

ELECTRONIC DIGITAL COMPUTER

Notes on Programming and Operating (2nd edition)

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1. The Code.

Orders are perforated on the tape as a block marking character or space code followed by five decimal digits. These five digits form the order code shown in Table A. It is a two-address code and for orders controlling arithmetical operations the first digit specifies the operation (addition, subtraction, multiplication or division) and the remaining four digits are two addresses defining the location of the two quantities which are to be operated upon. Further details of the arithmetical orders are given in paragraph 3, 4, 5, 6 and 7 below.

A second class of order, in which the first digit is 0, do not require arithmetical operations but result in various operations in the controlling part of the Computer. These orders are described in paragraphs 8 - 13 below.

2. Numerical Input.

Numbers are perforated on the tape in one of two forms, either eight decimal digits preceded by a space (or block marking character) and a positive or negative sign; or five decimal digits preceded by a space (or block marking character) and an asterisk (equivalent to a positive sign). This latter form was originally intended for orders which are to be read into the internal storage of the Computer, but it is useful for positive numbers when only five digits are necessary.

Throughout the Computer the decimal point is fixed after the first digit. The numerical capacity, N , of every storage location in the Computer is therefore $10 > N > -10$

A check is provided so that the computer cannot produce a number outside this range by normal arithmetical operations.

3. Initial Orders.

Two orders are stored permanently in the wiring of the computer and are used whenever the start key is operated or the computer restarts itself.

These orders are:

03101 i.e. Search for block No. 1 on tape reader 01.

02101 i.e. Transfer control to tape reader 01.

Hence the tape in reader 01 must begin with block No. 1 and the first order which is to be obeyed. The tape need not be loaded into the reader at block No.1.

4. Addresses.

Each storage group contains ten stores with addresses numbered, for example, 30, 31, 32 -- 38, 39. At present the computer is equipped with stores 10 to 99.

The addresses in the group 00 - 09 are allocated as follows:-

	As sending Address	As Receiving Address
00	Round-off Circuit	Drain
01	Tape reader	Printer
02	"	Perforator
03	"	Printer
04	"	Perforator
05	"	Spare
06	"	"
07	"	"
08	Last 7 digits of accumulator *	"
09	← All digits of accumulator →	

* with the sign which stands before the first digit of the accumulator.

5. Addition and Subtraction Including Input and Output Orders.

Addition and subtraction are specified by orders beginning with the digits 1, 2, 3 and 4. Digits 1 and 3 control Addition and Subtractions, respectively, when the contents of the sending store are to be retained. These are usually called "Add and hold" and "Subtract and hold". Digits 2 and 4 control addition and subtraction when the contents of the sending store are to be cleared. These orders are called "Add and clear" and "Subtract and clear".

Input is a special case of the orders with first digit 1 or 3, in which the sending address is a tape read (01 - 07) and the receiving address is a store or the accumulator. If the receiving address has not been cleared previously a sum or difference will be formed in it.

Output is another special case of the orders with first digit 1 or 3 in which the sending address is a store or either half of the accumulator (09 or 08) and the receiving address is a printer or reperforator (01 - 04). It is not possible to print out and clear the sending store. The layout of the printed message is determined by a layout order described in Para. 11.

Another special case of addition and subtraction is the order with first digit 7, which allows the transfer of the positive modulus. This examines the sign of the sending address, which must be a store or the accumulator. If it is positive it behaves as an "add and hold" order, or if it is negative it behaves as a "subtract and hold" order. There are no orders allowing the transfer of negative modulus or the transfer of modulus with clearance of the sending store.

The orders 209 -- and 409 -- clear the whole of the accumulator.

The two addresses in these, or any other, arithmetical orders must not be in the same group of ten stores with the following exceptions in the group 00 - 09, which are permitted.

Sending address	Receiving Address	Task
00	09	Rounding off the accumulator.
01 - 07	00	Reading into the drain
01 - 07	09	Reading into the accumulator
08	00	Transferring last 7 digits of accumulator to drain
08	01 - 04	Printing out last 7 digits of accumulator x 108
09	00	Transfer from accumulator to drain
09	01 - 04	Printing out first 8 digits of accumulator.

"Add and Clear" at "Subtract and Clear" orders are not permitted with these combinations of addresses.

