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# THE CIRCLE COMPUTER

THE LOW-COST GENERAL-PURPOSE COMPUTER FOR SCIENCE AND INDUSTRY

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Numerous high speed digital computers exist today which are available through rental -- either the machine itself or time on the machine -- to research and engineering organizations. Time on these machines is very costly and must be scheduled far in advance. Organizations requiring computational services on a more or less regular schedule find it to their advantage to own a computer. Most digital computers available today are costprohibitive to any but the very largest organizations.

The Circle Computer was designed to fill the growing demand for a low cost computer sufficiently flexible to solve most of the problems met in engineering and research organizations. At the same time, ease of maintenance and simplicity of operation minimize staff requirements for service and operation.

While storage capacity and speed have been sacrificed in the interest of economy, storage capacity is still sufficient to handle more than 90 per cent of the problems encountered in scientific work. Very large problems may be handled by breaking them into parts and handling separately. Even with the reduction in speed relative to existing large computers, speed of the Circle Computer is still some 400 times that of a skilled calculator operator. It is therefore feasible to use the Circle Computer for all but the very simplest calculations.

In summary, the Circle Computer is a practical investment for the organization which continually meets problems requiring the use of a computer but desires to avoid the inconvenience and cost of renting one of the larger installations.

#### USES OF THE CIRCLE COMPUTER

Before discussing uses of the Circle Computer it may be helpful to discuss uses of a digital computer in general. A digital computer may be used to perform any calculation which is a series of simple arithmetic steps. It is economically most feasible to use a computer for problems in which such a series of steps is repeated several times with different values assigned to one or more of the parameters of the problem on each excursion through the steps. Numerical methods of solution for many types of problems have been developed for use with hand computers. These same methods are applicable to digital computers with little or no modification. In addition to this, many problems too complex for hand computation may be quite easily solved by a digital computer. New methods of solution appear regularly in the literature. While most of these methods are developed for one of the larger computers, the modifications necessary to make them suitable for the Circle Computer are usually quite simple.

The Circle Computer may be used for problems in many fields.

Optical Ray Tracing Stress Analysis Design of Servo-mechanisms Analysis of Large Networks Reduction of Wind Tunnel Data Finding Eigenvalues and Eigenvectors of Large Matrices (20 × 20, or so) Solution of High Order Differential Equations Computation of Statistical Quantities Accounting Inventory

## PHYSICAL CONSTRUCTION FEATURES

The Circle Computer occupies about the same floor space as an office desk. The input and output typewriters and the operators control panel are attached to the computer by flexible cables and may be placed at the convenience of the user. These three units may be placed on a second desk so that the complete installation requires no more space than that occupied by two desks.

The Computer consumes about 3-1/2 Kw of power from a single phase 110 volt line. No special wiring is needed and air conditioning is not required.

## CIRCUIT DESIGN FEATURES

The Circle Computer uses 700 vacuum tubes which are operated well within the manufacturers ratings. No crystal diodes are used since it is felt that at present they are not sufficiently stable to meet our requirements for reliability. The electronic portion of the computer is divided into small subunits which are built on three-tube chassis. (See Fig. 1) These chassis are mounted on the Computer with screw terminals as screw connections are more reliable both mechanically and electrically than plugs. The units when mounted may be rotated about a vertical axis until the terminals are exposed -- either for checking the unit in operation or for speedy removal and replacement of a unit. (See Fig. 2) Any of these chassis may be removed and replaced in less than one minute.

It is possible to maintain the Computer with a small stock of tubes and replacement chassis since only three tube types and eighteen different subunits are used in the Circle Computer. Automatic checking circuits have been omitted in the interest of economy but diagnostic routines are established which will quickly locate malfunctioning units. These may then be replaced from stock.

A tester for the Computer tubes is incorporated in the control panel. Emission and cut-off voltage tests have been established so that any suspect tube may be quickly checked and replaced.

## LOGICAL DESIGN FEATURES

The logical design of the Circle Computer is patterned after the Princeton type machines which are today in the dominant position in the computing world. The Circle Computer user who has done his own coding may therefore code a problem for the larger computers of this type if the need arises.

