, June 1956, "The Computer Directory, 1956".

The purpose of this Who's Who is to give some information about persons interested in one or more parts of the computer field. The source of this information is correspondence or completed Who's Who forms received after May 3, 1956 and before June 3, 1956.

If your entry in the Who's Who in this or any previous issue is incorrect, please send us the correct information and we shall try to publish it in an early issue.

A full entry consists of: name / title, organization, address / interests (the capital letters "A,B,C,D,E,L,M,P,S" stand for main interests "Applications, Business, Construction, Design, Electronics, Logic, Mathematics, Programming, Sales", respectively) / year of birth, college or last school (background), year of entering the computer field, occupation, other information (distinctions, publications), etc. / code. In the code the digit such as 6 denotes the year ('56) when the information was received.

For the form of a Who's Who entry, see the June issue.

The editors of "Computers and Automation" express their thanks to those in the following list who made contributions towards the cost of preparing and printing the Who's Who.

## A

Angstadt, Lloyd H / Consultant, 1225 Midland Ave, Bronxville, N Y / AP / '96, Univ of Penn, '24, mgt consltnt, publ "Impact of Computers" / 6

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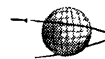
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Corkran, Davis H / Sales Engr, Electronic Assoc, Inc, Long Branch, N J / AS / '20, Univ of Md, '46, sales engr / 5r

(cont'd on page 34)



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Fink, J L / Mgr, Military & Spec Des, General Electric Co, 1200 Western Ave, Lynn, Mass / -, power systems / '26, Univ of Kansas, '53, engr / 6t

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 Greenwood, Ivan A, Jr / Assoc Hd, Res Dept. General Precision Lab, Inc, 63 Bedford Rd, Pleasantville, N Y / AD, editor, patents / '21, Case Inst. of Techn, '42, physicist / 6  
 Gumas, George / Analytical Engr, CDC Control Services, 400 S Warminster Rd, Hatboro, Pa / D / '24, Cooper Union, '50, engr / 6

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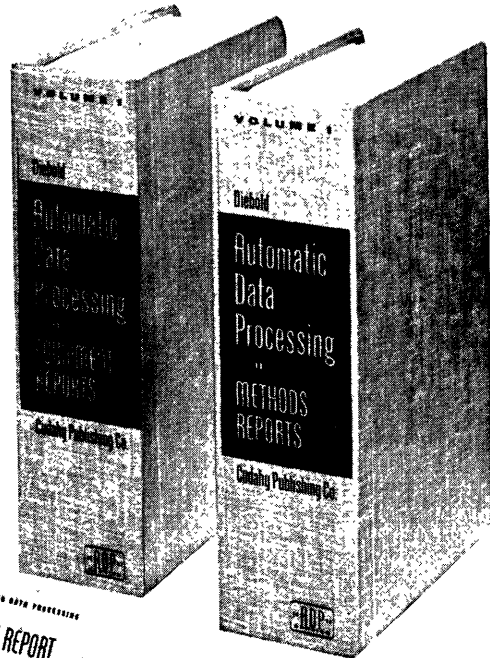
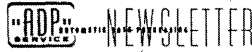
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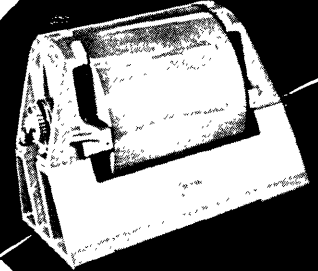
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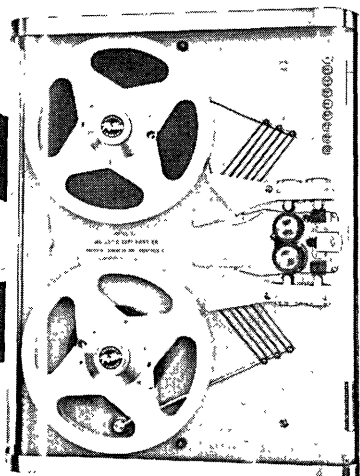
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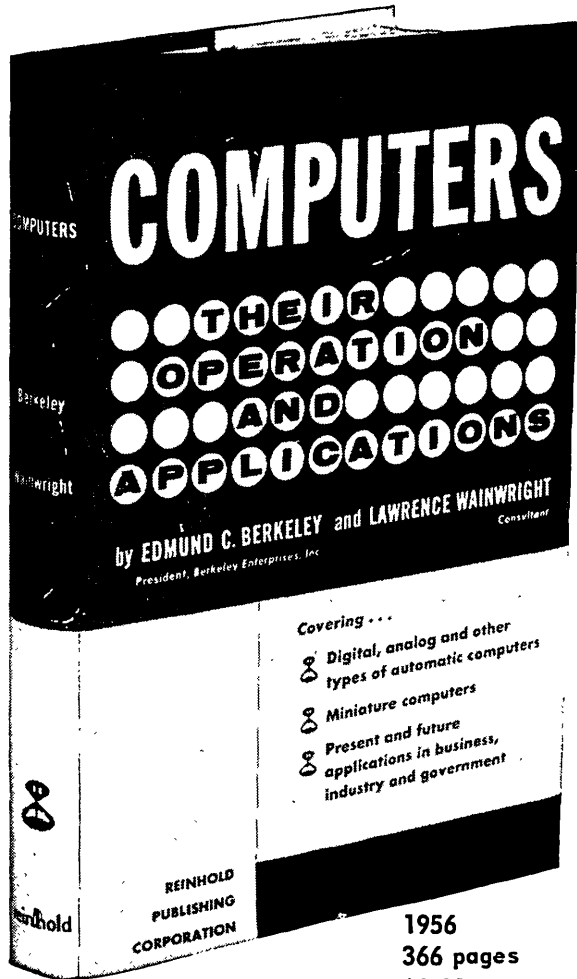
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Reinhold Publishing Corp., New York