6. Multiplication.

The multiplication order has the first digit 5. The two addresses must not be in the group 00 - 09. During multiplication the product is formed in the accumulator. If the accumulator has not been cleared the product is added to the previous contents. The multiplier is in the receiving address, and is cleared during multiplication.

Since the numerical storage of the computer, including the accumulator, has a capacity less than 10 a multiplication $(+3) \times (+3)$ is permissible but $(+3) \times (+4)$ will overflow the accumulator unless this already holds a negative number. $(-3) \times (-3)$ is also permissible. During multiplication with a negative multiplier the computer "overshoots" when dealing with each digit of the multiplier. This is very similar to the action of this computer or most mechanical calculators during division. For instance the multiplication $(+3) \times (-3)$ takes place as two operations:-

[(+3) x (-4)] + [(+3) x (+1)] The first product temporarily overfills the accumulator and the computer is stopped. In effect the capacity of the accumulator is reduced during multiplication with a negative multiplier.

7. Division.

The division order has the first digit 6. The two addresses must not be in the group 00 - 09. The dividend must be placed in the accumulator. The quotient is built up in the receiving address but there is no carry-over between digits so that this address must be cleared previously. The remainder, if any, is left in the accumulator after division.

There is no guard against overfilling the quotient register, except that a division which attempts to produce a quotient of, say 1000 will take about 45 seconds and the normal inactivity alarm (see Section II) will operate.

The dividend must not be +0 (i.e. all 0's) but may be -0 (i.e. all 9's). A dividend of +0 stops the computer, but no detailed warning is given.

An exact division of a positive dividend, which should leave zero remainder, produces an error of -1 in the seventh decimal place of the quotient and leaves a remainder. Division of a negative dividend is always correct.

Division is appreciably slower than multiplication, leaves a remainder which has to be cleared out of the accumulator and the quotient is not easily rounded off correctly. Where it is possible multiplication by a reciprocal is usually superior to division.

8. Sign Examination.

The order beginning with the digits 01 causes the computer to compare the sign stored in a specified address with the required sign. A Yes-No answer is stored until superseded by the result of another sign examination. This information is used in conjunction with orders relating to conditional transfer of control and conditional search but it need not be used immediately.

9. Transfer of Control.

After the initial permanent orders, described in paragraph 3, orders are read from tape reader 01, until an order beginning with the digits 02 is reached. Transfer control orders beginning with 021 are always obeyed. Those beginning with 022 are only obeyed, if the sign examination memory has stored an affirmative, otherwise the computer proceeds to the next order. If there has been no previous sign examination the computer stops.

In an 02 order transfers control to a storage address orders are read from successive stores until a further 02 order is found in a store.

10. Search Orders.

These orders provide a means whereby control can be transferred to another point on the same loop of tape, or another loop of tape can be prepositioned in readiness for transfer of control to it or reading information from it. They cause the specified tape reader to search for a particular one of (up to) ten distinctive characters or block numbers.

Orders beginning with digits 03 always cause a search. Orders beginning with digits 05 only cause a search if the previous sign examination has stored an affirmative, otherwise the computer reads in the next order.

In either case a guard circuit gives an alarm if no space code is encountered in any half minute or if a space code persists for more than about half a minute. A search for a non-existent block number continues indefinitely.

11. Printing Layouts.

Each number can be perforated in two ways or printed in 8 ways the choice being determined by orders with first digits 07. No output can take place until a layout has been specified. The ten layouts are used as follows:-

	Layout No	Use	
Perforating			
	1	8 digits.	
	2	5 digits with asterisk.	
Printing			
	3	8 digits, 5 columns, first or intermediate column.	
	4	8 digits, last number on line.	
	5	8 digits, last number on line, followed by blank line.	
	6	6 digits, 6 columns, first or intermediate column.	
	7	6 digits, 5 columns, first or intermediate column.	
	8	6 digits, last number on line.	
	9	6 digits, last number on line, followed by blank line.	
	0	feeds up five rows of blank paper.	

The printer stores one character mechanically. When switched off it retains the last character fed to it and prints it whenever another character is fed in. The tabulations are chosen so that this stored character is normally "Figures Shift", but under special circumstances it may be any code.

Print layout 0 allows any such stored character to be printed well clear of the genuine output and provides blank paper for headings.

