N O R C

Programming and Coding Manual

U. S. NAVAL PROVING GROUND
DAHLGREN, VIRGINIA

NORC PROGRAMMING AND CODING MANUAL

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FOREWORD

This coding manual for the Naval Ordnance Research Calculator was derived from only several months experience of machine operation. It is expected that further experience will indicate additional material which will be included in the future. It is hoped that its purpose, which is to provide adequate and accurate coding information for mathematicians preparing problems for the calculator, is fulfilled.

Acknowledgment is made to other members of the Programming and Coding, Engineering and Operating Staffs for their suggestions. Acknowledgment is also made to the NORC design manual, written by IBM engineers, which has been generously plagiarized.

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GLOSSARY OF TERMS
USED IN NORC PROGRAMMING AND CODING MANUAL

Access Time: The time interval between the instant at which information is requested and the instant when it is available for use.

Bit Count: The modulo-four sum of all the bits which represent the 16 low order digits of a word.

Bit Count, Indicated: The 3's complement of the bit count of a word. The digit in position 17 of a word represents the indicated bit count.

Blank Code: A code of 0000 in any address field of an instruction.

Instruction Register: A full word electronic register to which each instruction is transferred immediately prior to its being decoded and operated. It remains stored there throughout the operation of the instruction. The Instruction Register is also called Register 3.

Meta Transfer: A transfer of a 16 digit number and appropriate indicated bit count from one location to another after a column shift left or right of as many places as specified in the P field of the instruction.

Pack: To combine several elements of information in one word (when fewer than 16 digits are known or required for such elements).

Print Cycle: That time interval from the instant printing is called for until the time when all the data in CRT locations 0001 to 0007 is transmitted to the printer.

Program Transfer: A transfer of control to a specified address, usually interrupting the sequential cycling.

Read-Around-Ratio: In a CRT memory, the number of times a given spot may be referred to before adjacent spots must be regenerated (rewritten) if they are not to be spoiled.

Register 1, Register 2, Register Storage:

Registers 1 and 2 are 17 digit electronic registers composed of microsecond delay units, and are of basic importance in the organization of NORC. They are distinct from CRT memory locations 0001 and 0002.

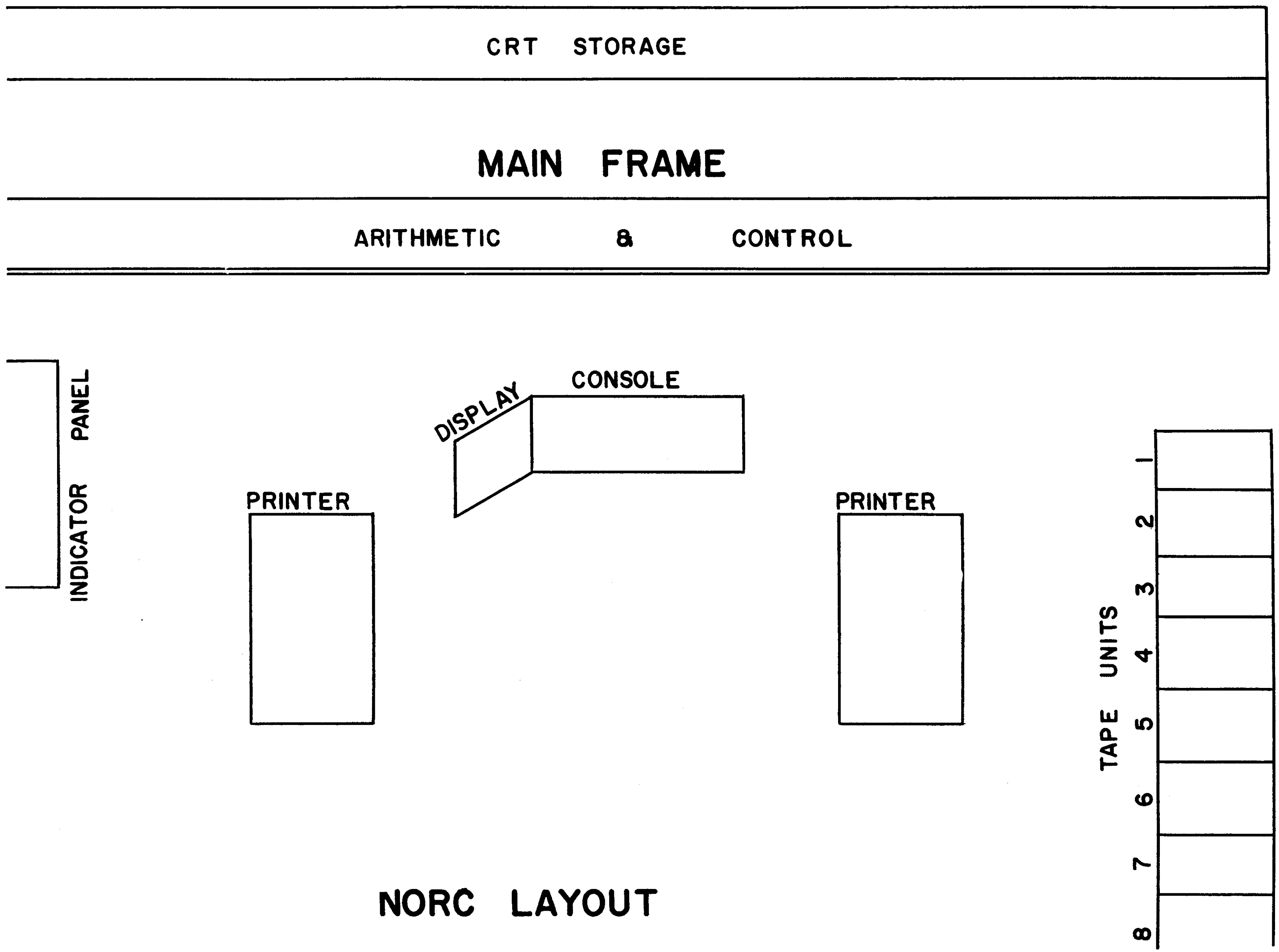
Registers 1 and 2 receive words from and transmit words to the CRT memory whether their origin or destination is the arithmetic unit, the tapes, the console or the printers.

The result of each operation (but for the exceptions noted below) is retained in both Register 1 and Register 2 for use as an operand in the subsequent instruction. A blank (0000) code in the R or S field of an instruction selects the contents of Register 1 or Register 2, respectively, as the operand in the instruction, thus making use of the previous result without making additional CRT accesses. The term register storage is used to refer to either or both Register 1 and Register 2 when referring to the place where the result of the preceding operation is stored or where the current result will be stored (exclusive of any CRT locations).

It might be noted that address modifier codes, the write, delete, and rewind codes and the conditional codes 64 to 69, 74 to 79 when inoperative, do not affect register storage; read and verify codes leave the end of block word in register storage; none of these codes make use of register storage. Code 63 does not affect register storage.

Round:

Throughout this manual, rounding will refer to the manner in which NORC rounds, that is the lowest order digit of the retained portion of the result is increased by one if the digit is even or remains unchanged if the digit is odd. This rounding is not done if the retained portion of the result is zero or if the discarded low order portion of the result is zero.


CRT STORAGE
MAIN FRAME
ARITHMETIC & CONTROL
INDICATOR PANEL
DISPLAY
CONSOLE
PRINTER
PRINTER
TAPE UNITS
1
2
3
4
5
6
7
8

NORC LAYOUT

Word: A set of 17 decimal digits, each of which is expressed in binary notation, that is, as appropriate combinations of four bits whose weights are 1, 2, 4 and 8. The digit positions are numbered 1 through 17, with the lowest order digit in the lowest order position. The 17th digit represents the indicated bit count of the word.

GENERAL DESCRIPTION

The computer proper consists of a 2000-word cathode ray tube memory, the electronic control and arithmetic section, eight high-speed magnetic tape units, two line-at-a-time printers, and a console allowing manual direction of the machine. An indicator panel, in conjunction with the console, contains alarm lights and indicator lights, showing the status of the calculator.

Associated but separate equipment include a card-to-tape-to-card machine and two machines used for testing purposes, one to test pluggable units and CRT boxes, and the other to test the tape units.

The NORC carries out its calculations on decimal numbers of 13 or fewer significant digits, under control of a stored program of the 3-address type with automatic address modification.

The organization of number words and instruction words is as follows:

A number word consists of a 13 digit decimal number (or coefficient) in which the decimal point is located at the right of the highest digit, i.e., between positions 13 and 12, a one-digit algebraic sign and a two-digit decimal index. This decimal index represents the power of 10 by which the number in the word must be multiplied to give the number its true magnitude. The index can have values 70 to 99, 0 to 30 corresponding to powers of 10 from -30 to +30. The algebraic sign, plus or minus is represented by 0 or 1 respectively.

An instruction word consists of two digits (Q field) to specify the operation to be performed, three fields of four digits each (R, S and T fields) normally specifying the CRT addresses of the numbers involved in the particular operation and two digits (P field) with a variety of meanings depending on the instruction.

There is a 17th digit in all cases representing the indicated bit count.

Example:

Number Word

Ind. Bit Count	Dec Index	Sign				
3	05	0	1	2314	1566	2851

$= 10^5 \times (+1.2314\ \ 1566\ \ 2851)$
$= 123141.5662851$

Instruction Word

Ind. Bit Count	P (Spec Index)	Q	R	S	T
1	04	20	0965	1316	0017

R, S, T: CRT Addresses

Add (20) the numbers in storage locations 0965 and 1316. Shift the result, if possible without overflow, so that it has a decimal index of 4, and store the result in location 0017.

The calculator will execute an average of approximately 14,000 instructions of this type (other than input-output) per second.

Input-Output

Information is recorded on the magnetic tapes in blocks containing any desired number of words from 1 to 2000, the size of the CRT memory. A single instruction suffices to read or write a complete block at an effective rate of approximately 2500 words per second.

The Card-to-Tape-to-Card machine or CTC, an auxiliary device, prepares magnetic tape suitable for input to the calculator from conventionally punched IBM cards. It also prepares conventionally punched IBM cards from the output tapes produced by the calculator. These cards may then be fed to a standard IBM 407 tabulator for printing. The CTC reads or punches four 16-digit words per card at a rate of 100 cards per minute.

Information may also be directly recorded, during computation, on either of two line-at-a-time printers at a maximum rate of 1050 words, (150 lines) per minute. Seven words, constituting one line of printing are recorded by a single instruction.

A keyboard on the console permits manual entry of information to any locations in the calculator, and a display panel on the console permits visual observation of any calculator location.

Cathode-Ray Tube Storage

The cathode-ray tube storage consists of 66 CRT storage units. Each unit contains one bit of each of the 2000 CRT locations, four CRT units being used to represent each decimal digit in the binary coded decimal system. Thus 64 of the CRT units carry the 16 digits of information of each word and the remaining two units contain the indicated bit count for each word.

The 2000 CRT locations have addresses 0001 to 2000. A blank (0000) address code makes reference to register storage only.

The access time to CRT storage is eight microseconds.

ARITHMETIC UNIT

The arithmetic unit adds, multiplies, and divides with subtraction performed by adding the tens complement of one operand to the other. The arithmetic unit is arranged to operate in either floating or specified decimal mode of operation depending upon the code in the index (P) field of the instruction word. Any number in the range 40 through 59 (normally 50) in this field designates floating index operation in the arithmetic unit. In this case any high order zeros in the result are removed and the index of the result decreased accordingly.