Orders and numbers are stored in the same memory and arithmetic operations may be performed on both. Thus the machine may modify its own coding depending on the results of previous calculations.

The Circle Computer word consists of forty binary digits plus two sign digits. A word may be interpreted as a number, in which case it corresponds to a 12 digit decimal number, or as an order pair. This means that two orders may be stored in one word position in the memory; the computer may then choose and carry out either of these orders.

The Circle Computer has two operating registers -- an accumulator register and a quotient register. These correspond to the accumulator and register, respectively, of a desk calculator. In addition there is a third register, not available to the operator, which handles numbers on their way to and from the memory. The Circle Computer operates serially throughout and uses a single address coding. The results of arithmetic operations appear either in the accumulator or quotient register and an additional order places these results in the memory. Greater flexibility may be realized with single address coding in the sense that it is somewhat easier to construct a special purpose order for a single address computer than for a multi-address computer.

The Circle Computer normally operates with fixed binary point. This point is located immediately to the right of the sign digits so that the computer normally handles numbers whose values lie between -1 and  $(1-2^{-40})$ . The Circle Computer may however be coded to operate with floating binary point.

The command table (27 commands) for the Circle Computer is conventional for the Princeton type machine and appears as Appendix I.

The customary transfer orders, i.e., conditional and unconditional transfer, are included as well as the rarer overflow transfer. This order transfers control of the machine when the number in the accumulator becomes greater than (1-2-40) or less than -1. Thus the machine may be programmed to stop at critical points in the problem if the number in the accumulator is too large.

The subroutine transfer order stores the floating address at the position called for by the order and then transfers the control to the memory position next after that. The subroutine which begins here is carried out by the computer. The last order in the subroutine is an unconditional transfer to the address stored at the memory position just prior to the beginning of the subroutine, i.e., to the floating address of the main routine. The computer thus enters a subroutine and returns to the main routine by using just two additional orders -- a single word of coding. Liberal use of such subroutines -- already coded -- thus greatly reduces the amount of coding necessary with a negligible increase in stor-age requirements.

Problem preparation and coding time for the Circle Computer is of the same order of magnitude as that for the card programmed computers. However, as the subroutine library is built up, coding time for the Circle Computer will decrease, perhaps as much as a factor of 3 or 4.

#### MEMORY

The memory and operating registers of the Circle Computer appear on a magentic drum rotating at 3540 rpm. The storage capacity of the drum is 1024 words. Average access time to a particular word in the drum is 8 milliseconds.

## COMMUNICATION

Input and output of the computer is by means of "Flexowriters" -- electric typewriters operating in parallel with punched paper tape.

The computer operates in the binary number system but input and output data are normally in decimal form. Conversion in both directions is automatic in the computer. Reading and writing speeds are 10 decimal digits per second.

## SERVICES TO USERS

A library of subroutines is being built up by Nuclear Development Associates and will be available to users of the Circle Computer at a nominal fee. These subroutines include floating binary point operation, evaluation of trigonometric functions, extraction of square roots, special input routines, diagnostic routines, etc.

A computation techniques consulting service is also available to users. Services range from straight coding of problems to integration of computation facilities into control systems.

The computer subunits may be returned to NDA for service if desired, however maintenance of the computer may be easily handled by the user.

Further information about the Circle Computer and its application to your computation problem may be obtained from:

The Circle Computer Division Nuclear Development Associates, Inc. 80 Grand Street White Plains, New York

### APPENDIX I

## Table of orders for Circle Computer

The following notation is used:

- $(z)_{B}$  means the contents of z before the order is carried out
- (z)<sub>A</sub> means the contents of z after the order is carried out