The use of the print layouts is illustrated in Appendix 1.

12. Shift Selection.

Additions and subtractions normally take place with the straight through shift position (Shift B). The orders beginning with digits 08 allow the next addition, subtraction or transfer of modulus (i.e. 1, 3, or 7 orders) to be performed with a specified shift over the range from one place to the left to seven places to the right. The sending store cannot be cleared when this facility is in use. The 08 order affects only one transfer following it, and shift B is then effective again.

It does not affect any input, output, multiply or divide orders which may occur between the 08 order and the 1, 3 or 7 order to which it refers. The following table shows the multiplying factors which are introduced:-

Order	Shift-selected	Factor
08100	A	10
08300	C	10 ⁻¹
08400	D	10 ⁻²
08500	E	10 ⁻³
08600	F	10 ⁻⁴
08700	G	10 ⁻⁵
08800	H	10 ⁻⁶
08900	J	10 ⁻⁷

The order 08200 is permissible, but it only selects the usual straight-through shift.

When using shift A the left hand digit is discarded. It is not added into the sign position. When using shifts C - J the right hand digits are discarded unless the receiving store is the accumulator.

13. Signal Orders.

These orders allow the computer to call for assistance. Two distinctive signals are provided :-

Order 00100 : "Finish". The computer can pass on to the next order if the "Pass Finish" key is operated permanently or temporarily. In passing this order the delayed alarm facility is reset.

Order 00200 : "Signal". The computer can pass onto the next order if the "Pass Signal" key is operated permanently or temporarily. The delayed alarm is not reset.

If either of these orders is encountered when the respective pass key is not operated the appropriate signal lamp lights and after a delay the inactivity alarm operates.

The computer ignores the order 00000 and passes on to the next order.

14. Round Off.

Section III para. 10, shows how a programme can be constructed to perform the usual rounding process by adding 5 into the right of the last digit which is being retained.

A less accurate method is available without elaborate programming. The sending address 00 is a device which produces randomly the digits 0 or 1 to be added (with the correct sign provided automatically) into the last digit which is to be retained. Unless preceded by an 08 order the round-off digit is added into the seventh decimal place.

II OPERATING THE COMPUTER.

1. The Operating Controls

The controls essential to the operator are :-

On the power rack

- (a) The "on" press switch. This switches on all power supplies.
- (b) The "off" press switch. This switches off all the computer except any equipment running off the monitor power sockets, which are controlled by a separate switch.
- (c) "Automatic Shut Down" switch. All equipment except the monitors shuts down when the alarm circuit operates if this switch is down.

On the Control Unit

- (d) "Start" key. Operate momentarily to start.
- (e) "Pass Finish" key. See Section I paragraph 13.
- (f) "Pass Signal" key.
- (g) Alarm key with positions "No Alarm", "Normal Alarm" and "Delayed Alarm" • The no alarm position is used while testing or to clear an alarm condition. The use of the other positions is described in paragraph 2.
- (h) "Busser Off" key. Disconnects the audible alarm.

2. Operating the Computer.

(a) Switch on Power Supplies by operating the "ON" push Switch on the power rack. After about one minute the Sealing tubes light and the computer is ready for use.

(b) Load the tape readers. If each tape has an order searching for the correct block number on any tape reader to which it is about to transfer control it is not necessary to load the tapes at any particular row. (See also paragraph I.3.) Check that the tapes are not reversed. The direction of motion is from the gate towards the raised end of the tape reader.

Tapes which lie on the floor or are otherwise in danger of becoming trapped or tangled should be passed over the support wire and under the tight tape lever of the tape reader.

(c) Operate the "Start" key (Green). This will be ineffective if the "No Alarm" key on the input table or the control rack is operated, and, until the internal clock mechanism generates an impulse.

(d) Set the required alarm conditions (Red key). The normal alarm gives a warning if the computer is inactive for 30-60 seconds. The delayed alarm returns the computer to the beginning of the programme when a period of inactivity is detected if the inactivity is not due to either Signal order. In general after three such attempts the normal alarm is given, but whenever a finish signal is passed the memory of my previous delayed alarms is lost and the full three lives are restored. The alarm key on the control rack should be set at "Normal Alarm".

(e) To Reset.