For specified index operation, the desired result index is entered in the P field and can range from -30 to +30, the 100's complement being used for negative powers. The calculation is performed like a floating index operation but the result is shifted to conform with the specified index.

For results smaller in absolute value than 10^{-30}, the result will have a decimal index of 70 (10^{-30}) and as many high order digits of the coefficient will be zero as dictated by the magnitude of the number. If the result is smaller in absolute value than 10^{-42} (the smallest number in NORC and represented by

70 0 0 0000 0000 0001)

the answer will be 16 digits of zero.

There are two sets of arithmetic codes, standard arithmetic made up of the 20 decade of operation codes and special arithmetic made up of the corresponding 30 decade of codes. If an overflow on the left would result from a standard arithmetic specified index operation, then left shifting is not performed, the index is adjusted accordingly, and the adjusted index indicator is turned on. If a special arithmetic code is used, the overflow digits will be dropped and the overflow indicator will be turned on.

Another distinction between standard and special arithmetic codes is that the results of standard arithmetic operations are rounded, those of special arithmetic are not. Rounding is performed by forcing a 1 in the lowest order digit of the retained portion of the result unless the retained portion or discarded low order portion of the result is zero. Forcing a 1 in the lowest order digit increases its value if the digit is even, but does not change it if the digit is odd.

In all cases, if the result of an arithmetic operation is zero, then the result will be 16 digits of zero even if a specified index is indicated.

If one of the operands of an arithmetic operation is zero (specifically, if the 13 decimal digit coefficient is zero) then the arithmetic operation will not be performed, but the non-zero operand (in the case of addition or subtraction) or a zero (in the case of multiplication and division) will be used to generate the result.

In operations which involve shifting of the result, the number of significant digits in the retained portion of the result is affected by the number of significant digits available prior to final shifting.

The relevant conditions prior to shifting are as follows:

Addition: the 14 most significant digits of the sum, or 15 in the event of a 15th digit carry, are available for shifting.

Subtraction: a 14 digit difference, whose highest order digit is of the same order as the most significant digit of the larger operand, is available for shifting. It should be noted that if the operands differ by a factor of 10^{13} or more (the smaller being non-zero), then the result will be such that 1 will be deducted from the lowest order digit of the larger operand.

Example:

If from

01 0 6 6666 6666 6666

the following number is to be subtracted

88 0 8 4321 0000 0000,

then these 14 digits would be available for final shifting:

(01 0)6 6666 6666 66651.

If the smaller number had an exponent less than 88 (10^{-12}), then these 14 digits would be available for final shifting:

(01 0)6 6666 6666 66659.

Multiplication: the 25 or 26 possible digits of the product are available for shifting.

Division: the 13 most significant digits of the quotient are available for shifting.

There are cases, however, when it is desirable to perform arithmetic operations on words, particularly instruction words, without regarding them as floating decimal numbers. For this purpose another arithmetic mode, termed meta-arithmetic, is provided. The operations of addition and subtraction (Q codes 40,41) are included in this mode. The operands are treated as positive 16 digit numbers; the addition or subtraction is performed without rounding, with fixed point, and any overflow digit is discarded. Meta-subtraction is performed by adding the tens complement of the subtrahend (S field) to the minuend, (R field).

Some average times for complete arithmetic operations including access times are:

addition, subtraction:	56 microseconds
multiplication:	72 microseconds
division:	272 microseconds

ADDRESS MODIFIERS

For purposes of automatic address modification there are three electronic storage locations in the machine, designated address modifiers M4, M6, and M8. Each has a capacity of four decimal digits, that is numbers from 0000 to 9999. All three may be loaded or incremented by single instructions.

The R, S, and T fields of instruction words usually contain addresses of CRT locations. If any of these addresses exceed 3,999, then the contents of one of the modifiers will be added to the address and the resulting address sum modulo-2000 will be used as the actual CRT address in the instruction. M4 will be used for addresses in the range 4000 to 5999, M6 for addresses in the range 6000 to 7999, and M8 for addresses in the range 8000 to 9999.

Example:

Assume M4 contains 0427 and M8 contains 3952 and the following instruction is operated:

P	Q	R	S	T
50	24	8001	1468	5999

i.e., multiply the contents of locations 1953 and 1468 placing the result in location 0426, since: 8001 + 3952 = 11,953
which = 1953 mod 2000

and: 5999 + 0427 = 6426
which = 0426 mod 2000

If the resulting sum is congruent to 0 mod 2000, then reference will be made to CRT location 2000, not register storage.

The address modifiers are not used for addresses in the range 2001 to 3999, but should such addresses be used, the CRT location referred to will be the address modulo-2000.

Address modification applies to all instructions except instructions 50 to 57 which reset and/or increment the modifiers themselves, instructions 90 to 98 which cover tape operations and the R and S fields of instruction 58.

INSTRUCTION SUMMARY

(Q Field)

The instructions available in the machine are described below. The contents of location X is designated as X'.

STANDARD ARITHMETIC (Operation codes 20 - 28)

Operands:	13-digit decimal coefficient, 2-digit decimal index, 1-digit algebraic sign.
Shift control:	Floated or specified index procedure designated by value in decimal index (P) field.
Overflow:	Index adjusted if specified index would cause an overflow on the left.
Rounding:	Automatic.
Register storage:	The result of each instruction is left in register storage.
Blank codes:	A blank operand address denotes that the contents of register storage is to be used, a blank result address indicates that the result is not to be stored in CRT.
Address modification:	Automatic for any CRT address.
Interlocks:	None.

20	Addition	R' + S'	to T
21	Addition with inverse result sign	-(R' + S')	to T
22	Subtraction	R' - S'	to T
23	Subtraction with inverse result sign	-(R' - S')	to T
24	Multiplication	R'S'	to T
25	Multiplication with inverse result sign	-(R'S')	to T
26	Division	R' / S'	to T
27	Division with inverse result sign	-(R' / S')	to T
28	Difference of absolute values	$\lvert R' \rvert - \lvert S' \rvert$	to T

SPECIAL ARITHMETIC (Operation codes 30 - 39)

Operands:	13-digit decimal coefficient, 2-digit decimal index, 1-digit algebraic sign.

Shift control:	Floated or specified index procedure as designated by value of P field.
Overflow:	Overflow digits caused by specified index are discarded.
Rounding:	None.
Register storage:	The result of each instruction is left in register storage.
Blank codes:	A blank operand address denotes that the contents of register storage is to be used, a blank result address indicates that the result is not to be stored in CRT.
Address modification:	Automatic for any CRT address.
Interlocks:	None.

30	Addition	$R' + S'$ to T
31	Addition with inverse result sign	$-(R' + S')$ to T
32	Subtraction	$R' - S'$ to T
33	Subtraction with inverse result sign	$-(R' - S')$ to T
34	Multiplication	$R'S'$ to T
35	Multiplication with inverse result sign	$-(R'S')$ to T
36	Division	R' / S' to T
37	Division with inverse result sign	$-(R' / S')$ to T
38	Difference of absolute values	$\|R'\| - \|S'\|$ to T
39	Truncating transfer	R' with S' to T. The decimal coefficient of S' is treated as the 13 low-order digits of a number whose index, sign, and high-order digits are represented by R'. This 26-digit number is under the control of the index procedure as indicated by P. In the event R' is zero, the functions of R' and S' are interchanged.

META ARITHMETIC (Operation codes 40,41)

Operands:	Positive 16-digit numbers (subtraction performed by adding the tens complement of the subtrahend).

Shift control:	None.
Overflow:	The overflow digit "1" in addition or subtraction is discarded.
Rounding:	None.
Register storage:	The result of each instruction is left in register storage.
Blank codes:	A blank operand address denotes that the contents of register storage is to be used, a blank result address indicates that the result is not to be stored in CRT.
Address modification:	Automatic for any CRT address.
Interlocks:	None.

40	Meta addition	R' + S' to T
41	Meta subtraction	R' - S' to T

ADDRESS MODIFIER INSTRUCTIONS (Operation codes 50 - 57)

Operands:	None.
Shift control:	None.
Overflow:	Discarded at the left of each of the 4-digit address modifiers.
Rounding:	None.
Register storage:	The contents of register storage is not affected by these instructions.
Blank codes:	Blank codes in the R, S, and T fields represent zero increments.
Address modification:	None.
Interlocks:	None.

50	Change modifiers	Without clearing, add R, S, and T to M4, M6, and M8, respectively
51	Change modifiers	Clear M4 and add R, S, and T to M4, M6, and M8, respectively
52	Change modifiers	Clear M6 and add R, S, and T to M4, M6, and M8, respectively

53	Change modifiers	Clear M4 and M6, and add R, S, and T to M4, M6, and M8, respectively
54	Change modifiers	Clear M8 and add R, S, and T to M4, M6, and M8, respectively
55	Change modifiers	Clear M4 and M8, and add R, S, and T to M4, M6, and M8, respectively
56	Change modifiers	Clear M6 and M8, and add R, S, and T to M4, M6, and M8, respectively
57	Change modifiers	Clear M4, M6, and M8, and add R, S, and T to M4, M6, and M8, respectively

SPECIAL MODIFIER INSTRUCTION (Operation code 58)

58: The 58 code is a hybrid containing properties both of the above mentioned 50 to 57 codes and the 60 and 70 decades of codes described below. It signifies: Add M4' to R putting the sum in M4. If this sum is unequal to S, perform a program transfer to T. If equal to S, continue to the following instruction. This is very useful for terminating loops in which M4 varies, as it performs both the conditional transfer of control and the incrementing of M4.

TRANSFERS (Operation codes 60 - 79)

The following group of instructions have a dual purpose-- (1) to alter the course of the program conditionally, and (2) to move the contents of cathode ray tube storage at a designated address regarded as a 16-digit number to a new location where it can be used more conveniently in a subsequent portion of the program. The number transfer (Meta transfer) may be accompanied by column shifting specified by codes 58.... 99, 00, 01....55 in the P field, 58 specifying a left shift of 42 positions and 55 specifying a right shift of 55 positions.

Operands:	Positive 16-digit numbers (subtraction performed by adding the tens complement of the subtrahend).
Shift control:	Column shift for meta transfers, no shifting for meta subtraction.
Overflow:	Overflow on either side in meta transfers with column shift and the overflow digit "1" in meta subtraction are discarded.
Rounding:	Automatic rounding only with the rounding transfer (62 code).
Register storage:	The result of each meta transfer or meta subtraction is left in register storage; instruction 63 does not affect the contents of register storage.

Blank codes:	A blank operand address denotes that the contents of register storage is to be used, a blank result address indicates that the result is not to be stored in CRT, a blank instruction address in a program transfer designates the current instruction address increased by 1.
Address modification:	Automatic for any CRT address.
Interlocks:	None.