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Berkeley Enterprises, publishers of  
"Computers and Automation"  
815 Washington St., R166  
Newtonville 60, Mass.

-----Mail this request or a copy of it-----

Berkeley Enterprises, Inc.  
815 Washington St., R 166  
Newtonville 60, Mass.

Please send me P 41: "Computers -- Their Operation and Applications" by Berkeley and Wainwright. I enclose \$8.00. (Returnable in seven days for full refund if not satisfactory).

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# ADVERTISING IN "COMPUTERS AND AUTOMATION"

Memorandum from Berkeley Enterprises, Inc.  
Publisher of COMPUTERS AND AUTOMATION  
815 Washington St., Newtonville 60, Mass.

1. What is "COMPUTERS AND AUTOMATION"? It is a monthly magazine containing articles, papers, and reference information related to computing machinery, robots, automatic control, 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 \$5.50 a year in the United States. Single copies are \$1.25, except June, 1955, "The Computer Directory" (164 pages, \$4.00). For the titles of articles and papers in recent issues of the magazine, see the "Back Copies" page in this issue.

2. What is the circulation? The circulation includes 2300 subscribers (as of June 10): over 300 purchasers of individual back copies; and an estimated 3000 nonsubscribing readers. The logical readers of COMPUTERS AND AUTOMATION are 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 May issue was 2700 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.

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. We reserve the right not to accept advertising that does not meet our standards.

4. What are the specifications and cost of advertising? COMPUTERS AND AUTOMATION is published on pages 8½" x 11" (ad size, 7" 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 a full page (ad size 7" x 10", basic rate, \$190) two-thirds page (basic rate, \$145), and half page (basic rate, \$97), and quarter page (basic rate, \$52); back cover, \$370; inside front or back cover, \$230. Extra for color red (full pages only and only in certain positions), 35%. Two-page printed insert (one sheet), \$320; four-page printed insert (two sheets), \$590. Classified advertising is sold by the word (60 cents a word) with a minimum of 20 words.

