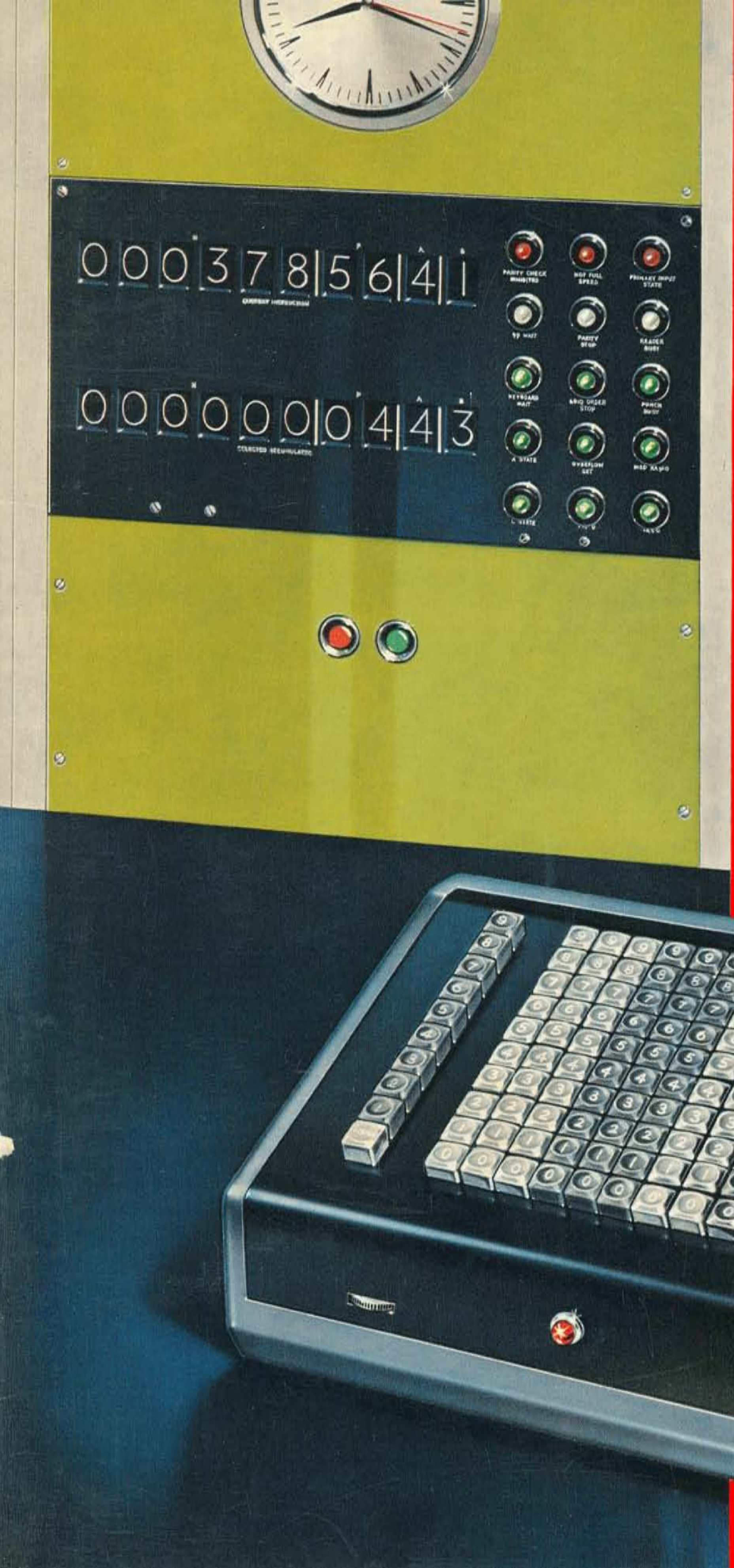

The advantages of the FERRANTI SIRIUS COMPUTER

LIST DC 43A
JANUARY 1961

The Basic Sirius Computer.

The advantages of the Ferranti Sirius Computer

CONTENTS

LIST DC.43A
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The advantages of the Ferranti Sirius Computer

1. Introduction

Electronic digital computers of what might be called a **'handy'** size have only quite recently appeared on the market. Their development has been the outcome both of the general trend towards miniaturisation in electronics and the great increase in breadth of knowledge of computing techniques that has been made in recent years. Ferranti Ltd., who have been making computers for many years, now have in production, as the smallest computer in their range, the **Sirius Computer,** a machine which can be installed in a medium-sized room.

Sirius is a **truly general purpose machine** suitable for a wide variety of uses in industry, commerce, science and technical education. Although a general purpose machine it is entirely suitable for industrial data-logging and process-control. Sirius has speed, versatility and reliability and, in addition, is cheap to install, run and maintain. It will thus meet the needs of establishments and departments which have no requirement for a large installation but which nevertheless do require a true digital computer.

The points considered in the first stages of the design of Sirius, and these are also the points potential users will consider, include the following requirements.

The computer should be:

1. Of small size.
2. Straightforward to programme.
3. Reliable and easy to maintain.
4. Fast in operation.
5. Versatile.
6. Simple to install and easy to move.
7. Usable with as many existing techniques and equipments as possible.

How these points have been dealt with in the design and construction of Sirius is described below.

2. Size and installation requirements

The basic computer is 6′ 9½″ × 10″ × 4′ 9″ high and is fixed behind a Roneo steel desk 6′ 6″ × 2′ 10″ × 2′ 5″ high. Thus the computer and desk together occupy a floorspace of about 25 sq. ft. Other standard items which require floorspace are a **Tape Editing Desk** and a **Teletype Output Punch.** All these items can well be installed in a room of only about 150 sq. ft. still leaving room for operation and maintenance. The weight of the computer and desk units, which together make up by far the heaviest part of the installation, is 13 cwt.