60	Program transfer and meta transfer	R' to S, use T for address of next instruction
61	Program transfer, meta transfer and stop	R' to S, stop after preparing to use T for address of next instruction
62	Program transfer and rounding meta transfer	Round R' unconditionally (after shifting) and store at S, use T for address of next instruction.
63	Program transfer on algebraic sign	Use R, S, or T for address of next instruction if the number in register storage is greater than, equal to, or less than zero, respectively
64	Program transfer and meta transfer on overflow indication	If condition indicator 64 (overflow) is "Off", proceed to next instruction; if condition indicator 64 is "On", reset condition indicator 64, turn on program light 64, and execute instruction 60
65	Program transfer and meta transfer on adjusted index indication	Analogous to 64, using condition indicator 65 (adjusted index) and program light 65 (instead of 64)
66	Program transfer and meta transfer on zero-result indication	Analogous to 64, using condition indicator 66 (zero result) and program light 66 (instead of 64)
67	Program transfer and meta transfer on end-of-file indication	Analogous to 64, using condition indicator 67 (end of file) and program light 67 (instead of 64)
68	Program transfer and meta transfer on tape-check-failure indication	Analogous to 64, using condition indicator 68 (tape check failure) and program light 68 (instead of 64)
69	Program transfer and meta transfer on printer-ready indication	If condition indicator 69 (printer ready) is "Off" proceed to next instruction; if condition indicator 69 is "On", execute instruction 60

70	Program transfer on zero meta difference	If $R' - S' = 0$ (meta difference), use T for address of next instruction
71	Program transfer and stop on zero meta difference	If $R' - S' = 0$ (meta difference), stop after preparing to use T for address of next instruction
72	Program transfer on nonzero meta difference	If $R' - S' \neq 0$ (meta difference), use T for address of next instruction
73	Program transfer and stop on nonzero meta difference	If $R' - S' \neq 0$ (meta difference), stop after preparing to use T for address of next instruction
74	Program transfer and meta transfer on condition switch 74	Turn on program light 74. If condition switch 74 is "Off", proceed to next instruction; if condition switch 74 is set on "Transfer", execute instruction 60; if condition switch 74 is set on "Stop", execute instruction 61
75	Program transfer and meta transfer on condition switch 75	Analogous to 74, using condition switch 75 and program light 75 (instead of 74)
76	Program transfer and meta transfer on condition switch 76	Analogous to 74, using condition switch 76 and program light 76 (instead of 74)
77	Program transfer and meta transfer on condition switch 77	Analogous to 74, using condition switch 77 and program light 77 (instead of 74)
78	Program transfer and meta transfer on condition switch 78	Analogous to 74, using condition switch 78 and program light 78 (instead of 74)
79	Program transfer and meta transfer on condition switch 79	Analogous to 74, using condition switch 79 and program light 79 (instead of 74)

PRINT INSTRUCTIONS (Operation codes 80 - 84)

Operands:	Positive 16-digit numbers.
Shift control:	Column shift for meta transfers.
Overflow:	Overflow on either side is discarded in meta transfers with column shift.
Rounding:	None.
Register storage:	The result of each meta transfer is left in register storage.

Blank codes:	A blank operand address denotes that the contents of register storage is to be used, a blank result address indicates that the result is not to be stored in CRT, a blank instruction address designates the current instruction address increased by 1.
Address modification:	Automatic for any CRT address.
Interlocks:	None of these instructions is executed until printer ready is indicated.

80	Print transfer	R' to S, use T for address of next instruction
81	Print 1	R' to S, print on Printer 1, use T for address of next instruction
82	Print 2	R' to S, print on Printer 2, use T for address of next instruction
83	Print 1 with special function	Same as 81, with special function
84	Print 2 with special function	Same as 82, with special function

TAPE INSTRUCTIONS (Operation codes 90 - 98)

Operands:	None.
Shift control:	None.
Overflow:	None.
Rounding:	None.
Register storage:	The end-of-block word or end-of-file mark is left in register storage after read and verify instructions, other tape instructions do not affect the contents of register storage.
Blank codes:	Blank R and S fields in write instructions indicate that an end-of-file mark is to be written, blank R and S fields in read and verify instructions

designate that the block is to be read and checked but no words are to be stored in CRT; a blank T field in write instructions assigns the block number 0000 (blank) to the block, a blank T field in read and verify instructions denotes the next block on the tape.

Address modification:	Not automatic.
Interlocks:	Write, delete, read, and verify instructions are not executed until printer ready is indicated and the tape unit involved is not rewinding.
90 Write	Write the words from the consecutive CRT addresses R through S on tape P as block T (R equal to or less than S)
91 Write Output	Same as 90, and leave a blank space on the tape between groups of 100 words
92 Delete	Delete the information on tape P in a space corresponding approximately to a block of length (S-R) words written by instruction 90
93 Delete Output	Delete the information on tape P in a space corresponding approximately to a block of length (S-R) words written by instruction 91
94 Read forward	Read forward, storing the words of block T from tape P at the consecutive CRT addresses R through S (R equal to or less than S); verify block T
95 Read backward	Read backward, storing the words of block T from tape P at the consecutive CRT addresses R counting downward through S (R equal to or greater than S); verify block T
96 Verify forward	Same as 94, and verify all blocks passed while searching for block T
97 Verify backward	Same as 95, and verify all blocks passed while searching for block T
98 Rewind	Rewind tape P

The T field of the instruction word indicates the block number. The R and S fields designate the first and last CRT storage addresses of the block. The P field indicates the tape address. Tape addresses may range from 01 through 12 with 12 switches provided on the control console so that any one of the 8 tape units may be selected by a given address in the P field. Any tape address refers to just one tape mechanism; but any tape mechanism may be selected by several tape addresses. Tape addresses 01, 02, 11, and 12 may be augmented by multiples of 20 without changing their meaning. Tape addresses 03 to 10 may be augmented by multiples of 10 without changing their meaning.

In the read and verify operations, code 0000 in the R and S fields indicates that the tape will move through the block specified and the words will be checked but no words will be stored in CRT. In read and verify forward operations, if the R field is nonzero and the S field is blank, then the block specified will be read into as many consecutive CRT locations starting at R as there are in the block. No block size check is made in this case. The above is similarly true for read and verify backward instructions except that numbers will be read into consecutive CRT locations <u>counting down</u> starting at R.

Thus if a 100-word block were read (forward) by this instruction:

01 94 0500 0000 0000

it would be read into locations 0500 to 0599. But to get this information into the same locations in the memory by a read backwards instruction, it would require an instruction of this type:

01 95 0599 0000 0000

These instructions are useful in dealing with blocks of unknown length.

In write operations code 0000 in the R and S fields indicates that an end-of-file mark is to be written.

Code 0000 in the T field of write instructions assigns block number 0000 to the block written, but such a block cannot be searched for, since code 0000 in read or verify instructions designates the <u>next</u> block on the tape rather than a block number. Block numbers which can be searched for range from 0001 to 9999.

OPTION SWITCHES

There are six option switches, switches 74 to 79, located on the console. Each of these can be manually set to one of three positions: off, transfer, or stop. There are six corresponding operation codes (Q field codes 74 to 79) whose meaning depends on the position of the manually set switches.

If option switch 7X (X = 4, 5,....9), is set to the off position, then an instruction with an operation code 7X will be ignored and control will pass to the next consecutive instruction.

If the switch is set to the transfer position, then a corresponding instruction will be operated as a 60 code, that is, a meta transfer and program transfer.

If the switch is set to the stop position, a corresponding instruction will be operated as a 61 code, that is, a meta transfer, program transfer and stop.

The use of any of the 7X codes when the corresponding switch is set to transfer or stop, will also turn on a light, called a program light, on the console. This light will remain on until manually reset by depressing a button on the console.

CONDITION SWITCHES

Similarly, there is a group of Q codes, 64 to 68, whose meaning, however, depends primarily on an internal condition arising during computation, rather than a switch. For example, the 68 code will be operated as a 60 code provided that a tape check failure has occurred. Otherwise, the 68 code will be ignored and control will be passed on to the following instruction.

When a tape check failure occurs, an indicator, called a condition indicator, is turned on and a condition light is turned on at the console. The operation of a 68 code resets the condition indicator and turns off the condition light. However, it also turns on a program light which remains on until manually reset so that one can see if a tape check failure occurred at all.

The above is similarly true for the following conditions:

64: Overflow indication. If a specified index special arithmetic code causes overflow of nonzero digits on the left, this indicator is turned on.

65: Adjusted index indication. If a specified index standard arithmetic code would cause overflow of nonzero digits on the left, then, since such overflow is not permitted under standard arithmetic codes, the index is adjusted and the high order 13 significant digits are retained. When this occurs, the adjusted index indicator is turned on.

66: Zero-result indicator. If the result of a standard or special arithmetic code (the 20 and 30 decades of codes only) is zero, this indicator is turned on.

67: End-of-file indicator. If an end-of-file* mark is encountered during reading or verifying, or if an end-of-file* label is encountered during writing or deleting, the end-of-file indicator is turned on.

Each of the above condition indicators and condition lights may also be reset by manually depressing a button on the console. This is not normally done.

There are also five condition switches associated with the above five conditions. They are also on the console and can be set to one of two positions, proceed or stop. All that has been described above will occur when the corresponding switches are

*See section on Tapes

set to the proceed position. If these switches are set to the stop position, the machine will stop as soon as the condition occurs.

There is also a 69 code which functions just as the codes 64 to 68, but on a printer ready indication. However, there are no condition or program lights or condition switches associated with this condition. If the printer ready signal is on at the time the calculator cycles to this operation, the 69 code will be operated as a 60 code; otherwise the 69 code will be ignored and control passed to the following instruction.

PRINTING

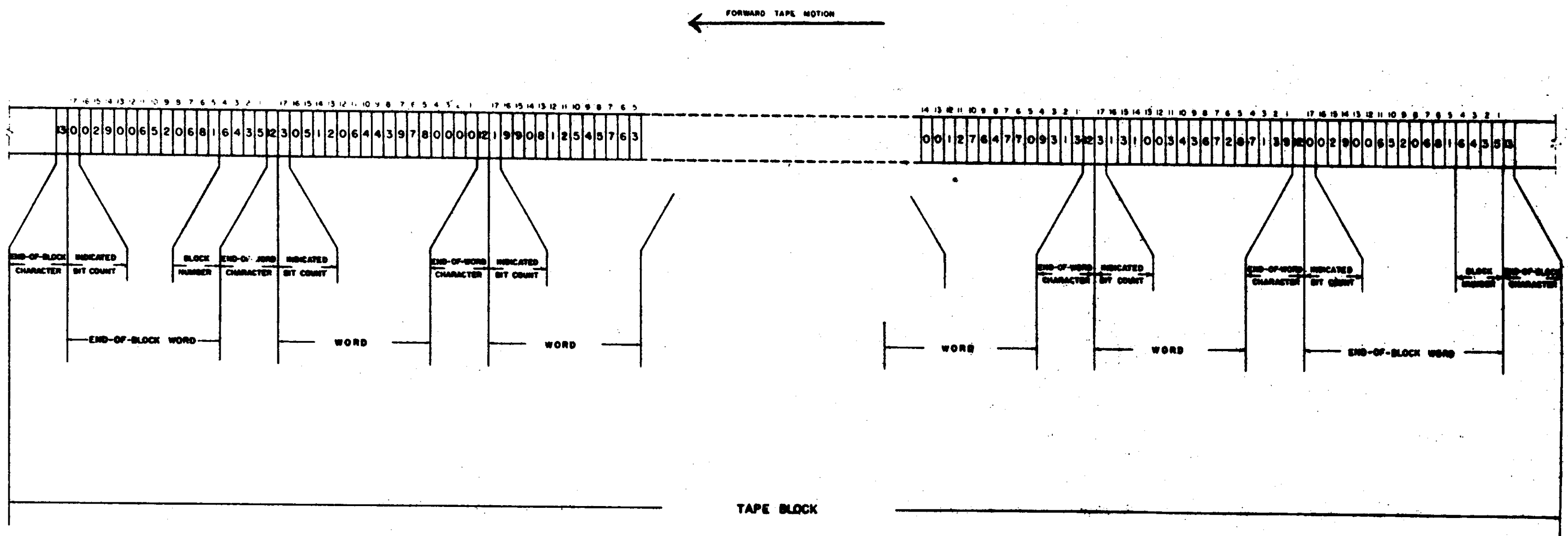
Two printers, printer A and printer B, are incorporated in the calculator. However, the print instructions make reference to printers 1 and 2. Jackplugs on the plugboards of printers A and B designate whether that printer is printer 1, printer 2 or even both, but without duplication. Printing cannot be done on both printers simultaneously; only one can be operated at a given time. One line of printing on either printer comprises 120 column positions.