When experimenting with a new programme it is not unusual to wish to restart the computer at the beginning of the programme. This can be done in two ways:-

If the computer has stopped cancel the existing alarm, if any, and allow the delayed alarm to operate. If the computer is running, select the delayed alarm and lift the tight tape lever of the tape reader in use.

Alternatively the 50 volt D.C. switch on the power distribution unit may be switched off momentarily and the "Start" key operated again. This is preferable to switching the, whole equipment off.

(f) The Order Monitor Display.

When the computer stops owing to a programme error on a faulty tape it is useful to know what order is stored in the control section of the computer or the address from which an order is being read. Five keys on the Control racks switch in a lamp display showing this information.

When using the display it will be noticed that the two "addresses" of non-arithmetical, "0", order are interchanged e.g. an order which is perforated as 03104 appears on the display as 00431.

3. Preparation of Tapes.

The normal procedure is to make a paper original using the keyboard perforator. From this a printed slip is produced and checked against the manuscript programme. Any errors are marked up and if necessary a corrected paper copy is made. The paper original or copy may then be proved in the computer and any further corrections inserted. Where the final loops of tape are required to pass through the computer more than a few dozen times linen copies are made from the paper originals.

4. Perforating the Paper Original.

The tape preparation equipment draws its power from the computer and the

110V and 50V supplies should be switched on. The three-bank keyboard of the perforator is similar in appearance to that of a typewriter but some of the upper case characters have been changed. The top bank is used for the digits 1 - 0, the middle bank for the block marking numbers 1 - 9, (labeled in red) and the lower bank for +, -, *, and the block number 0.

Perforating errors can be omitted in the subsequent copying processes. When a keying mistake is noticed, backspace by using the level near the perforating head, perforate "letters shift" (5 holes) over the incorrect row and all rows which follow it and then repeat correctly. The row of tape which has just been perforated is visible immediately to the left of the perforating head.

5. Printing and Perforating Copies.

The tape copying equipment has two inputs, tape readers A and B, selected by a key; and two outputs, the printer and the re-perforator, also selected by a key. The input may either be copied exactly ("copy" key operated) or certain codes may be omitted (key in "Edit" position). The codes which are omitted are selected by a key having three positions. "Blank", "Blank and Erase", and "Erase". As the "Erase" code is also the code for "Letters Shift" it is essential both to edit and erase codes when printing matter containing figures only and also to copy erase codes when printing a mixture of letters and figures.

To reproduce a tape, load the original into one of the tape readers and select the appropriate input, output and whether a direct or edited copy is required. Operate the "Motor On" control and then the "start" control. At the end of the tape operate the "Stop" control. The "Single Row" control may be used when only a few rows are to be copied or when it is essential to stop exactly on a particular row. When at rest the row standing in the gate of the tape reader has not been copied.

Blank tape may be run out of the re-perforator by using the "Edit Run-out" key when the perforator is selected as the output and the motor is running. If the printer is selected as the output and the motor is running the "Edit Run-out" key causes the printer to be set to the "figures Shift" position; it does not run out unprinted tape.

It is advisable to check copies against the original tape. This can be done by holding the two tapes together and viewing against the light.

Badly worn tapes may often be copied more successfully if they pass through the tape reader inverted and reversed. This has the double advantage that the tape is driven by the unworn edges of the feed holes and the reading pins bear against the raised side of the distorted tape. The tape readers associated with the copying equipment operate with a greater pressure on the reading pins than the other readers and so unless the tape is inverted they may fail to copy

correctly a tape which has been found worn but serviceable in the computer.

Splice the tape into loops by cutting the ends to a blunt point, allowing an overlap of two or three rows. Coat both ends sparingly with thick paste on one side and join ,with the leading end on top. The joint should be lined up carefully to ensure that there is no discontinuity at the edges and that the feed holes are clear. Press the joint together firmly and dry thoroughly before use. Avoid excess paste on the linen tape as the starch impregnation is easily removed by moisture.

6. Reading the Perforated Tape.

The accuracy of the perforated tape is usually checked by printing out the contents but, when modifying or correcting a tape or when experimenting with a new programme, it is useful to be able to read the perforations visually.

The five positions in which holes may be perforated are labelled "a" to "e". Holes a and b are separated from holes c, d and e by the smaller feed hole.