There are, of course, many other items of equipment that can be fitted, such as

A Sirius Computer in use.

further computer storage cabinets and other items of peripheral equipment, but there are none of them of great size, so no great increase in space available is needed for their installation. The space requirements of Sirius are, in fact, such that it will probably be simple to find room for the machine quite close to the people, scientists, technicians or students, who require to use it in their day to day work. It is also perfectly feasible to move the machine at short notice, as might be necessary, for instance, if it is to be taken off general purpose computing and used for a while in a data-logging or process-control role in a laboratory or on a shop floor.

The computer itself consumes only 600 watts, and a full installation of computer and associated equipment will probably consume only about 2 kW. Also, unless fluctuations in the electricity supply are very severe, there is no need for voltage stabilising equipment to be fitted. With such simple power requirements as these it is unlikely that there will be any difficulty in installing a Sirius System anywhere. However, a small motor generator set can be supplied if necessary.

Because of the small heat dissipation, cooling or air conditioning is not required and a normal well-ventilated room will suffice.

As instances of the easy portability of Sirius it can be mentioned that the machine has been installed at exhibitions in London, Birmingham, Cambridge and Belfast, without any troubles being encountered.

3. Design features of Sirius

The features of the design which it is important to bring out in this description of the advantages of Sirius are as follows:

3.1. Sirius operates in the serial mode. Although serial operation is not so fast as parallel or serial-parallel operation the expense and complexity of these other methods of working was thought not to be justified. Sirius is still, however, a commendably fast machine, having a basic word time of 80 microseconds.

3.2. To make the machine as easy as possible to operate, the monitor displays have been arranged to show the contents of registers, etc., in their decimal form and the controls have been made similar to those of conventional desk calculating machines. These points will be appreciated by experienced computer users but will be specially valued by those approaching computers for the first time.

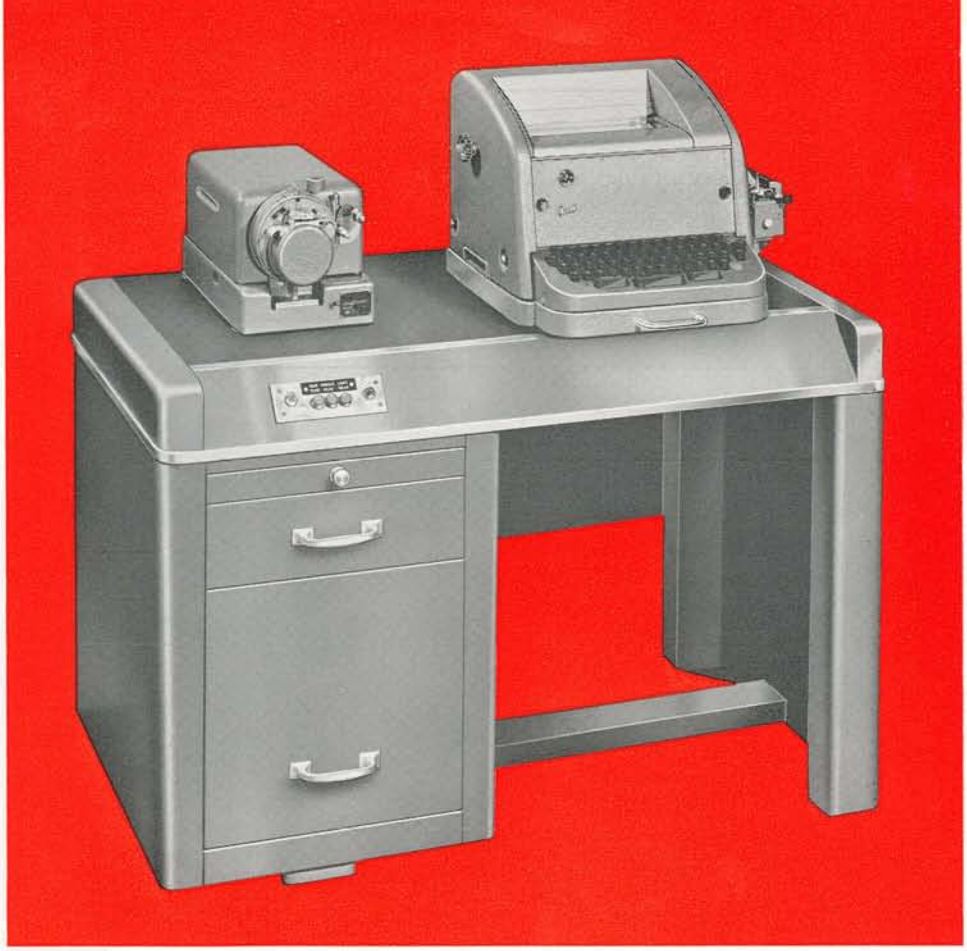
3.3. Sirius has been made with **multiple accumulators** in which arithmetic can be carried out. Because of this feature it was possible to make the instruction code very powerful and comprehensive and yet still simple to understand. The use of multiple accumulators also increases the speed of the computer. Instructions for Sirius occupy one computer word each. Over 60 different functions are available to cover a wide range of operations and they are all in a form that can be readily understood by the programmer.

3.4. The serial mode of operation prompted the use of **delay-line storage** for Sirius. In the Ferranti Pegasus and Perseus computers, which have achieved a reputation for great reliability, delay-lines are used for the working store; but in Sirius their use is carried a stage further in that storage is on delay-lines throughout the computer. In fact there is no distinction made between working store and main store; that is, all storage is on a single level and no time is wasted in transfers between parts of the store. The delay-lines used in Sirius are of an improved form. The improvement consists in using torsional propagation in the lines rather than the longitudinal propagation used in the past. This method allows very robust lines to be constructed and the result is a storage medium of great reliability that is intermediate in cost and speed between drum storage and magnetic core storage. The use of magnetic core storage would, of course, be inappropriate in a serial machine, for the high speed characteristics of this form of storage would be largely wasted.