When a print instruction is given, the 112 digits in CRT locations 0001 through 0007 are transmitted to the printer. These, or as many of these as desired, are printed on one line along with any minus signs, decimal points, blanks, digits or alphabetic characters generated in the printer and provided for by printer control panel (plugboard) wiring.

The printers run on a basic 400 millisecond cycle. Only during the first 170 milliseconds of this 400 millisecond cycle is the data transmitted to the printers from CRT. But the printers are not synchronized with the program so that it may take from 0 to 400 milliseconds before the transmission of data will start. A print cycle, that is the period from the time printing is called for until all the data is received by the printer, therefore requires between 170 and 570 milliseconds. During this period, computation will be interrupted for only 10 one-millisecond intervals when the data is being transferred to the printer. However, all tape instructions except rewinding will not be executed during this period, and if called for, will stall the calculator until the print cycle is completed. The coder should bear this in mind when deciding how to alternate tape and printer instructions.

CRT locations 0001 through 0007 should remain unchanged during a print cycle; should they be changed, incorrect information will in all likelihood be transmitted to the printer, and a printer check failure will occur. A print transfer instruction (Q code 80) is provided to facilitate the loading of CRT locations 0001 to 0007. This is a program and meta transfer which is interlocked so that it will not be operated until the current print cycle is completed. That is, if a print cycle is in progress and an 80 code is to be operated, the machine will stall until the printer ready indication is signalled, indicating the completion of the print cycle, and then the 80 code will be operated.

The 81 print code is similar to the 80 code but it also calls for a line of printing on printer 1 (after the meta transfer is executed). The form of this line of printing is dictated by the wiring of the printer plugboard.



NOTES

1. DIGITS OF WORDS REPRESENTED IN THIS LAYOUT ARE FOR SAMPLE PURPOSES ONLY
2. THE END-OF-BLOCK CHARACTER IS ALWAYS A "13" AND THE END-OF-WORD CHARACTER IS ALWAYS A "12"
3. THE DISTANCE BETWEEN ADJACENT DIGITS IS NOT DRAWN TO SCALE
4. DIGIT POSITIONS ARE INDICATED IN THIS FIGURE BY THE CONSECUTIVE NUMBERS ABOVE THE DIGITS. HIGHER DIGIT SIGNIFICANCE IS EQUIVALENT TO HIGHER DIGIT POSITION

ARRANGEMENT OF INFORMATION ON STORAGE TAPE

Code 83, the special function print code for printer 1, may be used to provide a different form of printed line. This code differs from the 81 code only in that an additional impulse arrives at the printer plugboard. This impulse can be wired to provide, for example, vertical and/or horizontal spacing different from that provided by the 81 code.

Corresponding to codes 81 and 83 for printer 1, are codes 82 and 84 respectively for printer 2.

THE NORC TAPE SYSTEM

Information is stored on magnetic tape in four parallel tracks of weights 1, 2, 4 and 8. The non-return-to-zero system of recording is used; each change of flux irrespective of polarity represents a zero. The information is transferred to and from the tape, serial by decimal digit, at the rate of one digit per 14 microseconds. For all operations the tape moves at the rate of 140 inches per second. The bit density on tape is 510 bits to the inch thus yielding an information rate in excess of 70,000 digits per second.

As recorded on the tape, a block of n words (normally $1 \leq n \leq 2000$) appears as follows: Actually n + 2 words are recorded. The extra two words, called end of block words, are written such that one precedes and one follows the n information words. The low order 4 digits of the end of block words constitute the block number assigned the block and identify it as such when searched for by the NORC or CTC. Separating each word of the block is a "12" character (8 and 4 bit = 1) and terminating the block at both ends is a "13" character. Since each recorded word consists of 17 digits, the 16 decimal digits and the indicated bit count, then a total of 18(n + 2) + 1 digits are recorded for each n word block. When a block is written in the machine by an instruction of the type

P 90 R S T

i.e., write on Tape P, words from consecutive CRT locations R through S as block T, the end of block words and "12" and "13" characters are recorded automatically. In this case, the end of block words are the instruction that wrote the block. Thus not only the block number, but the range of CRT addresses (R through S) from which the block was written is specified in the end of block words.

There is a space, the interblock space, of about 1.5 inches between blocks. In the 10 milliseconds allowed the tape to get up to speed, the tape moves about .75 inches. Since the tape must be moving at full speed to read information correctly, when the tape is at rest the read-write head must be .75 inches from the end of the block. Since the tape can be read in either direction, the read-write head must be .75 inches from the block behind it as well as the block ahead of it, fixing the minimum interblock space at 1.5 inches.

Erasing is accomplished by passing the tape over an erase head which supplies an alternating field at each of two gaps spaced .75 inches from each other. The distance from the read-write head to the nearest gap is 1.6 inches. Information can be written on tape in the forward direction only and the tape passes the erase head before it gets to the read-write head. When writing is started at the front end of a tape, a delay is introduced which leaves a blank space approximately three times as long as the normal interblock space in front of the first block. This initial delay insures that the front end of the first block is covered by the erase head when the writing of a new series of blocks is started again at the front end of a tape. Thus previously used tape can be used since it will be erased clean as new information is recorded.

The use of a 2-gap erase head permits the interspersing of read and write commands even though magnetically unclean tape is used. After reading information that has been recorded, the tape unit can be positioned for further writing by reading through the last block written. The use of two gaps, each of which performs a complete erase, eliminates the possibility of leaving small bits of old information unerased because of the mechanical tolerances involved in repositioning.

It should be noted that it is not possible to write over any currently written blocks. When in position to do so, the front part of the block to be overwritten is already between the read-write head and the erase head so that it would not be erased before writing.

However, it is possible to obliterate a block by means of the delete code. This is normally applicable only to the last written block. The tape is positioned for the delete operation when the block to be deleted will be the first one encountered by the read-write head if the tape is moved in the forward direction. The delete operation differs from the write operation in that the read-write heads are turned on immediately while the tape is still stationary and the heads are not permitted to switch polarity but saturate the tape in the direction in which they were turned on. This insures smearing of the very first digits of the block to be deleted. A deleted area of tape is ignored by the read-write head just as an erased region. The delete instruction indicates the length of tape to be deleted. It reads

P 92 R S T

i.e., delete on tape P a length of tape corresponding to S-R words. The T field is irrelevant since deletion begins at the point where tape P is resting.

In the case of deleting a very short block, it is conceivable that mechanical tolerances in positioning the tape for the delete operation may make it possible for a portion of the old block to escape obliteration. To safely avoid this, it is recommended that the tape be moved until that portion of the tape that was under the nearest erase gap at the commencement of the delete operation pass under the read-write head. Since the distance between the read-write head and nearest gap is 1.6 inches and .75 inches is traversed during the 10 milliseconds start time, it is desirable to delete for a minimum of .85 inches (about 25 words).

End of Tape Labels and End of File Labels and Marks

Several aluminum foil labels are placed on the plastic side of each reel of tape and are sensed on by photo-cells with which each tape unit is equipped. The labels serve to position the tape and to prevent running all the way off a reel.

There are 2 photocells, an end of tape cell and an end of file cell, located on each tape unit and each photocell scans half the width of the tape only. The aluminum foil labels on that half of the tape scanned by the end of tape cell are called end of tape labels, any labels on the other half are called end of file labels.

Whenever an end of tape label is sensed by the end of tape cell, the tape unit comes to a halt. One end of tape label is always placed near the beginning of each reel of tape. This end of tape label is called the load label. The tape unit is at its rewind position when it comes to a halt after sensing the load label. Care is taken during manual loading of a tape reel on a tape unit so that just as in normal machine operation, the load label is sensed while the tape is moving backwards. Thus the tape comes to rest in essentially the same position whenever rewound.

If an end of tape label is encountered during any tape operation other than rewind, the calculator, as well as the tape unit, stops.

At the other end of the tape another end of tape label is placed to prevent running off the far end of the reel. Preceding this label by about 110 inches, but on the other half of the tape width, is an end of file label. Its purpose is to give warning of the approaching end of tape. It is sensed <u>only</u> when writing or deleting. When the end of file cell senses the end of file label, the end of file indicator is set and normally neither the tape unit nor calculator is halted. This setting of the end of file indicator can be sensed by the coder (operation code 67) and a transfer of control can be made to take appropriate action. Enough space is left between the end of file and end of tape labels to complete the writing of the current block and to write an end of file <u>mark</u>.

An end of file mark is a block on tape written by an instruction of the following form:

P 90 0000 0000 T

As it appears on tape this block consists only of this instruction along with its indicated bit count and terminated on both ends by a "13" character. Note that this end of file mark differs from a one-word block which appears on tape as three words, the two end of block words as well as the information word. The end of file mark consists only of the single end of block word.

It is used to indicate the termination of a file of information blocks on tape. When sensed, the end of file mark sets the end of file indicator just as the end of file label does, but the end of file mark is only sensed during read or verify operations just as the end of file label is only sensed during write or delete operations. Unlike the end of file label, when an end of file mark is encountered, the tape unit comes to a halt.

To repeat, normally the setting of the end of file indicator (either the label or the mark will do this) will not also signal the calculator to halt, but if the coder desires this, a switch on the console is provided.

In particular, an end of file mark should be written to terminate a sequence of blocks which are to be converted to cards on the C-T-C. The C-T-C will signal and stop after reading an end of file mark.

If an instruction is given to read or verify a block, and an end of file mark is encountered before reaching that block, the tape unit halts after the end of file mark and only the end of file indicator is turned on; a tape check failure is not signalled.

Card to Tape to Card Machine

The Card-to-Tape-to-Card machine contains its own CRT storage unit with a capacity of 100 words, a tape unit interchangeable with the other NORC tape units, and a modified 519 reproducing punch. When transcribing data from tape to cards, the CTC reads a block from tape, including the end of block words, into its CRT memory and then punches four words on a card at the rate of 100 cards per minute. End of block words are distinguished by X punches on the cards.

Since the capacity of the CTC's memory is but 100 words, provision must be made for transcribing blocks larger than 98 words. (A 98 word block plus the end of block words would fully occupy the CTC memory.) After the CTC reads 100 words, the tape unit must stop and wait until the corresponding 25 cards are punched. But 1.5 inches of tape is traversed while stopping and starting and any information written there would be lost. To avoid this difficulty, a write-output instruction (code 91), is included in the machine. This differs from the write instruction only in that for blocks larger than 98 words, a space of about 1.5 inches of blank tape called the sub-block space, is left between groups of 100 words (including end of block words). These groups are called sub-blocks; all sub-blocks of a block but the last, contain 100 words. The last may contain, of course, 1 to 100 words. The CTC can then transcribe data from such tapes without loss of information.

When the NORC reads a block written by a write output instruction, the tape units do not stop in the sub-block space; there is no difference (except the additional time to traverse the sub-block spaces) between the reading of standard written blocks and write output written blocks. Except in cases of test or emergency, the NORC tape units do not stop within blocks.

Corresponding to the write output operation, a delete output operation (code 93) is included, which deletes a space corresponding to S-R words written by a write output instruction.