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

Aircraft-Marine Products, Inc.  
American Bosch Corp.  
Ampex Corp.  
Armour Research Foundation  
Arnold Engineering Co.  
Automatic Electric Co.  
Bendix Aviation Corp.  
Cambridge Thermionic Corp.  
Epsco, Inc.  
Ferranti Electric Co.  
Ferroxcube Corp. of America  
General Electric Co.  
Hughes Research and Development Lab.  
International Business Machines Corp.  
Lockheed Aircraft Corp.  
Lockheed Missile Systems  
Logistics Research, Inc.  
The Glenn L. Martin Co.  
Monrobot Corp.  
Norden-Ketay Corp.  
Northrop Aircraft, Inc.  
George A. Philbrick Researches, Inc.  
Potter Instrument Co.  
Ramo-Wooldridge Corp.  
Reeves Instrument Co.  
Remington Rand, Inc.  
Republic Aviation Corp.  
Sprague Electric Co.  
Sylvania Electric Products, Inc.

Did you see our story in Life Magazine, March 19, pp 173-176 ?

MAKE YOUR OWN BABY GENIUS COMPUTERS  
WITH

# GENIAC

Electric Brain

Construction Kit No. 1

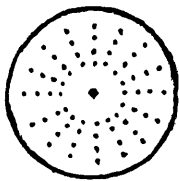


Diagram of the versatile multiple switch, which can be assembled to make any switch combination from 16 decks of 2 positions, to 2 decks of 16 positions.

This kit is an introduction to the design of arithmetical, logical, reasoning, computing, puzzle-solving, and game-playing circuits. It is simple enough for intelligent boys to assemble, and yet is instructive to computer men because it shows how many kinds of computing and reasoning circuits can be made from simple components.

With this kit and 64-page manual, you can easily make over 30 small electric brain machines that exhibit intelligent behavior. Each runs on one flashlight battery. All connections with nuts and bolts; no soldering required. Price, \$17.95 (add 80¢ for shipment in U. S. west of Mississippi, \$1.80 for shipment outside U. S.). If not satisfactory, returnable in seven days for full refund.

A few of the machines you can make:  
Logic Machines: Reasoning, Syllogism Machine, Intelligence Testing. Game-playing Machines: Nim, Tit-tat-toe. Arithmetic Machines: Adding, Subtracting, Multiplying, Dividing, Carrying, etc. Cryptographic Machines: Secret Coder and Decoder, Combination Locks. Puzzle Machines: The Space Ship Airlock, The Fox Hen Corn and Hired Man, Douglas Macdonald's Will, The Uranium Ship and the Space Pirates.

-----Mail this Request-----  
or a Copy of It

Berkeley Enterprises, Inc.  
815 Washington St., R166  
Newtonville 60, Mass.

Please send me Geniac Kit No. 1 and Manual. Price, \$17.95 (add 80¢ for shipment in U. S. west of Mississippi, \$1.80 for shipment outside U. S.) I enclose \_\_\_\_\_ in full payment. (If in good condition, it is returnable in seven days for full refund.) My name and address are attached.

ELECTRONIC ENGINEERS,  
MATHEMATICIANS

## If you can do original work

... you should consider The Johns Hopkins University Applied Physics Laboratory (APL), where creative ideas are recognized and supported.

The Laboratory is primarily concerned with research, development and engineering of guided missiles and missile systems. A sizeable program of fundamental research is concurrently in progress.

APL is responsible for technical direction of the Navy's Bumblebee guided missile program. As pioneers in guided supersonic flight, APL developments include the first supersonic ramjet, and the missiles TERRIER, TALOS, and TARTAR. The Laboratory presently is engaged in further development of these and more advanced missiles.

An organization of and for scientists and engineers, APL's staff of 1200 includes nearly 500 professional men. Two features distinguish the organization: (1) the self-dependence of staff members who work in an atmosphere of free inquiry and are unhampered by the usual administrative details, (2) the fluidity of relationships among the groups engaged in the many areas of technical endeavor.