3.5. The store of Sirius has been made readily extendable because experience has shown that after a computer has been in use for a year or so it frequently becomes the case that it is required to solve problems requiring more store space than hitherto. There are 1000 words of storage in the basic computer and up to 9000 more may be added at any time in units of 100 words. The extra storage is contained in cabinets each holding up to 3000 words. All extra storage can be used in exactly the same manner as the storage contained in the basic computer.

3.6. The operating speed of Sirius is comparable in many respects with that of the larger Pegasus computer. Inside the machine instructions are obeyed in 0·24 millisecond except where they require reference to the store, which needs 4 milliseconds, or are for multiplication or division, which need an average of about 8 milliseconds. Analysis of existing programmes has shown that about 10% of instructions require reference to the store and about 5% are for multiplication or division. Thus 1000 instructions in a programme would be performed in about one second.

3.7. New transistorised logical elements have been designed for Sirius. They are called 'neurons', and they are now also being used in the Ferranti Orion computer. These elements are very well tried and laboratory work has shown that the pulse rate used in Sirius (0·5 megacycles per second) could be doubled at least without their limits of operation being approached. This very conservative use of the elements ensures great reliability in their performance.



TAPE EDITING EQUIPMENT. The Creed 75 teleprinter shown may be used for tape preparation and for printing out results.

3.8. The electronic circuits of Sirius are entirely of plug-in package construction, there being some 700 packages of 10 different types. In addition, the storage units are arranged in trays of 100 units each. Package construction has many advantages, including ease of large-scale manufacture, ease of testing, and ease of fault rectification. Also, with package construction, great attention can be given to the design of each package with the aim of making its operation independent of changes in component values, waveforms and operating voltages.

4. Input and output for Sirius

Ten input and ten output channels are available on Sirius, and channel selection can be directly dependent on programme instructions or, by means of modifiers, be dependent on the result of previous operations. No time is lost in input or output selection. The value of these extensive input and output facilities will be most apparent when Sirius is used in a data-logging or process-control role. The use of Sirius for these purposes is described in appendix C.

Input and output **paper tape equipment** that is unusually fast for a machine of the size of Sirius is fitted. The tape reader usually operates at 250 characters per second and can attain 300 in special cases, and the output punch operates at 60 characters per second. The achievement of these speeds is greatly aided by the decimal representation of numbers within the machine, for this makes the tasks of reading in numbers and of assembling them for output relatively simple. There is, in fact, a careful balance struck between the various internal and external speeds of Sirius and its paper tape equipment, and the result is that Sirius is faster than other machines of comparable cost. The benefit of this high speed will probably be felt most after a Sirius has been installed for a year or so and is perhaps being used for a work-load greater than that envisaged at first – a work load that might require double or treble shift working with a slower machine.

The punched card equipment for Sirius comprises a card reader and a card punch combined in the same machine, 80-column cards of standard Bull/IBM/Hollerith type being used. Column punchings, as customary in commercial work, and binary punchings, as from automatic recording equipments, can both be dealt with, and the operating speed for both reading and punching is 120 cards per minute. The equipment embodies elaborate conversion and checking facilities such as are required for the efficient use of card machinery. Cards are read twice on input, and are reread after punching on output.

5. Error detecting facilities on Sirius

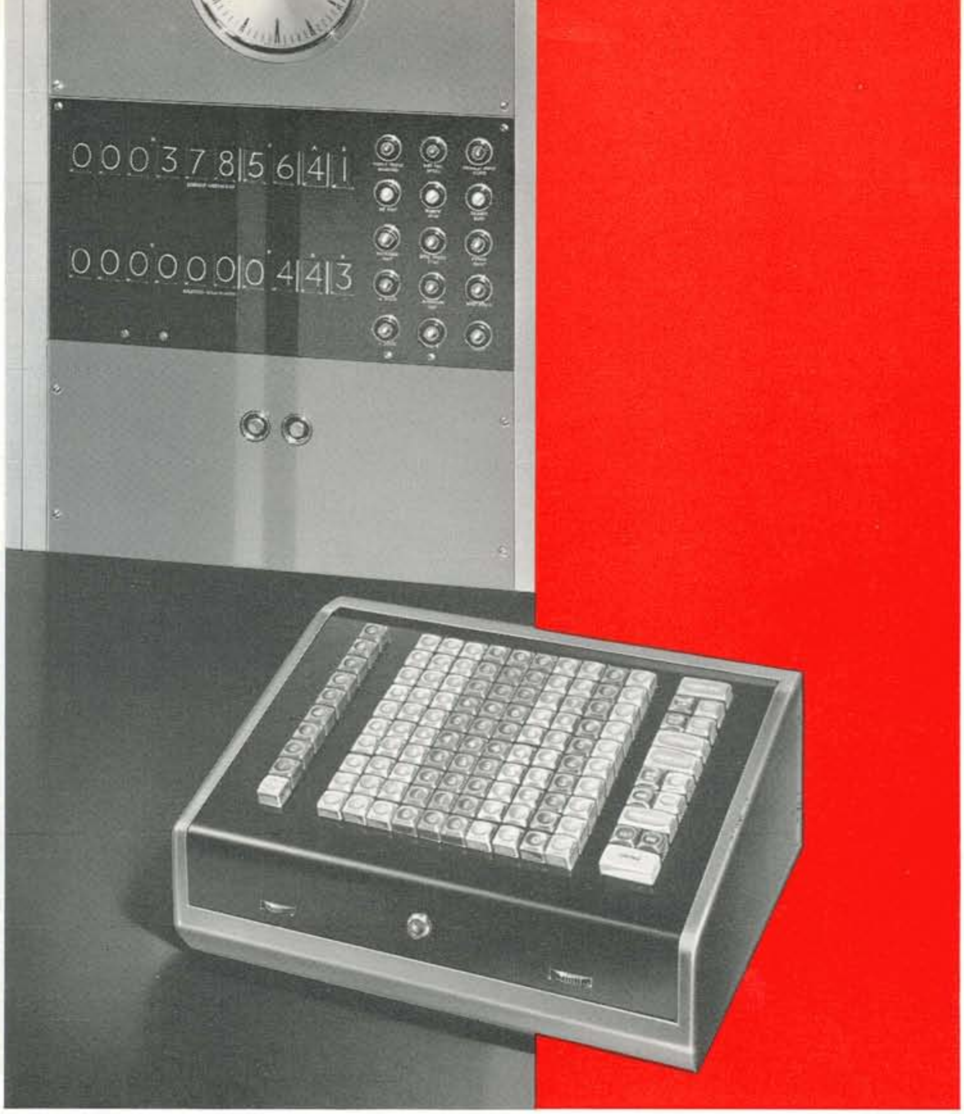
It is of great importance that an indication should be given by some means or other if an error should occur in the handling of programme or data both inside and outside the computer. Without such an indication the user might believe the results produced to be correct when in actual fact they are faulty. Ferranti Ltd. have always attached great importance to this point and **all Ferranti computers have extensive checking and indicating facilities to deal with the following occurrences.**