For fickle or forgetful coders, a write output switch is provided on the console. When set to the "on" position, all write and delete codes will be performed as if they were write output and delete output codes.

For transcribing data from cards to tape, four words are keypunched on each card. The end of block words must be included on the cards. They are distinguished by X punches in appropriate columns as noted below. If the blocks are to be searched for in the machine, the T field of the end of block words must contain the block number. Other information, such as the length of the block, might well be included in the end of block words. In this way, the program may determine the length of the block, since the end of block word is available in register storage for use by the program whenever a block is read, with or without storing.

At present, as the plugboard in the CTC is wired, the four words per card (64 digits) are punched in card columns 12 to 75. An X punch in column 12 designates the word punched in columns 12 to 27 as the first end of block word. This first end of block word, that is the end of block word that the read-write head first encounters when the tape is moving in the forward direction, is often called the beginning of block word. An X punch in either of columns 27, 43, 59 or 75 designates the 1st, 2nd, 3rd, or 4th word respectively as the terminating end of block word. The information card columns 12-75 should not contain blank or double punched columns except for the X punch denoting beginning or end of block words. New blocks must be started on new cards.

Blocks of any size desired may be punched. For blocks larger than 98 words, sub-block spaces will be included automatically and the appearance on tape of CTC-made blocks will be the same as write output written blocks.

It is often desirable to pack input and output data, whenever possible, so as to make more efficient use of the CTC and printers. Several factors contribute to this consideration among which are:

1. For many problems the computer processes information much more rapidly than the relatively slow input-output devices.

2. Inefficient use of the monitor printers can effectively slow the NORC since too frequent printings may cause the machine to spend much time waiting to print information. Furthermore, the operation of tape instructions other than rewind, is delayed until any current print cycle is complete.

TRUNCATING TRANSFER

The truncating transfer code:

P 39 R S T

is particularly useful for multiple precision arithmetic operations.

It is performed by treating the decimal coefficient of S' as the 13 low order digits of a 26 digit number whose index, sign, and high order digits are represented by R'. This 26 digit number is shifted under control of the index procedure designated in the P field. After shifting, the 13 high order digits together with index and sign are available for readout. This is useful for lining up the operands before performing a double precision addition, for example.

However, in the event that R' is zero, then the coefficient of R' will be treated by the truncating transfer as the low order digits of a 26 digit number whose index, sign, and high order digits are represented by S'. A use for this feature may be illustrated by considering the double precision subtraction of two numbers whose high order parts are identical. This yields a zero for the high order part of the sum. The index of this high order part is also zero. Now, unless the indices of the high order parts of the operand were zero, a truncating transfer of the sum would yield an answer with the wrong index. But since the truncating transfer interchanges R' and S' in this case, the correct answer is obtained.

AUTOMATIC CHECKING FEATURES

The automatic checking provisions in the NORC employ a bit-count-modulo-four system for checking the CRT storage, the universal registers, the tape units, the printers, the card-to-tape-to-card machine, and the transmission channels interconnecting these units. Arithmetic operations are checked by the use of an independent computer in the NORC which operates in the number-modulo-nine system.

In general, transmission and storage of words is checked by use of the bit-count-modulo-four, and arithmetic is checked by the number-modulo-nine computer with the two checking systems being arranged to provide continuity of checking at the transition points between the systems.

The bit count modulo four for each word is initially evaluated at the card-to-tape-to-card machine where its 3's complement is recorded on the magnetic tape as the seventeenth digit of each word. This recorded count is referred to as the "indicated bit count". From there the indicated bit count is carried with the word through the transmission and storage channels of the calculator and is modified appropriately when the word is modified. When a word passes into the arithmetic section of the calculator, it comes under the number-modulo-nine check--the latter check taking over when the bit-count check leaves off. When a word leaves the arithmetic section, the indicated bit count is resumed at the point the final number-modulo-nine check is made. When a word reaches one of the outputs of the calculator (the card-to-tape-to-card machine or the printers), the bit count is again evaluated and compared with the indicated count.

In addition to the final comparison between the word and its indicated bit count, intermediate comparisons are made whenever the word is transferred between CRT storage and any other portion of the calculator or whenever it is regenerated within CRT storage.

The checking procedures used in the different parts of the machine are listed in the following table and discussed in the subsequent paragraphs.

List of Checking Procedures

	Unit	Checking System
1.	CRT (word check)	Bit count modulo four
2.	CRT (column check)	Bit count modulo two
3.	Registers	Bit-count-modulo-four inventory Greater-than-nine test
4.	Card-to-Tape-to-Card	Bit count modulo four
5.	Tape Units	Bit count modulo four Digit count Greater-than-nine test Block number Block size End of tape
6.	Printers	Bit count modulo four from echo pulses
7.	Arithmetic Section	Number-modulo-nine computer Greater-than-nine test Zero Divisor Check Index Check
8.	Control Section	Operation Code Check Sign Check

Any of these failures occurring during normal operation, with the possible exception of tape check failures, will stop the machine as soon as they are detected, lighting appropriate lights. Switches are provided on the console to permit the calculator to continue running when failures occur, but this is normally done only during testing and trouble-shooting. However, coders often choose not to stop when a tape check failure occurs and use standard subroutines to try to correct these errors. Such subroutines include rereading a block when an error has occurred on first reading, in the expectation that such errors are intermittent and deleting and rewriting the last written block to bypass faulty spots on tape. Coders differ in their approach to tape check failures, depending upon how and how much the tapes are used in a particular problem and the coder's feeling of security about the tapes.

1. <u>CRT Storage</u> (word check)

The input-output lines of CRT storage are connected to a parallel bit counter which performs a bit count modulo four on a word in approximately three microseconds. Each read-in, read-out, or regeneration of a word is checked by evaluating its bit count modulo four and comparing it with the indicated count. This parallel bit counter is used to verify the indicated bit count of all words connected to the CRT lines but is not used for the initial evaluation of an indicated count. Errors detected during read-in are distinguished from those detected during read-out or regeneration to differentiate between those originating in memory and those originating elsewhere.

The parallel bit counter also applies a greater-than-nine check to the digits of words entering, leaving, or being stored in CRT. This feature provides additional general protection and detects any end-of-word characters which may enter CRT from tapes as the result of loss of digits on tape.

2. CRT Storage (column check)

This check, although essentially a diagnostic one, is included in this discussion because of its relationship to the CRT word check.

For diagnostic purposes a continuous odd-even count (bit count modulo two) is kept for each of the sixty-six binary columns of the 2000-word storage. This count for each column is stored on one of sixty-six external latch circuits which are referred to as the "column-check indicators". During normal operation, these indicators are read into only during a CRT read-in. A CRT read-in which changes the number of bits in a given binary column changes the state of the indicator for that column. The indicators are set up initially by being cleared and read into for a full CRT regeneration cycle. If, during operation of the calculator, the word check indicates an error in a word in CRT, the location of the error is obtained by again reading into the indicators for a full regeneration cycle. An indicator which does not return to its cleared state indicates a binary column whose contents have been changed by other than a normal read-in. If a single error has been made in the CRT, that error may be corrected by altering the contents of the binary position indicated by the word check and the column check.

3. Registers

Each of the three registers has an extra half digit of storage for the indicated bit count. During all phases of most operations, the contents of these bit-count stores correspond to the contents of the registers.

Register 1 and register 2 have modulo-four-bit-count computers which maintain a continuous inventory on the contents of each register by changing the indicated bit count as the number in the register is changed. Parallel read-in of a word and its indicated count from CRT to the register replaces the previous word and its count with the corresponding new values.

Transmission of the new word and its indicated count from CRT to register is checked after the word is in the register by temporarily connecting the register output to the CRT lines and the parallel bit counter. Parallel read-out of a word and its indicated count from the register to CRT causes the CRT to accept the word and indicated count without altering the contents of the register or its bit-count store. For serial transmission to or from the register by right or left shifting, the bit count of any digit shifted out is subtracted from the indicated bit count of the word, and the bit count of any digit shifted in is added. Also, a greater-than-nine test is applied to digits shifted out. Changes in index or in sign, or forcing a "1" in rounding alters the indicated count appropriately.

In the instruction register the treatment of the indicated count is the same as in the other registers for parallel read-in or read-out, but no special computer is used since the word in the instruction register is always changed in its entirety.

4. Card-to-Tape-to-Card

In card to tape operation, the first card reading station reads the 16 digit words from the input cards and evaluates the indicated bit counts of the words. At the second card reading station the 16 digit words are read again and transmitted to the CRT storage along with the indicated bit counts evaluated at first reading. When this information is transmitted from CRT to the tape unit, the indicated bit count of the word is re-evaluated and checked against the indicated bit count in CRT. After the tape is made, it is rewound and then verified forward. (Tapes cannot be verified backward on the CTC.) This verification re-evaluates and checks the indicated bit counts of the words.

In tape to card operation, each word (including the indicated bit counts) is read to CRT. Each time the CRT storage is regenerated, the indicated bit count is re-evaluated and checked. When transmitted to the punch unit from CRT, the indicated bit count is stored in relays at the punch unit, while the other 16 digits are punched in an output card. (The indicated bit count may also be punched on the card, if desired.) The output card then passes another reading station; its indicated bit count is evaluated and checked against the stored indicated bit count.

5. Tape Units

The tape units are used in conjunction with register 1 to read blocks of words from tape to CRT or from CRT to tape. In the first process each word and its indicated bit count is transmitted from the tape unit through register 1 to CRT storage. As each word is read from the tape, it is checked for number of digits by use of the end-of-word characters; as it enters CRT, it is checked against its indicated bit count by the parallel bit counter. The instruction word controlling the tape-reading process specifies the CRT addresses of the first and last words (not including the end-of-block words) of the block being read into memory. After the address counter has reached the address specified for the last word, the next word on the tape is automatically checked for an end-of-block character and for the correct block number.

In the process of reading a block of words from CRT to tape, the words and their indicated bit counts pass consecutively from CRT through register 1 to the tape unit where they are recorded on the tape. At the parallel output of the register, the words and their indicated bit counts are checked by the parallel bit counter.

In summary then, the following checks are performed when a block of information is read or verified into the CRT memory:

(1) Bit Count modulo four check

(2) 17 digits per word

(3) Greater than nine check

(4) Block size is same as specified by read or verify instruction.

(5) Block number is same as specified by read or verify instruction.

If any of these failures are detected while a block is being read into the CRT memory, storing ceases as soon as the error is detected.

If a word fails one of checks 1, 2, or 3 above, it will not be stored in CRT. If the block length specified is smaller than the actual block size, only as many words as called for will be stored; if the block length specified is larger than the actual block size, only as many words as are in the block will be stored. In any case, the tape moves through the end of the block and the end of block word is retained in register storage.

When a block is read or verified without storing or is an intermediate block passed over during a verify operation, only the first three of the above tests are applied.

If an intermediate block causes a tape check failure during a verify operation, the tape will stop at the end of the bad block and its end of block word will be retained in register storage.

(6) End of Tape Check failure. If an end of tape label is encountered during a tape operation other than rewind, the tape unit and the calculator halt and an end of tape check failure is indicated by a light on the console.

6. Printers

In the printing operation the words in CRT storage positions one through seven are transmitted consecutively through register 1 to one of the printers at ten different times as called for by the printer. An indicated bit count accompanies each of these words and the seven indicated counts are stored in the printer. After the printing has been completed, the echo pulses from the print wheels operate seven modulo-four bit counters whose results are compared with the stored bit counts from CRT. Should a printer run out of paper, a format stop will be signalled and the calculator will halt.