Problems are attacked by teams, each composed of members drawn from all requisite professions. A close contact between research and engineering is maintained. This team approach allows each staff member to acquire broad knowledge of the problem under attack, find his creativity heightened and supported. Salaries are comparable to those of other R & D organizations in the missile field. Relocation expenses are paid for applicants selected.

Our new air-conditioned laboratories are exceptionally well equipped. Their location in the Washington, D.C.-Baltimore periphery places staff members near fine housing in all price ranges and near recreational and cultural facilities. Several excellent universities in the area make it convenient for staff members to avail themselves of our liberal educational benefits.

OPENINGS EXIST IN: *Programming for electronic analog computers, programming for Univac, dynamic analysis of closed-loop control systems, servomechanisms design, missile systems design, missile systems dynamics, transistor and magamp applications to control circuits, operations research.*

*For Additional information write:  
Professional Staff Appointments*

## The Johns Hopkins University Applied Physics Laboratory

8641 Georgia Avenue, Silver Spring, Md.

# ADVERTISING INDEX

The purpose of COMPUTERS AND AUTOMATION is to be factual, useful, and understandable. For this purpose, the kind of advertising we desire to publish is the kind that answers questions, such as: What are your products? What are your services? And for each product, What is it called? What does it do? How well does it work? What are its main specifications?

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

- Aircraft Marine Products, Inc., 2100 Paxton St., Harrisburg, Pa. / Patchcord System / Pages 23, 24 / CA No. 28
- Arma Division, American Bosch Corp., Roosevelt Field, Garden City, L.I., N.Y. / Inertial Navigation / Page 35 / CA No. 29
- Arma Division, American Bosch Corp., Roosevelt Field, Garden City, L. I., N.Y. / Digital Engineers / Page 37 / CA No. 30
- Automatic Electric Co., 1033 W. Van Buren St., Chicago, Ill. / Insure Bind-Free Operation / Page 47 / CA No. 31
- Berkeley Enterprises, Inc., 513 Ave. of the Americas, New York 11, N.Y. / Robot Show Stoppers, Books and Publications, Geniac Kit / Pages 37, 39, 41, 43 / CA No. 32
- Bryant Chucking Grinder Co., P.O. Box 620-K, Springfield, Vt. / Magnetic Drums / Page 39 / CA No. 33
- Classified Advertising / Page 28 / CA No. 34
- Computers and Automation, 513 Ave. of the Americas, New York 11, N.Y. / Back Copies, Advertising / Pages 40, 42 / CA No. 35

- Cudahy Publishing Co., 6141 N. Cicero Ave., Chicago, Ill. / Automatic Data Processing Service / Page 38 / CA No. 36
- Ferroxcube Corp., East Bridge St., Saugerties, N.Y. / Magnetic Core Materials / Page 38 / CA No. 37
- General Electric Company (Aircraft Nuclear Propulsion Dept.) Cincinnati 15, Ohio / Help Wanted / Page 30 / CA No. 38
- International Business Machines Corp., 590 Madison Ave., New York 22, N.Y. / Ideas at Work / Page 2 / CA No. 39
- Johns Hopkins University, Applied Physics Laboratory, 86-41 Georgia Ave., Silver Springs, Maryland / Help Wanted. / Page 45 / CA No. 40
- Potter Instrument Co., 115 Cutter Mill Road, Great Neck, N.Y. / Magnetic Tape Handler / Page 40 / CA No. 41
- R.C.A. Service Co., Inc., Missile Test Project, P.O. Box 1226, Melbourne, Florida / Help Wanted / Page 35 / CA No. 42
- Ramo-Wooldridge Corp., 8820 Bellanca Ave., Los Angeles 45, Calif. / Employment Opportunities / Page 5 / CA No. 43
- Sprague Electric Co., 377 Marshall St., North Adams, Mass. / Miniature Pulse Transformers / Page 48 / CA No. 44

## READER'S INQUIRY

If you wish more information about any products or services mentioned in one or more of these advertisements, you may circle the appropriate CA Nos. on the Reader's Inquiry Form below and send that form to us (we pay postage; see the instructions). We shall then forward your inquiries, and you will hear from the advertisers direct. If you do not wish to tear the magazine, just drop us a line on a postcard.