5.1. Malfunctioning of equipment

Apart from actual electronic and mechanical failures in the computer and its associated equipment (and the routine maintenance should detect the onset of these before they actually occur) there is always the chance of transient errors. It has been found by experience that the majority of such machine errors affect only a single binary digit in any word, a one appearing instead of a nought or *vice-versa*, and this fact permits simple automatic checking of the two most critical parts of a computer installation – the input/output equipment and the storage system.

The input/output checking for paper tape is as follows. The five-channel punched paper tape code is so designed that errors of one binary digit (one hole) in all decimal numbers and in certain important symbols are readily discernible. This is done by using an odd number of holes for each of these characters so that any one-digit error will produce an even code that does not represent any other number or important symbol. If there has been an error in the output circuits of the computer or in the output punch then the unlikely character produced will readily be detected on examination of the print-out of the output tape. On the input to the computer the circuits are so arranged that such an error in numbers or major symbols will stop the computer – it being most important that errors should not get further than the input to the machine. The computer will be programmed for a pre-determined form of input, and on any deviation from this as, for example, if an even number of holes is read when the input should be characters or major symbols, the computer will stop and an indicator light will show what has happened.

The punched card input/output checking has already been mentioned. On card reading the card is read twice (at separate reading stations) and the images read are compared to see if they are the same. On card punching the card is read after punching and the image is compared with the signals which were sent to the punch. In each case



The Sirius Displays and the keyboard.

the machine stops if the comparison shows a discrepancy. This method of checking has been found to be quite the most powerful method of performing the checking necessary on card equipment.

The checking of the storage system is as follows. Whenever a word is put into the store it passes through circuits which count the number of ones and an extra one is automatically inserted if the number is even. Thus all stored words contain an odd number of ones. When a word is taken out of the store a check is made that the number of ones is still odd and the added one, if present, is removed. Should the check show an even number of ones the machine will stop. **This automatic procedure is known as parity checking.**

5.2. Errors by the operator

The great majority of punching errors and operator's errors are detected by the very comprehensive programme, used for reading in programmes and data, called the **Initial Orders.** Conventions, designed to be as versatile and natural as possible, have been laid down for preparing programmes and data, and if any of these conventions are contravened on input, as may be the case if there is an error, then the machine will stop. The machine will also stop if asked to obey a nonsensical order.

5.3. Numbers going out of range

When programming, it is necessary to know the approximate values of all numbers which are going to occur in the course of computation so that arrangements may be made for keeping all numbers within the limits of size imposed by the capacity of the storage registers and accumulators. If a number does get too big part of it would be lost, unknown to the operator, if there were no warning system incorporated. Such errors are, in fact, most insidious. As with other Ferranti computers, in Sirius there is an **overflow register** to note any overflows that occur and indicate that they have taken place. The nature of the overflow can then be tested by certain instructions.

In conclusion, with these comprehensive checking facilities, which are a feature of all Ferranti computers, users quickly come to rely on the computer and the correctness of the results it produces. If stops occur in the development of a new programme most experienced programmers will check the programme rather than assume that the machine is at fault.

6. The integration of Sirius with existing techniques and equipments

Ferranti computers have been bought by ten universities and one college of advanced technology; and, in addition, some 40 other machines have been sold to research centres and industrial and commercial companies. Hence, not only have over a thousand people learnt to programme 'Ferranti fashion', but much of what has become normal computing practice has been derived from the use of Ferranti machines. Ferranti have considered it important that full advantage should be taken of these points, and Sirius has been designed so that it has much in common with the other Ferranti computers and can be used with much existing peripheral equipment.