7. Arithmetic Section

The arithmetic operations of the calculator excluding meta arithmetic are checked by a number-modulo-nine computer whose inputs are the numbers modulo nine of the input terms of the arithmetic operation. The check is obtained by performing the nominal operation with the modulo-nine computer and comparing its output with the number modulo nine of the result of the arithmetic operation.

In operation the numbers modulo nine of the input terms are evaluated as the terms are shifted serially out of registers 1 and 2. As each digit of a term is shifted out of a register, its value is added to a number-modulo-nine counter, and its bit count modulo four is simultaneously subtracted from the indicated count of the register. After the read-out from the registers is completed, the contents of the modulo-nine counters are used as inputs for the modulo-nine computer.

The output of the modulo-nine computer is compared with the number modulo-nine of the computed result evaluated at the input of the result register. As each digit enters the register, its value is added to a number-modulo-nine counter and its bit count is added to the indicated count of the register. After completion of the read-in, the contents of the modulo-nine counter are compared with the output of the modulo-nine computer, and the contents of the register and its indicated bit count are checked by the parallel bit counter.

Furthermore, if a zero divisor is called for in a division, the calculator will halt and signal this occurrence.

If the exponent of the final result of an arithmetic operation should exceed 30 in absolute value then an index check will be signalled, and the calculator will halt. (During the progress of an arithmetic operation, the indices are allowed to change within the limits of -43 through +56.)

8. Control Section

It should be noted that all instructions have operation codes (Q field) in the range 20 to 98. Thus Column 14 of an instruction word contains a digit ≥ 2. Column 14 of a number word, however, is the sign digit and thus has the value 0 or 1. If the calculator should cycle to an "instruction" in which Column 14 is < 2, an operation code check failure will be signaled and the calculator will halt.

Similarly if in a standard or special arithmetic operation, an operand is encountered with its sign digit > 1, a sign check failure will be signaled and the calculator will halt.

SUBROUTINES

Subroutines are written in relatively addressed machine codes starting at any machine location. They may be incorporated in a program by any of the following methods, arranged in order of increasing ease:

(1) They may be recopied on the coding sheets of a problem, simultaneously reorienting addresses to fit the machine locations desired.

(2) An assembly routine, which orients subroutines to specified locations, may be used. This will be described in a separate report.

(3) A compiler routine, which automatically incorporates subroutines in the program as well as performing several other services for the coder may be used. This is also described in a separate report.

Several types of call lines to subroutines have been used, some of which are:

Loc.	P	Q	R	S	T
n	00	60	n	0000	a

or

n	08	60	n	0000	a

where "a" is the first instruction of the subroutine to be operated. In this way the instruction that calls the subroutine is available in register storage and thus the location of that instruction (n) is available to the subroutine.

The subroutine needs this information in order to extract the parameters for the subroutine which are on lines n + 1 and succeeding ones if necessary, and to determine where to return control to when finished.

Another type of call line used is:

Loc.	P	Q	R	S	T
n	00	60	n+1	0000	a

Here location n + 1 must contain the location of the instruction to which the subroutine is to return control.

STARTING AND STOPPING

Before starting a problem, the operator at the console sets all condition, option, and tape code switches as specified by the coder. He also resets the entire CRT memory to zero and resets all program and condition lights and indicators by depressing three buttons.

In order to minimize operator error, standard start and stop procedures have been devised and they are used whenever possible. The nonconformist, however, who wishes to deviate from these procedures is inhibited only by the frowns of the rest of the staff and the necessity for writing out special start and stop instructions. The standard start procedure involves the following:

The tape code assigned the mechanism on which the program tape is placed is 09. Preceding the first program block is a 6-word block of the following form which is read into CRT Locations 0002 to 0007:

0002	09	94	R	S	T	This reads the program block in.
0003		68			0006	If a tape check failure occurs go to 0006
0004		81			Start Line	Transfer control to first line to be operated and print words 0001 to 0007 on printer 1
0005						
0006		61				Stop (if a tape check failure occurred)
0007	Problem Identification No.					

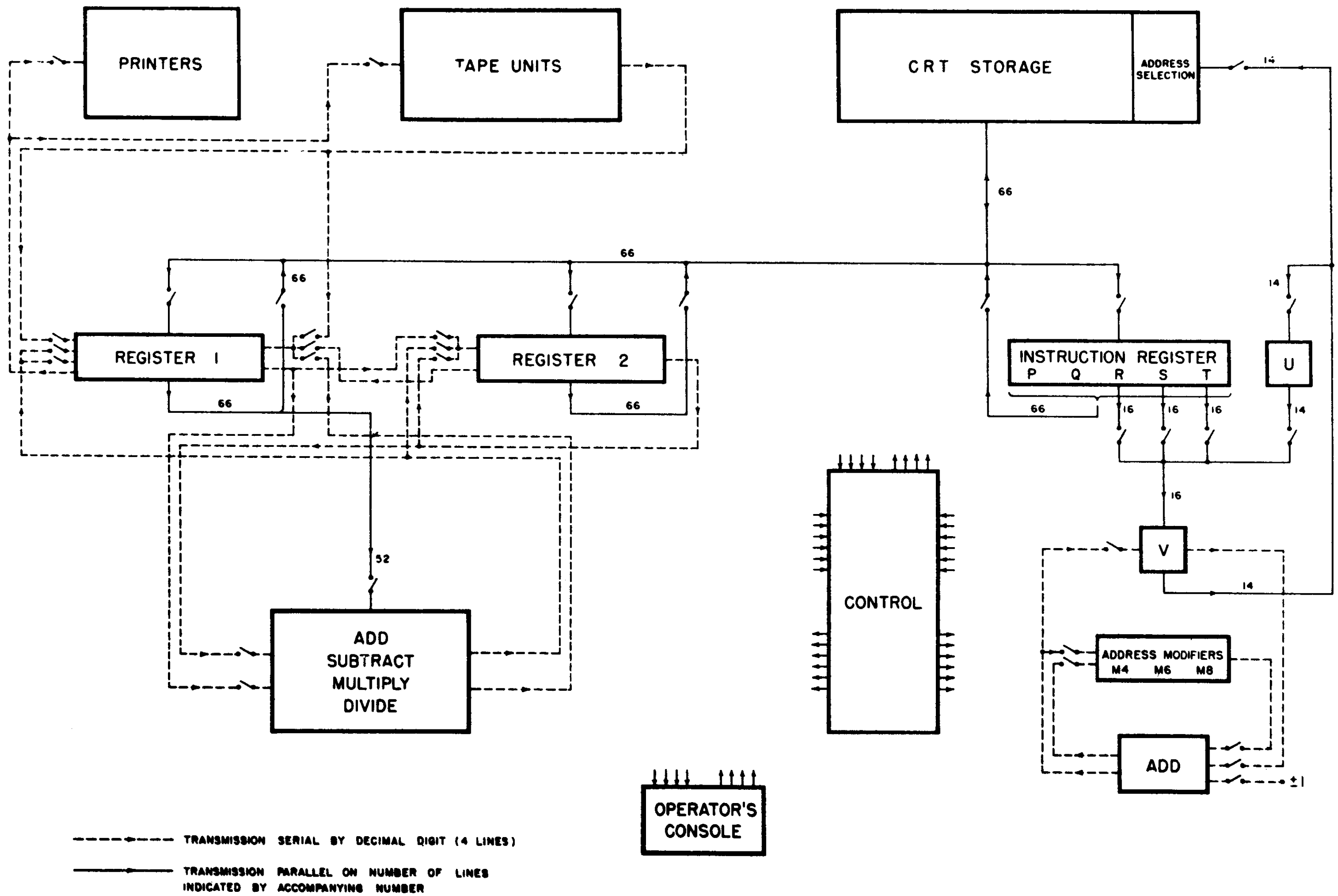
Thus, in order to start any problem, the operator at the console need only:

1. Key into Register 1 (or 2) the following instruction:

   09 94 0002 0007 0000

and load it into CRT location 0001.

2. With the Source of Instruction switch set to V, Start. In this way, the instruction placed in CRT location 0001 is operated first and it reads the standard 6-word block into CRT locations 0002 to 0007. Then the program block is read into the machine; if a tape check failure occurs, the machine stops; if there is no tape check failure, control is transferred to the first line to be operated in the program. Locations 0001 to 0007 are also printed on printer 1, where the problem number and initial instructions can be read and checked.



NORC — GENERAL BLOCK DIAGRAM

Since CRT locations 0001 to 0007 are the locations from which printing is done, these locations are rarely used to store anything other than information to be printed.

The standard stop procedure used to terminate a problem which is presumably successfully completed involves the following:

Control is transferred to CRT location 0001 which is previously loaded with a Stop (61 code) instruction. Other coded stops (arising from mathematical or machine difficulties) should occur at other locations. Thus when a program stop occurs at CRT location 0001, the operator's feeling of security and euphoria is not disturbed.

GENERAL BLOCK DIAGRAM

The general block diagram indicates the relationships between the various sections of the NORC. In order to illustrate the use of the 4-decimal digit V, U, and address modifier registers, the operation of an instruction is briefly traced below:

Consider the division instruction

P	Q	R	S	T
50	26	0125	0126	6001

stored in location 1843. Assume M_6 contains 0089.

The <u>V register is the input to the CRT address selection circuits</u>. Thus, at the start of the operation of this instruction, V contains 1843. The word in CRT location 1843 is then read to the instruction register.

The number in V(1483) is transferred to U. V will shortly be changed but the location of the current instruction must be remembered so that normal cycling may contine to the subsequent instruction. Most of the time, the U register, then, contains the address of the current instruction.

R is then transferred to V. The number in CRT location 0125 is read to Register 1. S is then transferred to V and the number in CRT location 0126 is transferred to Register 2.

The division is performed with the result appearing in both registers 1 and 2.

T is read to V meanwhile, but since T is a number between 6000 and 7999, then the number in V(6001) is added to the number in M_6 (0089) and the sum (6090) stored in V.