### READER'S INQUIRY FORM

Paste label on envelope: ↓

Enclose form in envelope: ↓

**4¢ Postage Will Be Paid By ---**

**BERKELEY ENTERPRISES, INC.**

38 East 1st Street  
New York 3, N. Y.

**BUSINESS REPLY LABEL**

NO POSTAGE STAMP NECESSARY IF MAILED IN U.S.A.

**READER'S INQUIRY FORM**

Name (please print).....

Your Address?.....

Your Organization?.....

Its Address?.....

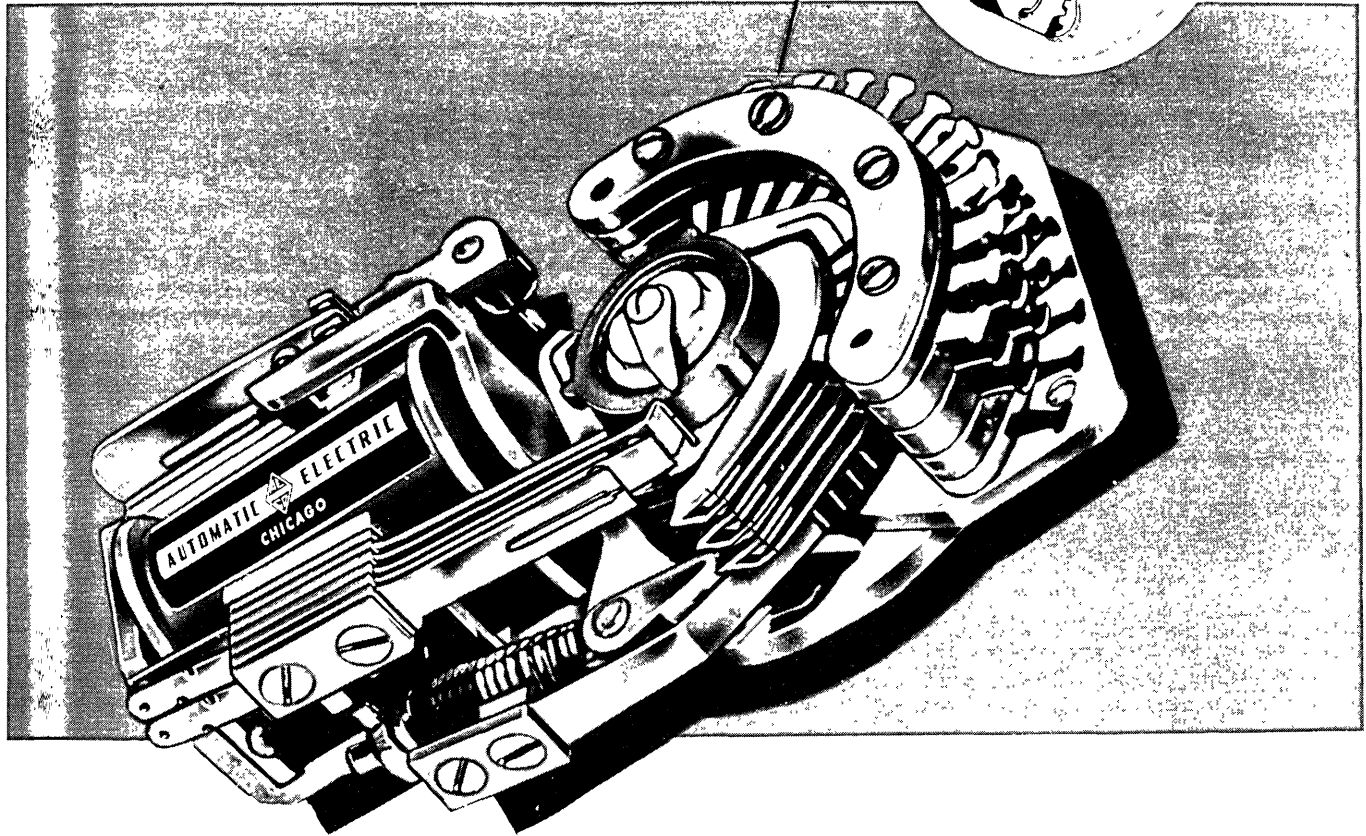
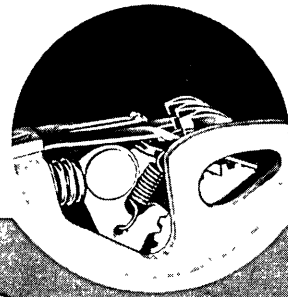
Your Title?.....