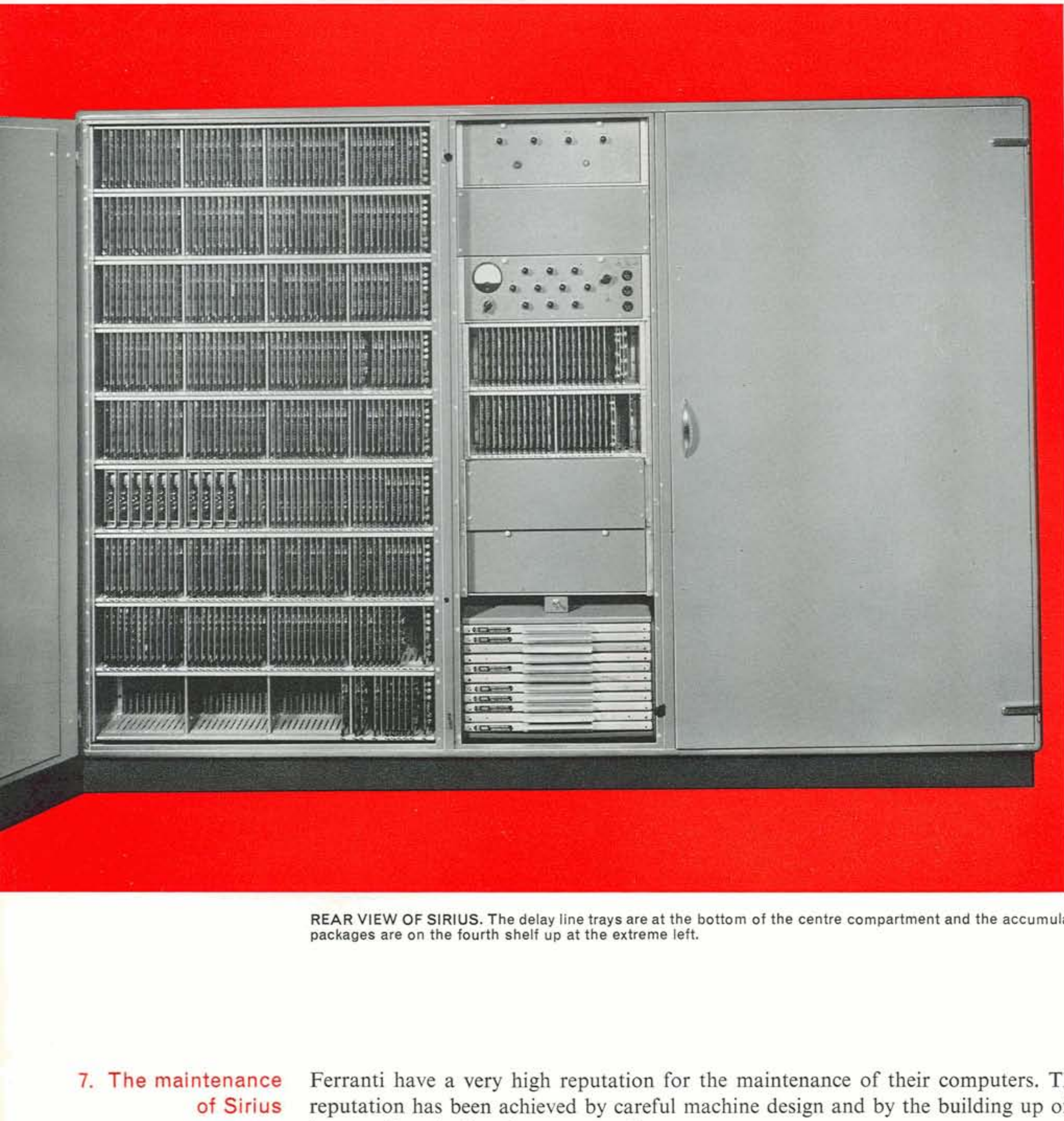
The important points to note in this respect are:

a) **The Autocode** for Sirius has been designed so that it will accept Autocode programmes written for the Pegasus computer. Thirty-three Pegasus computers have already been sold in Great Britain alone, and by now there are many Pegasus Autocode programmes in existence, and the fact that they can also be used on Sirius is of great importance. Although Pegasus is basically a rather faster machine than Sirius, an interesting point to note is that, when working in Autocode, programmes are obeyed twice as fast on Sirius as they are on Pegasus.

   A further scheme will permit Sirius programmes to be run on the Mercury computer and a similar arrangement for Orion is envisaged.

b) **The input and output channels** on Sirius are the same as those on Pegasus, Mercury and Orion so that the same peripheral devices can be attached to each of these computers (although the faster ones may not run at full speed when connected to a slower computer). The object of these common input/output channels is to give the user as much freedom as possible in attaching whatever devices he wishes to use. Some of the equipments which may be attached to Sirius *via* these channels are listed below in appendix D.

c) **Tape editing equipment** is similar for all Ferranti computers, including Sirius. The five-channel tape code is the same as that used on Pegasus and Mercury and it is acceptable on Orion. This means that users who are doing the majority of their work on a Sirius or a Pegasus may hire time on a neighbouring Mercury or Orion for any occasional large problems they may have, and their own tape editing equipment can be used for the production of the necessary tapes.



REAR VIEW OF SIRIUS. The delay line trays are at the bottom of the centre compartment and the accumulator packages are on the fourth shelf up at the extreme left.

7. The maintenance of Sirius

Ferranti have a very high reputation for the maintenance of their computers. This reputation has been achieved by careful machine design and by the building up of a large well-trained maintenance staff.

The maintenance of the Sirius computer will be (unless the customer wishes otherwise) entirely the responsibility of Ferranti Ltd. An engineer will be stationed on the site for an initial period after installation, and thereafter will visit the site approximately every fortnight to do checking and routine preventative maintenance and will also be on call if any trouble should arise. Courses are also held at the factory for the instruction of customers' own staff in the simpler aspects of the maintenance of Sirius.

8. Ferranti library services

As with other Ferranti computers, users of Sirius will be supplied with an extensive **library of routines and subroutines.** Full programmes will also be available. Ferranti have an unequalled reputation for the library services they provide for their computers. It has been estimated, for instance, that 500,000 man-hours have gone into the development of the Pegasus Library; and supplementary to the libraries are such activities as users meetings and interchange schemes for programmes developed by users. Every effort is made to ensure that users can make the best possible use of Ferranti computers.