The codes with only one hole per row are :-

Code	Perforations	Use
	E D C B A	
A	0	+ Sign
B	O	Line Feed *
C	O	Space
D	O	Carriage Return *
E	O	- Sign

* Not used during the preparation of tapes

The codes with two holes per row represent the tens digit :-

Code	Perforations	Use
	E D C B A	
BA	O O	0
EB	O O	2
DC	O O	4
ED	O O	6
AE	O O	8

Code	Perforations	Use
	E D C B A	
CA	O O	1
DB	O O	3
EC	O O	5
AD	O O	7
BE	O O	9

The codes with three holes per row represent the ten block marking characters and are the complement of the corresponding digit codes e.g. block marking character 1 is codes BDE and digit 1 is coded AC

Code	Perforations	Use
	E D C B A	
EDEB	O O O O	Asterisk
AEDC	O O O	Decimal Point *
BAED	O O	Figures Shift
CBAE	O O	Letter N only *
DEBA	O O	Letter Only *

* Not used during the preparation of tapes

The five hole code is used for "Letters Shift" and also for erasures.

The perforations on the tape and the printed characters on paper slip have a similar spacing. This can often be used as a guide to a point on the tape with sufficient accuracy that only a few orders need be read visually. It will also be found that the most easily recognised codes are the asterisks (code bedc) and these/can often be a help when looking for a point on a tape.

III PREPARING THE PROGRAMME

1. Subdividing a programme on one tape

Any programme which is suitable for automatic computing is repetitive and usually consists of a number of repetitive sub-routines.

Consider a programme which has a sequence of orders, A, used to control the initial intake of information and clear the stores, a sequence B which has to be repeated N times and during which it is necessary to repeat a third sequence C, m times. It would be possible to perforate all these orders on one loop or tape, heading sequence A with Block No.1 and sequences B and C with block numbers 2 and 3. It is easy to devise orders at the end of sequence B which will cause a search for block number 2 to occur -1 times and some other order e.g. 'Finish' the nth time sequence B is completed. At the appropriate point in Sequence B there can be an order causing a search for block number 3 so that sequence C is introduced. At the end of sequence C a simple routine can cause a return to block number 3 the first (m-1) times and a return to the correct point in sequence B (marked with another Block number) after the m th application of sequence C.

This is the simplest arrangement of several sequences of orders but it wastes time, tape, and machine life. Although sequence A is needed once and sequence B n times both have to pass through the tape reader $n \times m$ times to give access to sequence C. Some improvement can be affected by perforating sequence C in times on the tape, but this may not be convenient if it makes the tape very long or if m is variable.

It is usually only necessary to arrange several sequences on one tape if a programme would otherwise require more than seven tape readers, and it is then usually possible to collect together several sequences of orders which are not used frequently.

2. Subdividing a programme on more than one tape

Continuing with the example of paragraph 1, it is more convenient to have sequences A, B, and C on separate loops of tape. Then these loops only pass through their tape readers 1, n and $n \times m$ times respectively. Searching time is eliminated, the loops may be kept to reasonable lengths and there are no complications if n and m are variable. Furthermore if $n \times m$ is greater than the expected life of the tape, about 500 passages through the tape reader, it may be possible to perforate sequence C $n \times m / 500$ times in one loop of reasonable size.

3. Use of Stored orders

Under some circumstances it may be useful to store a sequence of orders in successive stores, but as it takes longer to read orders from the stores than from the tape this is seldom profitable unless some advantage can be gained by performing arithmetical operations in the orders.

In the example above the sub-routine loop for sequence C must always transfer control back to sequence B and a simple 02 order is adequate. If sequence C could be entered from either of the sequences A or B and must return control to the same sequence the transfer is more complicated. One solution is to have a store in which sequence A or B, before control by sequence C, writes an 021 order to transfer control to sequence A or B respectively. Then at the end of sequence C a discrimination either repeats C or transfers control to the stored order. This, in turn, transfers control to the tape reader from which it was originally derived.

4. Some Arithmetical Difficulties

The points which are summarised here are peculiarities of this particular computer which have already been mentioned in preceding paragraphs.