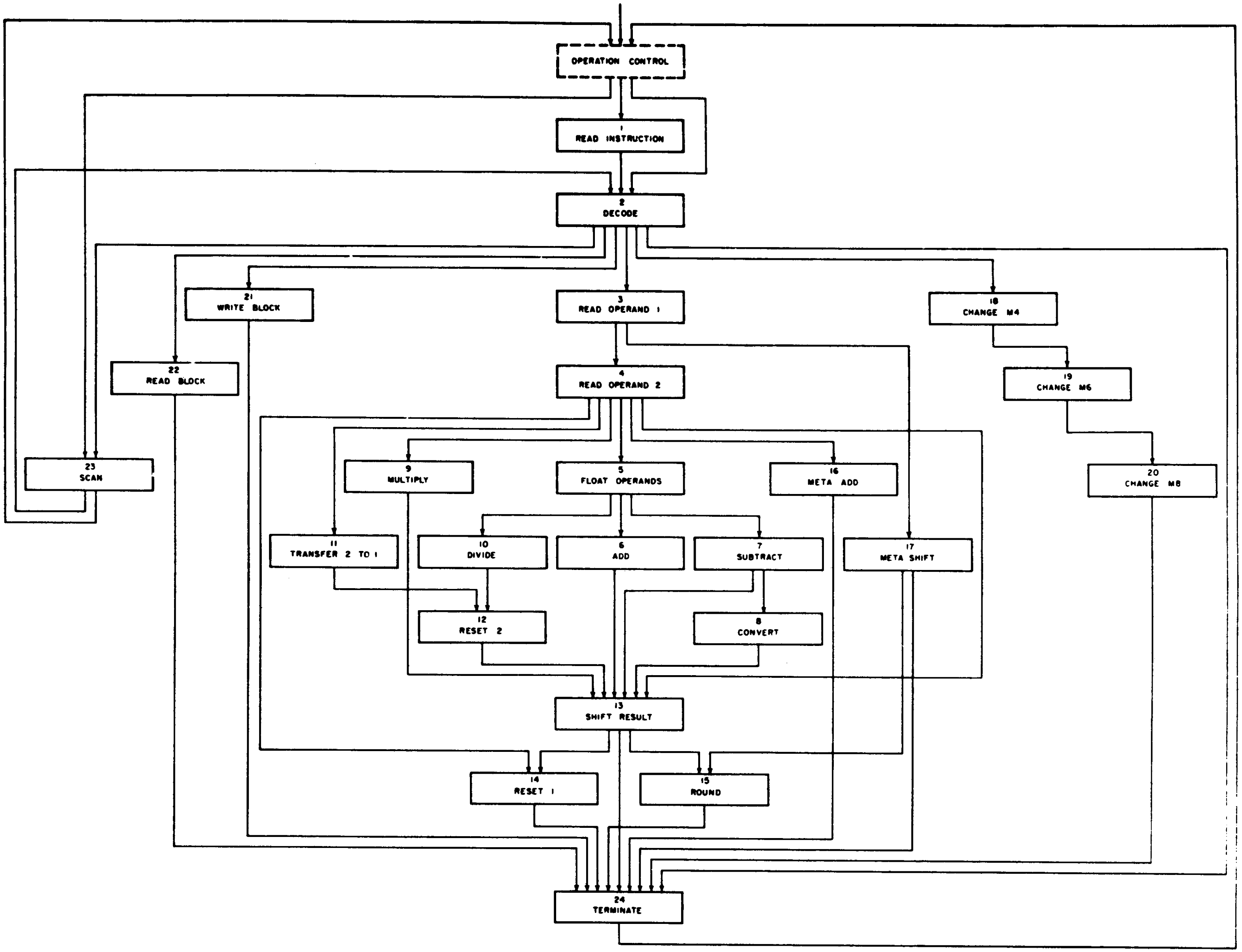
The quotient in register 1 is transferred to CRT location 0090 since

$$6090 \equiv 0090 \mod 2000$$

Since no program transfer is indicated by this instruction, the number in U(1843) is added to 1 and the sum (1844) stored in V. The operation of the next instruction may now begin.

In general, when the machine has stopped after operating an instruction, the number in U contains the address of the instruction just operated which is in the Instruction register

N O R C SUBOPERATIONS — FLOW CHART



and V contains the address of the next instruction to be operated. Registers 1 and 2 contain the result of the operation. All of these, along with the contents of the address modifiers, are displayed at the display panel at the console. They are arranged in the following format; (Parentheses indicate the number of decimal digits)

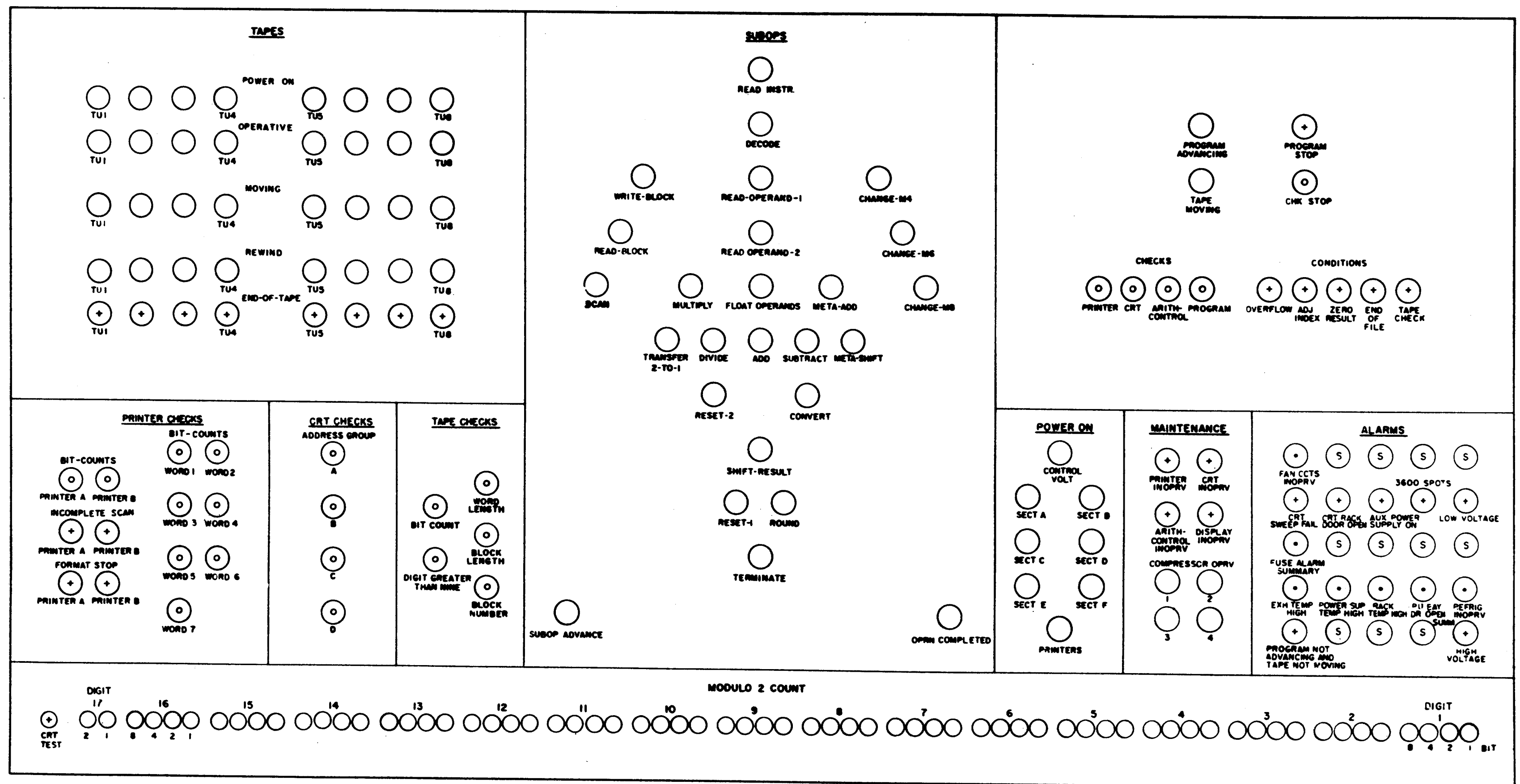
V	U	M_4	M_6	M_8
(4)	(4)	(4)	(4)	(4)

INSTRUCTION REGISTER
(17)

REGISTER 1
(17)

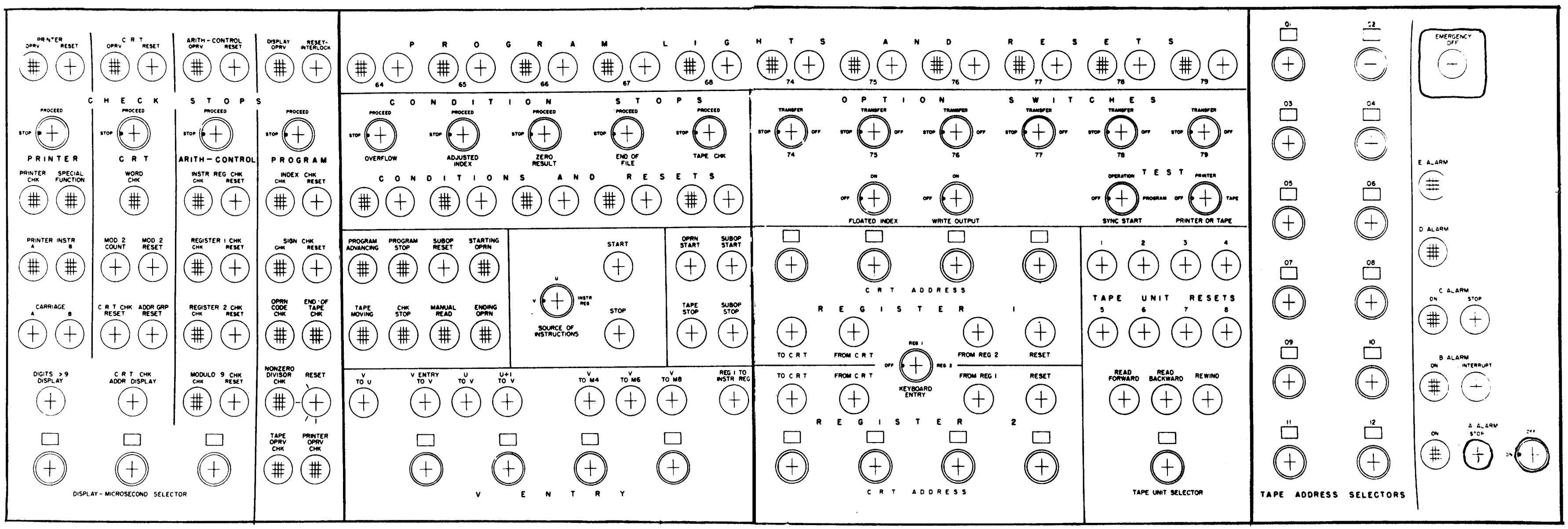
REGISTER 2
(17)

INDICATOR PANEL



- GREEN LIGHT
- AMBER LIGHT
- RED LIGHT
- SPARE LIGHT
- BLUE LIGHT

CONSOLE



LIGHT

PUSH BUTTON

ROTARY SWITCH

SUBOPERATIONS

Each operation in NORC is broken up into a sequence of steps called suboperations. There are some 24 different suboperations. Each operation has a particular path (or paths) through the suboperation ensemble. All possible paths from suboperation to suboperation are indicated by the directed lines in the diagram of the NORC suboperations flow chart.

When the NORC detects an error that causes the machine to stop, say a CRT error detected during regeneration, the machine will stop at the end of the <u>suboperation</u> taking place when the error was detected.

The central panel of the indicator panel (see diagram of indicator panel) contains a set of lights each of which is associated with a suboperation. These lights are turned on when the suboperation they represent is initiated. When the machine stops in the middle of an operation, the lights which have been turned on represent the suboperations already operated.

THE CONSOLE

Several functions, not previously discussed but of interest to the programmer, that can be performed at the console are briefly described here.

A keyboard (not shown in the console drawing) with buttons corresponding to digits 0 through 9 is located at the console. Depressing the digit buttons left shifts into Register 1 or Register 2, as selected by the keyboard entry switch, the corresponding digit.

Near the center of the console are two sections labeled Register 1 and Register 2, each containing 4 ten-position switches and 4 push buttons. The switches can be set to the address of any CRT location. Depressing the "To CRT" button in the Register 1 section, for example, transfers the word in Register 1 to the CRT location specified. Depressing the "From CRT" button transfers the word in the CRT location specified to Register 1. Register 1 can also be reset to zero by depressing the "Reset" button. The "From Reg 2" button will transfer the word in Register 2 to Register 1. All the above is also similarly true for the Register 2 section.

To the left of the Register 2 section on the console is the V entry section. The 4 10-position switches in this section can be set to any value up to 9999, and the "V entry to V" switch will transfer the number in the switches to the V register. V can be transferred to U, M_4, M_6, or M_8 by depressing appropriate buttons. U or U + 1 can also be transferred to V. It should be noted again that at the display panel immediately to the left of the console the contents of the V, U, M_4, M_6, M_8, Register 1, Register 2 and Instruction registers can be seen.