Specifically

(ar) = contents of the accumulator register

(qr) = contents of the quotient register

(x) = contents of memory position x

(cc) = contents of control counter

CODE	DESCRIPTION	AVG. TIME REQUIRED (milliseconds)
	$(2\pi) = (x)$	25
xuO	$(ar)_A = (x)$	25
xd5	$(ar)_A = -(x)$	25
xd9	$(ar)_{A} =  (x) $	25
xdc	$(ar)_A = - (x)$	25
xd2	$(ar)_A = (ar)_B + (x)$	25
xd6	$(ar)_{A} = (ar)_{B} - (x)$	25
xda	$(ar)_{A} = (ar)_{B} +  (x) $	25
xdf	$(ar)_{A} = (ar)_{B} - (x)$	25
	CODE xdO xd5 xd9 xdc xd2 xd6 xda xda xdf	$\begin{array}{llllllllllllllllllllllllllllllllllll$

Note: If, in the above orders, a 5 is substituted for the d the orders are carried out in the same way except that only the left half of the word in memory position x is used.

Multiply without rounding off	xc2	$(ar)_{A} = most significant$ half of $(qr)_{B} \cdot (x)$ $(qr)_{A} = least significant$ half of $(qr)_{B} \cdot (x)$	45
Multiply, and round off	xc0	$(ar)_{A} = (qr)_{B} \cdot (x)$ , rounded off to 40 digits	45
		$(qr)_{A} = least significant half of (qr)_{B} \cdot (x)$	
Divide	xc8	$(qr)_A = (ar)_B \div (x)$ $(ar)_A = remainder$	45
Memory to reg- ister	xc4	$(qr)_A = (x)$	25

Note: If, in the above four orders, a 4 is substituted for the c these orders are carried out on the left half of the word at memory position x.

Store (qr)	x84	$(x)_A = (qr)$	25
Store (ar)	x8c	$(x)_A = (ar)$	25
Store left half of (qr)	x04	<pre>left half of (x)<sub>A</sub> = left half of (qr)</pre>	25
Store left half of (ar)	x0c	left half of (x) A = left half of (ar)	25
Substitute left address	x08	<pre>left address digits of (x)<sub>A</sub> = left address digits of (ar)</pre>	25
Substitute right address	x88	right address digits of (x) <sub>A</sub> = right address digits of (ar)	25
Unconditional transfer left	x34	<pre>(cc)<sub>A</sub> = left half of word x; i.e., the next order which the computer carries out is that stored in the left half of word x</pre>	17

Unconditional transfer right	xb4	$(cc)_A = right half of word x$	17
Conditional trans- fer left	x38	$(cc)_{A} = left half of word x$ if (ar) $\langle 0; otherwise$ $(cc)_{A} = (cc)_{B} + 1/2$	17
Conditional trans- fer right	xb8	$(cc)_{A}$ = right half of word x if (ar) $\langle 0$ ; otherwise $(cc)_{A}$ = $(cc)_{B}$ + 1/2	17
Overflow transfer left	x3c	$(cc)_{A} = (cc)_{B} + 1/2$ if -1 $\leq$ (ar) $\leq$ 1, otherwise $(cc)_{A} =$ left half of word x	17
Overflow transfer right	xbc	$(cc)_{A} = (cc)_{B} + 1/2$ if -1 $\leq$ (ar) $\leq$ 1, otherwise $(cc)_{A} =$ right half of word x	17
Subroutine trans- fer left	x00	add 1/2 word to the address in the control counter and store in the left half of memory position x. Place the order which is stored in the right half of memory position x in the control counter.	25
Subroùtine trans- fer right	x80	add $1/2$ word to the address in the control counter and store this address in the right half of memory posi- tion x. Place the order which is stored in the left half of the memory position [x + 1] in the control counter.	25
Stop	x70	Computer idles until start button is pushed	-
Ignore	x78	Go on to next order.	-

Convert, decimal binary	00090	convert the binary coded deci- mal number in qr to a binary number and place in ar	45
Right shift η times	xa0 x20	right shift the number in ar $\eta$ times (the value of $\eta$ depends on x)	17 - 35
Left shift η times	xa4 x24	left shift the number in ar $\eta$ times (the value of $\eta$ depends on x)	17-35
Print a deci- mal no.	x30	convert the number in the ac- cumulator to decimal and print it	-
Transfer to ad- dress on tape	x60	transfer control of machine to address contained in next digit on input tape.	100