Please send me additional information on the following subjects for which I have circled the CA number:

1	2	3	4	5	26	27	28	29	30	51	52	53	54	55	76	77	78	79	80	101	102	103	104	105	126	127	128	129	130
6	7	8	9	10	31	32	33	34	35	56	57	58	59	60	81	82	83	84	85	106	107	108	109	110	131	132	133	134	135
11	12	13	14	15	36	37	38	39	40	61	62	63	64	65	86	87	88	89	90	111	112	113	114	115	136	137	138	139	140
16	17	18	19	20	41	42	43	44	45	66	67	68	69	70	91	92	93	94	95	116	117	118	119	120	141	142	143	144	145
21	22	23	24	25	46	47	48	49	50	71	72	73	74	75	96	97	98	99	100	121	122	123	124	125	146	147	148	149	150

REMARKS:

Be sure the  
rotary stepping switches  
YOU use have this  
"free-floating" pawl



## Automatic Electric Rotary Stepping Switches

# **insure bind-free operation**

Look at the pawl in the small illustration above. Automatic Electric's Type 44 and 45 rotary stepping switches can't bind. Automatic Electric has eliminated the old-style pawl stop block that jammed the pawl and caused binding. Instead, Automatic Electric uses a unique "free-floating" pawl, and a set of stopping teeth on the end of the armature. These teeth engage the ratchet wheel smoothly, without jarring or jamming. They stop the wiper assembly positively, and position it exactly right on the bank contacts.

Automatic Electric offers many exclusive advantages over older type rotary stepping switches:

- Pawl breakage is eliminated

- Re-adjustment of armature stroke is never required
  - There's no possibility of pawl binding, even at very low temperatures
  - There's no possibility of double-stepping or overthrow
- No wonder more and more design engineers are choosing Automatic Electric rotary stepping switches!

Plan now to use the Automatic Electric Type 44 or Type 45 rotary stepping switch in your products.

For complete information, write for Circular 1698. Address Automatic Electric Sales Corporation, 1033 West Van Buren Street (HAYmarket 1-4300), Chicago 7, Ill. In Canada: Automatic Electric Sales (Canada) Ltd., Toronto. Offices in principal cities.

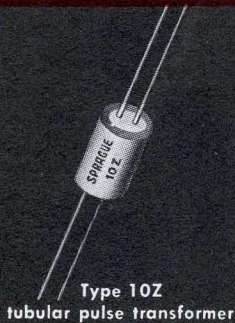
**AUTOMATIC**  **ELECTRIC**

Originators of the dial telephone • Pioneers in automatic control

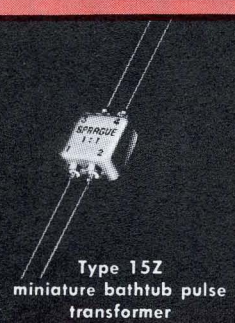


choose from this complete line of

# MINIATURE PULSE TRANSFORMERS



Type 10Z  
tubular pulse transformer



Type 15Z  
miniature bathtub pulse transformer



Type 20Z  
drawn-shell bathtub pulse transformer



Type 41Z  
cylindrical pulse transformer

NOW YOU CAN CHOOSE from eighteen standard pulse transformers in four major construction styles, all in quantity production at Sprague. The standard transformers covered in the table below offer a complete range of characteristics for computer circuits, blocking oscillator circuits, memory array driving circuits, etc.