9. Programming highlights of Sirius

A full description of the facilities available for programming Sirius can be found in List LD. 11 **'Sirius Programming Manual'.** The purpose of this short section is only to call attention to some of the details which are covered by the well-designed instruction code and which will illustrate the care which has gone into the design of the Sirius computer.

A major feature of Sirius is its **multiple accumulators**. These allow arithmetic on numbers, and the holding of intermediate results, to be handled quickly and easily

SIRIUS COMPONENTS. A delay line tray with cover removed and front and back of a neuron compartment.

with little or no reference to the store. In this respect Sirius has a 'two and a half address' instruction code. For example, the single instruction

0089   357892

will add 357892 **and** the contents of accumulator 9 to the contents of accumulator 8 where the result will remain until wanted later in the calculation.

The address of any instruction referring to the store of Sirius can be modified and this is not affected in any way by the actual position of the instruction in the store.

When counting, one or two registers need to be available to hold the counters. These are provided in Sirius by the accumulators. (These are genuine 'B-lines' (so-called) in that the counter can both be held in an accumulator **and** tested there. It is not necessary to alter the counter in one part of the machine and transfer it to another part for testing each time.)

Sirius contains nine jump instructions, all different. Apart from providing a variety of these instructions, care has been taken that they are **complementary**, *i.e.* corresponding, for example, to a 'jump when positive' there is a 'jump when negative'. Thus a programmer can correct any errors in the 'jumps' of his programme without having to insert extra instructions.

A particular feature of the Sirius jump instructions is that the control address can be automatically added to the jump address. This means that the internal jump instructions of a routine will work correctly wherever the routine is actually placed in the store.

For example, the instructions 0030–1
5231–8

would decrease a counter (held in accumulator 3) by 1 and then jump eight instructions back in the routine when the counter became zero.

Provision for the use of subroutines is simple. In Sirius, one instruction (69) is used both to enter a subroutine **and** to set the link for returning to the main programme after the subroutine has been obeyed.

Appendix A Sirius Basic Instruction Code

INSTRUCTION LAYOUT
10 DECIMAL DIGITS

		N				F		A	B

N is a main store address or a constant
F is a function from the table shown below
A and B are accumulators
n, a, b are the contents of N, A, B respectively
a' is the contents of A after the operation
OVR is the overflow indicator

In all instructions up to 69, b is added to N before the instruction is obeyed. **This is the basic instruction code, and only includes the commonly used functions.** The full code is given in List LD.11 'Sirius Programming Manual'.

00	$a' = a + (N + b)$	20	$a' = 10a + (N + b)$
01	$a' = a - (N + b)$	21	$a' = 10a - (N + b)$
02	$a' = -a - (N + b)$	22	$a' = -10a - (N + b)$
03	$a' = -a + (N + b)$	23	$a' = -10a + (N + b)$
04	$a' = N + b$	24	$a' = 10a +$ M.S.D. of $(N + b)$
05	$a' = a + 10^4(N + b)$	25	$a' = 10a + 10^4(N + b)$
06	$a' = a - 10^4(N + b)$	26	$a' = 10a - 10^4(N + b)$
07	$a' = -a - 10^4(N + b)$	27	$a' = -10a - 10^4(N + b)$
08	$a' = -a + 10^4(N + b)$	28	$a' = -10a + 10^4(N + b)$
09	$a' = 10^4(N + b)$	29	$a' = 10a +$ M.S.D. of $10^4(N + b)$
10	$a' = a + n$	30	$a' = 10a + n$
11	$a' = a - n$	31	$a' = 10a - n$
12	$a' = -a - n$	32	$a' = -10a - n$
13	$a' = -a + n$	33	$a' = -10a + n$
14	$a' = n$	34	$a' = 10a +$ M.S.D. of n
40	$a' = (a + 5)/10$ Arithmetical Shift down (Rounded)		
44	$a' = a/10$ Arithmetical Shift down (Unrounded)		
45	$a' = (a + 5)/10 +$ L.S.D. of N (Rounded)		
49	$a' = a/10 +$ L.S.D. of N (Unrounded)		
50	Dummy	55	Jump to N unconditionally
51	Jump to N if M.S.D. of $a \neq 0$	56	Jump to N if M.S.D. of $a = 0$
52	Jump to N if $a \neq 0$	57	Jump to N if $a = 0$
53	Jump to N if OVR set	58	Jump to N if OVR clear
54	Jump to N if $a < 0$	59	Jump to N if $a > 0$
	Instructions 53 and 58 clear the OVR		
60	$n' = a$	70	$x'_0 =$ quotient, $a' =$ remainder, on dividing (a, x_0) by b. Unsigned
64	$n' = 0$	71	$a' =$ TAPE
66	$a' = a \& N$	72	(TAPE)$' = a$
68	$a' = a \& 10^4 N$	73	(TAPE)$' = a$ and $a' =$ TAPE
69	$a' = x_1$ and jump to N	79	$(a, x_0)' = b \times x_0$
99	Wait		

Appendix B The Tape Code

Tape character	Value	Printed character	
		Figures	Letters
`   ·  `	0	figure shift	
`   · ●`	1	1	A
`   ·● `	2	2	B
`   ·●●`	3	*	C
`  ●·  `	4	4	D
`  ●· ●`	5	(	E
`  ●·● `	6	)	F
`  ●·●●`	7	7	G
` ● ·  `	8	8	H
` ● · ●`	9	≠	I
` ● ·● `	10	=	J
` ● ·●●`	11	−	K
` ●●·  `	12	*v*	L
` ●●· ●`	13	*LF*	M
` ●●·● `	14	*Sp*	N
` ●●·●●`	15	,	O
`●  ·  `	16	0	P
`●  · ●`	17	>	Q
`●  ·● `	18	≥	R
`●  ·●●`	19	3	S
`● ●·  `	20	→	T
`● ●· ●`	21	5	U
`● ●·● `	22	6	V
`● ●·●●`	23	/	W
`●● ·  `	24	×	X
`●● · ●`	25	9	Y
`●● ·● `	26	+	Z
`●● ·●●`	27	letter shift	
`●●●·  `	28	.	.
`●●●· ●`	29	*n*	?
`●●●·● `	30	*CR*	£
`●●●·●●`	31	⁎	⁎