Above the V entry section of the console is a source of instructions switch. When set to the V position, as is normally done, and the Start button is depressed, the machine will begin cycling at the instruction whose address is in the V register. If the operation start button were used, the machine would only execute that instruction and then stop. This, however, is frequently done when the source of instructions switch is set to the U or Instruction Register position. In this case the instruction whose address is in the U register or the instruction in the instruction register respectively would be operated.

To the right of Register 2 section on the console is a tape unit selector switch. This can be set to any of the tape units 1 to 8 (not the tape addresses 01 to 12 but the physical mechanisms themselves). The three buttons above this switch permit one to read forward or backward through the next block (without storing, of course) or rewind the tape unit selected. When one reads a block forward or backward this way, the end of block word is retained in Register 1 only. This ability to manipulate tapes from the console is very convenient.

There is also a floating index switch on the console which when set to the on position will cause the machine to ignore any specified indices in standard or special arithmetic and float all results. It is probable that this switch will almost always be set to the off position.

SAMPLE PROBLEM #173:

The following brief sample problem is only intended to illustrate the use of the NORC operation codes:

A sequence of consecutively numbered blocks, each of which consists of 14 numbers X_o, Y_o, X_1, Y_1, -----X_6, Y_6, is located on the tape unit corresponding to tape address 08. The last of these blocks is followed by an end of file mark.

From each pair X_i, Y_i compute

$$Z_i = \frac{X_i^2 + Y_i^2}{X_i - 1}$$

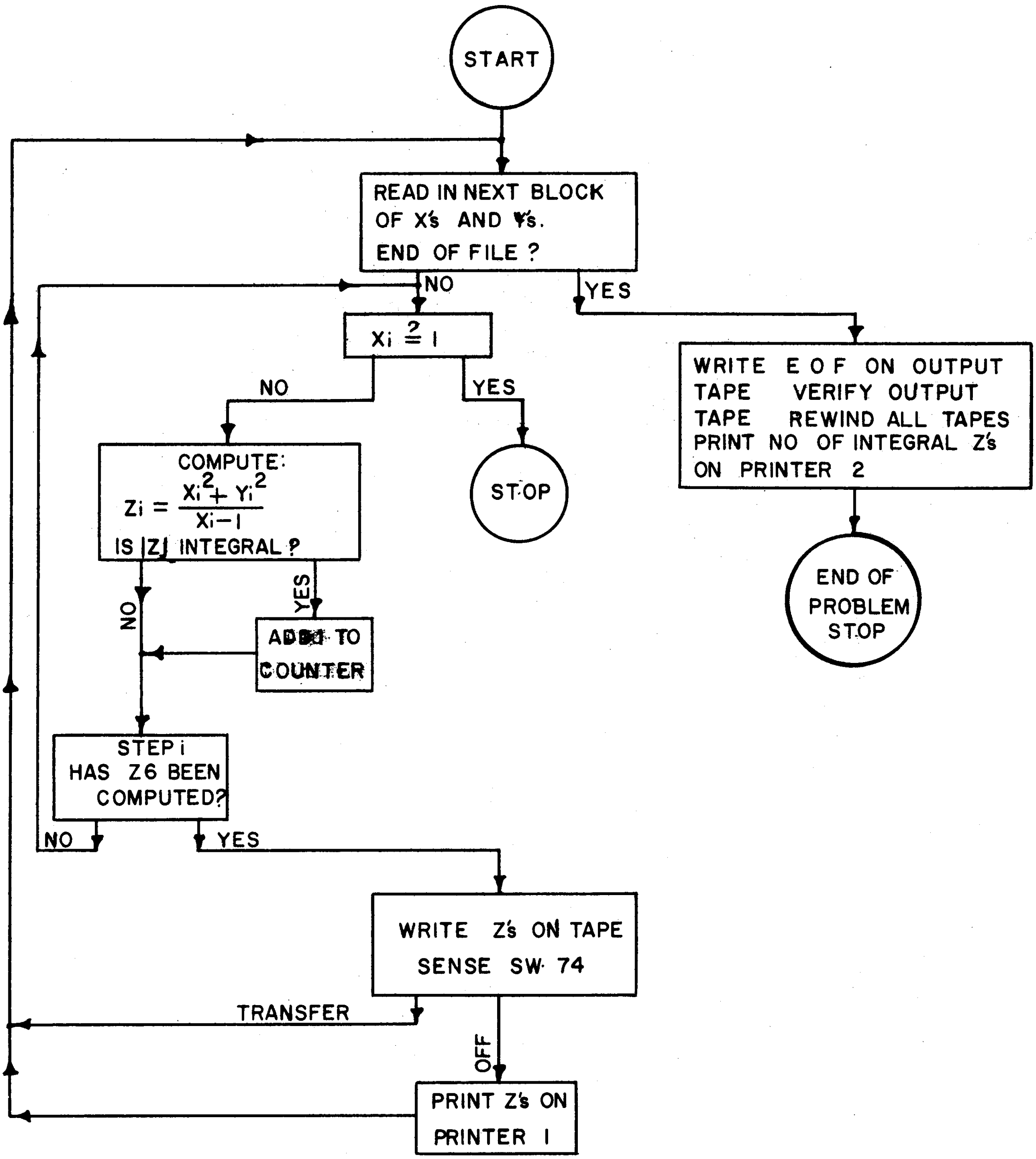
Each group of Z_i's (i = 0 to 6) is written in separate blocks on tape address 01. If option switch 74 is set to the off position they will also be printed on printer 1.

The number of Z's which are integers is counted and printed on printer 2.

The program itself is stored on tape address 09.

These abbreviations are used:

TCF: Tape Check Failure
EOF: End of File



FLOW CHART FOR SAMPLE PROBLEM

EXPLANATION	LOCATION	P	Q	R	S	T
Operator manually loads	0001	09	94	0002	0007	
this instruction into 0001						
Then starts 0001						
This is the first block						
on tape 09						
This reads in Program Block	0002	09	94	0008	0054	
If TCF, transfer to stop line	0003		68			0006
Print 0001 to 0007, transfer to 0008	0004		81			0008
	0005					
Stop	0006		61			
Problem identification number	0007					0173

EXPLANATION	LOCATION	P	Q	R	S	T
Read in X's and Y's	0008	08	94	0060	0073	0001
If end of file sensed, transfer to 0034			67			0034
If tape check failure, transfer to 0045			68	0008	0046	0045
Clear M4 and M8			55			
Multiply $X_i \cdot X_i = X_i^2$ into 0049	0012	50	24	4060	4060	0049
Y_i^2		50	24	4061	4061	
$X_i^2 + Y_i^2$ into 0049		50	20	0049		0049
$X_i - 1$ into register storage only		50	22	4060	0054	
Stop if $X_i - 1 = 0$	0016		71		0051	
$\frac{X_i^2+Y_i^2}{X_i-1} = Z_i$ into loc 0080 + i		50	26	0049		8080
If $Z_i = 0$, transfer to 0023			70		0051	0023
$\lvert 10^{-13} \rvert - \lvert Z_i \rvert$ into register storage.		50	38	0053		
If $\lvert Z_i \rvert \leq 10^{-13}$ $(Z \neq 0)$ transfer to 0024	0020		63	0024	0024	0021
Obtain fractional part of Z_i		99	34	0054	8080	
If not zero, transfer to 0024			72		0051	0024
Add 1 to count register			40	0052	0050	0052
Add 1 to M8	0024		50			0001
Add 2 to M4. If M4 ≠ 14 transfer to 0012			58	0002	0014	0012
Write block of Z_i's		01	91	0080	0086	0001
If printing of Z_i's not desired transfer to 0031			74			0031
$Z_i \rightarrow i$ (M4 = 14 initially)	0028		80	4066	5987	
Add 1 to M4. Until = 20 transfer to 0028			58	0001	0020	0028
$Z_6 \rightarrow 0007$ Print			81	0086	0007	
Increase block number by 1			40	0008	0050	0008
Increase block number by 1	0032		40	0026	0050	0026

NORC CODING SHEET #1
FRNC-NPG-402

EXPLANATION	LOCATION	P	Q	R	S	T
Transfer to 0008	0033		60			0008
Write end of file mark on output tape		01	90			
Verify backwards next block		01	97			
End of file mark should be sensed. If so go to 0038			67			0038
Stop	0037		61			
Verify backwards to block 0001		01	97			0001
Rewind input tape		08	98			
Rewind program tape		09	98			
Rewind output tape	0041	01	98			
If tape check failure occurred, go to stop			68	0038		0037
Print no. of integral z's on printer 2			82	0052	0001	
Put stop code in loc. 0001, transfer to 0001		92	80	0013	0001	0001
Read through next block backwards	0045	08	95			
Reread block that caused failure	[					]
If it failed again, go to stop			68	0008		0037
Return to 0009			60			0009
Temporary location for X_i^2; $X_i^2+Y_i^2$	0049 [					]
	0050					0001
0	0051					
Counter for integral z_i's	0052					
10^{-13}	0053	87	01			
1	0054	00	01			

NORC CODES (Q Field)

Primed Letters (R', S') indicate contents of R, S
Transfer: Shift R' P places into S, go to T for next instruction

Overflow on left not allowed.	Overflow on left permitted.	
Rounded	**Un-Rounded**	**Arithmetic Instructions**
for $39<P<60$	float result	
20	30	R' + S' to T
21	31	- (R' + S')
22	32	R' - S'
23	33	- (R' - S')
24	34	R' x S'
25	35	- (R' x S')
26	36	R' / S'
27	37	- (R' / S')
28	38	$\lvert R'\rvert - \lvert S'\rvert$
29	39	Truncating Transfer R' with S' to T
	40	Meta R' + S'
	41	Meta R' - S'

Modifier Instructions

50 no clearing
51 clear M4
52 clear M6
53 clear M4 and M6
54 clear M8
55 clear M4 and M8
56 clear M6 and M8
57 clear M4, M6 and M8

The 50 to 57 codes add R, S, T to M4 M6, M8 respectively, after any indicated resets.

Print Instructions

80 Print interlock and Transfer
81 Print 1 and transfer
82 Print 2 and transfer
83 Print 1 with special function and transfer
84 Print 2 with special function and transfer
Print X: Print words 0001 to 0007 on Printer X

Logical Instructions

58 M4' + R to M4. If unequal to S go to T, otherwise continue
60 Transfer
61 Transfer and stop
62 Transfer with rounding
63 Program transfer on algebraic sign, +, 0, -.
64 Transfer on overflow indication
65 Transfer on adjusted index indication
66 Transfer on zero result
67 Transfer on end of file
68 Transfer on tape check failure
69 Transfer on printer ready indication
70 Program transfer on zero meta difference of R' and S'
71 Program transfer and stop on zero meta difference of R' and S'
72 Program transfer on non-zero meta difference of R' and S'
73 Program transfer and stop on non-zero meta difference of R' and S'
74 Transfer on condition switch 74
75 Transfer on condition switch 75
76 Transfer on condition switch 76
77 Transfer on condition switch 77
78 Transfer on condition switch 78
79 Transfer on condition switch 79

Tape Instructions

on TAPE P, words R to S, block T

90	Write
91	Write output (space between each 100 words)
92	Delete
93	Delete output
94	Read Forward
95	Read Backward
96	Verify Forward
97	Verify Backward
98	Rewind