These hermetically sealed units will meet such stringent military specifications as MIL-T-27, and operate at temperatures up to 85°C. Special designs are available for high acceleration and high ambient temperature operation. In addition, the electrical counterparts of each transformer can be obtained in lower cost housings designed for typical commercial environment requirements.

Complete information on this high-reliability pulse transformer line is provided in Engineering Bulletin 502A, available on letterhead request to the Technical Literature Section, Sprague Electric Company, 377 Marshall Street, North Adams, Massachusetts.

## ELECTRICAL CHARACTERISTICS OF SPRAGUE PULSE TRANSFORMERS

Type No.	Turns Ratio	Pulse Width $\mu$ seconds	Rise Time $\mu$ seconds	Primary Inductance	Leakage Inductance	Repetition Rate	Load and Output	Typical Applications
10Z1	5:1	0.1	0.04	200 $\mu$ H	5 $\mu$ H	1 to 2 MC	15 volts 100 ohms	Used in digital computer circuitry for impedance matching and inter-stage coupling. Pulses are of sine wave type.
10Z2	4:1	0.07	0.03	200 $\mu$ H	20 $\mu$ H	1 to 2 MC	20 volts 100 ohms	
10Z3	1:1	0.07	0.03	125 $\mu$ H	12 $\mu$ H	1 to 2 MC	20 volts 200 ohms	
10Z4	3:1	0.07	0.03	160 $\mu$ H	15 $\mu$ H	1 to 2 MC	20 volts 100 ohms	
10Z6	4:1	0.1	0.04	200 $\mu$ H	6 $\mu$ H	1 to 2 MC	17 volts 100 ohms	
10Z12	1:1	0.25	0.02	200 $\mu$ H	2 $\mu$ H	12KC	100 volts	Blocking Oscillator
10Z13	1:1	0.33	0.07	240 $\mu$ H	2 $\mu$ H	2KC	50 volts	Blocking Oscillator
10Z14	7:1:1	0.50	0.05	1.2 mH	20 $\mu$ H	1MC	25 volts	Impedance Matching
15Z1	3:1	5.0	0.04	7.5 mH	22 $\mu$ H	10 KC	10 volts 100 ohms	Impedance Matching and Pulse Inversion
15Z2	2:1	0.5	0.07	6 mH	15 $\mu$ H		40 volts	Blocking Oscillator
15Z3	5:1	10.0	0.04	12 mH	70 $\mu$ H	10 KC	10 volts	Impedance Matching
15Z4	1:1.4	6.0	0.1	16 mH	15 $\mu$ H	0.4 KC	15 volts	Blocking Oscillator
20Z1	5:5:1 Push-Pull	1.5	0.25	4.0 mH	0.3 MH		5 volts 10 ohms	Memory Core Current Driver
20Z3	6:1	1 to 4	0.22	18 mH	0.8 MH	250 KC (max.)	21 volts 200 ohms	Current Driver
20Z4	6:1:1	1 to 7	0.25	55 mH	0.3 MH	50 KC (max.)	22 volts 400 ohms	Current Driver and Pulse Inversion
20Z5	3:3:3:3:1	2.4	0.2	2.8 mH	0.2 MH		2.5 volts 6 ohms	Memory Core Current Driver
20Z6	11:1	6.0	0.2	90 mH	0.2 MH	50 KC (max.)	10 volts 75 ohms	Current Transformer
41Z1	7:1:1	0.50	0.05	1.2 mH	20 $\mu$ H	1 MC	25 volts	Impedance Matching

Sprague, on request, will provide you with complete application engineering service for optimum results in the use of pulse transformers.

**SPRAGUE**® WORLD'S LARGEST CAPACITOR MANUFACTURER