LF = line feed
Sp = space

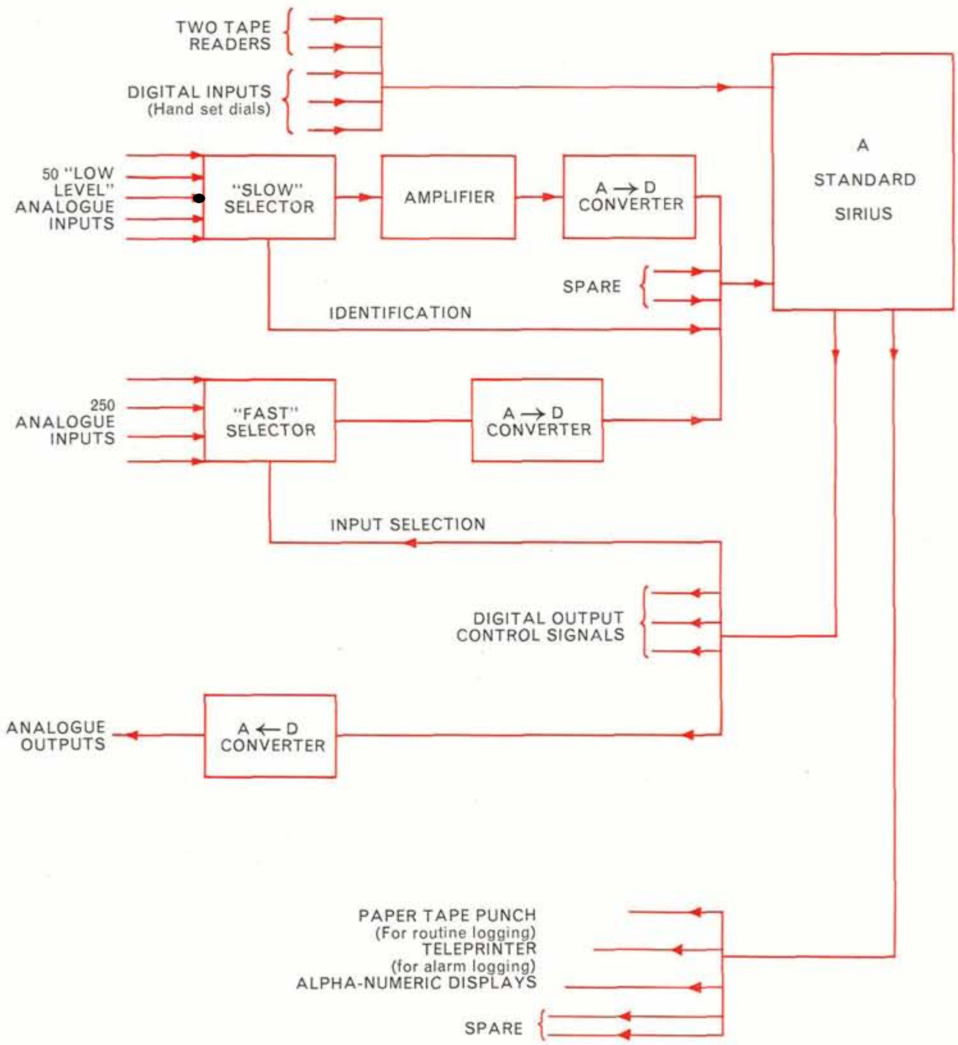
CR = carriage return
⁎ = the erase symbol

Appendix C Process Control Applications

The standard Sirius computer can, with minor modifications to some of its input/output channels, be used for data-logging and limited process-control work. Such modifications will not in any way alter the computer's capacity as a general purpose computer.

The techniques required in order to feed analogue signals into Sirius are the same as are required for all other process-control digital computers, and a considerable amount of useful equipment has already been developed by Ferranti Ltd. in connection with the Argus process-control computer. On the output side, a wide range of logging devices can be attached and, if the machine is to be used for control work, analogue and digital signals can be generated.

A diagram showing a possible process-control system using Sirius is shown below.



Appendix D Additional Equipment

The following items of equipment, together with their electronic circuits to connect them with the computer, working in the 'standard' mode, should all come into existence during 1960 and can be connected to Sirius.

1. Ferranti TR7 Tape Reader. (With integral spooling arrangements.)
2. Creed 3000 Tape Punch at 300 characters per second (from Ferranti Ltd.).
3. Magnetic Tape Input/Output system, maximum speed, 1000 characters per second, but usually used at 250 characters per second. A single tape mechanism is used either for input or for output. This is primarily intended for high-speed recording of results for printing, the magnetic tape subsequently being transcribed to punched paper tape at 33 characters per second for ultimate printing on one or more teleprinters or Flexowriters at 10 characters per second. A second application is as a 'dump' for recording data from the computer which is going to be read in again on a later occasion. The data is recorded on the magnetic tape as six-bit characters. There are automatic checking facilities both on recording and on reading back. Data is recorded at 100 characters per inch and the maximum length of tape on a spool is 1800 feet.

The following items of equipment have been considered for use with Sirius but no detailed development work on them has, at the time of writing, been begun.