- (a) In all arithmetical orders the two addresses must not lie in the same group of stores with certain exceptions in the group 00 - 09.
- (b) When adding or subtracting with a shift preset by an 08 order it is not possible to clear the sending store.
- (c) The preset shift order (08) does not apply to additions or subtractions involving the input or output.
- (d) The capacity of the accumulator is reduced during multiplication by a negative multiplier. See Section I, paragraph 6.
- (e) The dividend must not be +0 (all 0's). If there is any risk that this may happen, take the precaution of subtracting 0 into the accumulator before each division, thus converting +0 into -0. If the dividend is +0 the computer stops with the A shift selected and no direct indication of the nature of the fault.
- (f) Where an error of one unit in the quotient cannot be tolerated, or where it would look unsightly in the printed output change the sign of divisor and dividend, where necessary, to make the latter negative.
- (g) The receiving address (quotient register) for division must be cleared. It is sometimes assumed that a store is ready for use as the quotient register if it has previously been the multiplier register.

If the multiplier was negative the register address will be cleared to -0 which is not suitable for the quotient register.

5. Completing the Loop.

The tape can be joined into a loop with no gap between the first and last orders if the first order is repeated or several rows of letters shift are perforated after the last order. The highest standard of splicing is necessary if all the overlapping holes are to be exactly coincident. Such a loop of tape can be identified by a written label but there is a risk that copies will not be marked and so cause confusion.

These difficulties have led to the practice of perforating an identification number at the head of each tape and a search order for block number 1 at the end of each order tape. The splice can then be of any length and only the feed holes need accurate alignment. All copies, both perforated and printed, carry the identification code, which should indicate :-

- (a) The tape reader, so that a set of tapes can be loaded quickly.
- (b) The job or programme so that tapes can be sorted and stored easily.
- (c) The "Mark No" of the programme so that the latest modification can be distinguished.

6. Testing for Zero.

This computer represents zero in two ways, as +0 (all zero's) and -0 (all nines).

The form +0 is produced by clearing a store, adding one cleared store into another, subtracting -0 from +0, or by the clearance of a positive multiplier during multiplication. The form -0 is produced by all other operations, including subtracting +0 from +0 or by the clearance of a negative multiplier during multiplication.

A simple test for either form is that zero is the only number whose positive modulus can be added to -0 and give a negative result. Where the numbers to be tested are usually zero this test can be applied very easily by adding the modulus of each number into a store containing -0 and inspecting this store for negative sign. Whenever this system is used to test a number which is not zero the testing store has to be cleared and replaced at -0.

7. Controlling the repetition of a sub-routine

The test to determine when a sequence has been repeated n times can be arranged in several ways, but these fall into two classes which are illustrated here. If we write +n in a store and subtract unity from it during each repetition of the sequence the sign will change from + to - at the nth subtraction. On the other hand if we write -a in a store and add unity during each repetition, the sign

changes from - to + at the $n + 1$ addition.

There is often some advantage to be gained by choosing the right form of this test.

8. Testing for the end of a numerical input tape.

Where a problem can only be expressed as "carry out this operation on as many numbers as you find on the input tape" it may be difficult to terminate the progress neatly.

If no particular action is required after reaching the end of the input tape the crude expedient of letting the tape reader step off the end of the tape and produce an alarm might suffice.

If some further action is needed, as would be the case if the computer were to print out the answer when the last item had been read in, it is possible to head the input tape with a number which indicates the number of items on the tape. The intake routine can then repeat while counting down from this number.

Where each item or a part of each item, on the input tape is always positive the last item can be indicated by perforating it with a negative sign. A test of the sign of each item which is read in reveals the last item.

9. Reading into the Drain.

When it is necessary to pass over a few number groups on a wholly numerical tape it may be more convenient to do this by reading the unwanted groups into the drain rather than by marking the tape with a system of block numbers so that the next wanted group can be found.

10. Alternative orders for correct Round-Off.

Correct round off i.e. not using the random round off facility, is a good example of the method by which one of two alternative groups of orders can be chosen.

If the 8th digit of the accumulator is to be rounded off we require a sequence of orders which will add 5 into the 9th digit of the accumulator if the accumulator has a positive sign, but subtract 5 if the accumulator is negative. Assume we have 0.5 in store 20 and the tape reader in use is 03.

Suitable orders are :-

08900 Set shift J

01109 Examine the accumulator for +ve sign

05203 Conditional search for block Number 2
32009 Subtract 5 from 9th digit of accumulator using the shift J set above.
03303 Search for block number 3.

Block No.2.

12009 Add 5 into 9th digit of accumulator using the shift J set above.

Block No.3. and next order.

Correct round off for division follows the same general lines but as there is not a ninth digit in the quotient register the same effect can be produced by adding half the divisor into the dividend with the appropriate sign and Shift

11. Other examples of alternative orders.

Some systems of alternative orders need only one block number. For instance, if the sign of a specified store has to control whether a certain number is added or subtracted into the accumulator and cleared, one block number is sufficient.

Assume that the controlling sign is in store 20, the number to be transferred to the accumulator is in store 21, and the tape reader is 03.

The following orders may be used :_

01120 Examine 20 for +ve sign
05203 Search for Block No. 2 (if 20 has +ve sign)
42109 Subtract and clear 21 into accumulator.

Block No.2.

22109 Add and clear 21 into accumulator.

Note that this last order will be carried out for both +ve and -ve sign in store 20, but in the latter case the order 42109 has already cleared stored 21.

The sign of a controlling store can also be used to modify a sub-routine by similar systems of alternative orders. This has been used where it is necessary to insert some modifications in a long sub-routine during its first application. The latter part of the sub-routine is made to write a number of known sign into the controlling store, but the previous tape writes in a number of opposite sign. The sign in this store is then an indication of the first application of the sub-routine. The alternatives are to have the modified routine as a separate tape or as a part of the preceding tape.

12. Refinements in printing layouts.

Before the printer is used in any programme it is usual to set the tabulation 0 (order 07000) and have an order to print out from any store. This prints no digits but feeds up five blank rows of paper suitable for inserting headings. The same order can be used between sections of a programme where a larger break than one clear line is desirable.

The appearance of the printed output is usually improved if it is split into groups of a few lines separated by a blank line. Where the programme does not naturally provide a control for such grouping it is often convenient to have a separate tape for the printing orders. This tape can then contain several (usually four) repetitions of the printing orders for one line, ending with a number printed with layout 4 or 8 (single line feed) and then the printing orders for one line ending with layout 5 or 9 (two line feed). This tape, may only have the printing orders for the last number in the line (i.e. 4 orders with layout 4 or 8, followed by one order with layout 5 or 9) since the orders for the first and intermediate numbers on the line will probably be the same throughout the programme. It is usually simpler to have a separate tape than to have a counting-down routine which can recognise every nth line and control alternative printing orders.

Where the output is needed in more than five or six columns it is possible to print out the first five or six columns on printer 01 and the next five or six columns on printer 02 so that the sheets of paper may be joined later.

The tape preparation equipment can be used to print headings containing letters and figures by transferring the whole paper carriage to the tape copying printer.

13. Adding Block numbers to the perforated Output.

The two output layouts (1 and 2) which control perforated outputs precede the eight or five digits with a space, whereas it may be, essential to have eye block numbers on the tape when it is used subsequently as an input to the computer. The block numbers 0, 3, 6, 7, 8, 9 can be perforated, by keyboard perforator or hand punch, over the space row as these block numbers include hole "C". Other block numbers can only be introduced while copying the output tape.

14. Clearing Stores.

When the computer is switched on the stores contain unwanted (but probably not random) numbers. There are two approaches to clearing out these number and

subsequently providing clear stores where needed.

One system which has been used is that of clearing each store just before it is required for use. This has the advantage that the programmer can construct each part of the programme separately without considering which stores have been cleared by previous parts of the programme. This is often helpful when a programme has to be modified. It does not lead to the most economical use of clearing orders since these are essentially orders which leave a store cleared after it has been used.

Another alternative is to clear all stores at the beginning of the programme and then clear each store, as far as possible, after it is used. It is not necessary to write out or key the orders for clearing all the stores each time a programme is prepared. These orders may either be copied from a master tape or one tape reader can be reserved for a "store clearing sub-routine".

15. Estimating Running Time.

To obtain a rough estimate of the running time for a sequence of orders allow:-

Addition

Subtraction

0 orders, except search 2 seconds

Reading in 5 seconds

Printing out 10 seconds

Multiplication 15 seconds

Division

Search 1.4 orders per second
0.8 eight digit numbers per second.