4. Creed 75 Teleprinter to give direct output printing at 10 characters per second for monitoring purposes.
5. The Creed Fast Printer at 100 characters per second, which is at present under development.
6. Graphical Display Unit as being developed at Manchester University. This could accept two 10-digit signals, one for the X co-ordinate and one for the Y co-ordinate, for each point to be displayed on a fluorescent screen.
7. Analogue/Digital Converters which may be used either to accept signals from instruments, for example, or to deliver signals to control equipment. Consideration has been given to such devices by Ferranti Ltd., G.W. Department, Wythenshawe; Messrs. Hilger & Watts Ltd.; Imperial Chemical Industries Ltd.; and Sunvic Controls Ltd.
8. A clock with digital read-out (for example, Messrs. Hilger & Watts Ltd.).

Appendix E A Machine Code Programme

Problem: Calculate the arithmetic mean $\bar{x}$ and the standard deviation SD for each of several sets of numbers x_i. Each set has a reference number M and contains N items.

Also $0 < x_i < 0{\cdot}5$ and $\Sigma x_i < 0{\cdot}5$

$$\bar{x} = \frac{1}{N}\Sigma x_i, \qquad \text{SD} = \left(\frac{1}{N}\Sigma x_i^2 - \bar{x}^2\right)^{\frac{1}{2}}$$

Description of Programme: The programme consists of four portions, namely

1. The main programme (32 words)
2. An input subroutine (46 ,,)
3. An output subroutine (50 ,,)
4. A square root subroutine (20 ,,)

The programme occupies 148 words, and is designed to print out on one line, the values of M, N, $\bar{x}$ and SD for each set of numbers.

Standard Library subroutines are used for input, output and the square root; brief specifications of them are given below. Following these are the instructions of the main programme.

Library subroutines:

Input subroutine:

Reads into X9; link must be set in X2; enter first instruction for integer, second for fraction. Uses X7, 8, 9.

Output subroutine:

Punches from X9; link in X2, enter first, second, third or fourth instructions to print integer new line, same line; fraction new line, same line respectively. Uses X7, 8, 9.

Square root subroutine:

x in X9, link in X2; gives $x^{\frac{1}{2}}$ in X9. Uses X5, 6, 7, 8, 9.

Main Programme

(The first instructions of the main programme, input subroutine, output subroutine and square root subroutine are labelled $\nu 1$, $\nu 2$, $\nu 3$ and $\nu 4$ respectively so that, for example, the instruction 6920 $1\nu 3$ jumps to the second instruction of the output subroutine.)

INSTRUCTIONS F AB	N	NOTES
6920	$\nu 2$	Read M to X9
6920	$\nu 3$	Print M, new line
6920	$\nu 2$	Read N to X9
0430		X3 $= 0$ ($= \Sigma x_i$, initially)
0440		X4 $= 0$ ($= \Sigma x_i^2$)
0459		X5 $= N$
0469		X6 $= N$ (= count for loop)
6920	$1\nu 3$	Print N, same line
6920	$1\nu 2$	Read x_i to X9
0039		Increase Σx_i
0489		X8 $= x_i$
7988		X8 $= x_i^2$
0048		Increase Σx_i^2
0160	1	Reduce count by 1
5261	−7	Jump if count $\neq 0$
0470	1	X7 $= 1 \times 10^{-10}$
0465		X6 $= N \times 10^{-10}$
0490		Clear X9
7076		X9 $= 1/N$
0459		X5 $= 1/N$
7993		X9 = X9 × X3 $= \bar{x}$
0439		X3 $= \bar{x}$
6920	$3\nu 3$	Print $\bar{x}$, same line
0493		X9 $= \bar{x}$
7993		X9 $= \bar{x}^2$
0439		X3 $= \bar{x}^2$
0494		X9 $= \Sigma x_i^2$
7995		X9 $= (1/N)\, \Sigma x_i^2$
0193		X9 = (SD)^2
6920	$\nu 4$	X9 = SD
6920	$3\nu 3$	Print SD, same line
5500	$\nu 1$	Return to first instruction to deal with next set.

Appendix F An Autocode Programme

The complete Autocode programme for the same problem as in Appendix E is given below. Explanatory notes to assist the reader in following an Autocode programme are included in List CS.231.

	INSTRUCTIONS	NOTES
2)	$n1 = \text{TAPE } 2$	$n1 = M, n2 = N$
	PRINT $n1$, 3000	Print M, new line
	PRINT $n2$, 4000	Print N, new line
	$\nu 1 = 0$	$\Sigma x_i = 0$
	$\nu 2 = 0$	$\Sigma x_i^2 = 0$
	$\nu 3 = 1 / n2$	$\nu 3 = 1/N$
1)	$\nu 4 = \text{TAPE}$	$\nu 4 = x$
	$\nu 1 = \nu 1 + \nu 4$	increase Σx_i
	$\nu 4 = \nu 4 \times \nu 4$	$\nu 4 = x^2$
	$\nu 2 = \nu 2 + \nu 4$	increase Σx_i^2
	$n2 = n2 - 1$	decrease count by 1
	$\rightarrow 1, n2 \neq 0$	Jump if count $\neq 0$
	$\nu 1 = \nu 3 \times \nu 1$	$\nu 1 = \bar{x}$
	PRINT $\nu 1$, 3008	Print $\bar{x}$
	$\nu 1 = \nu 1 \times \nu 1$	$\nu 1 = \bar{x}^2$
	$\nu 2 = \nu 3 \times \nu 2$	$\nu 2 = 1/N \, \Sigma x_i^2$
	$\nu 2 = \nu 2 - \nu 1$	$\nu 2 = (\text{SD})^2$
	$\nu 2 = \text{SQRT } \nu 2$	$\nu 2 = \text{SD}$
	PRINT $\nu 2$, 3008	Print SD
	$\rightarrow 2$	Jump to first instruction
	$(\rightarrow 0)$	Enter programme

(The numbers in the PRINT instructions specify certain printing layouts.)

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