9. Yathindra, N. and Sundaralingam, M., *Nucleic Acids Res.*, 1976, **3**, 729.
10. Srinivasan, A. R., Yathindra, N., Rao, V. S. R. and Prakash, S., *Biopolymers*, 1980, **19**, 165.
11. Yathindra, N. and Sundaralingam, M., In *Structure and Conformations of Nucleic Acids and Protein-Nucleic Acid Interactions*, Eds. M. Sundaralingam and S. T. Rao, Univ. Park Press, 1974, p. 649.
12. Yathindra, N. and Sundaralingam, M., *Proc. Natl. Acad. Sci.*, 1974, **71**, 3325.
13. Jayaraman, S. and Yathindra, N. (Unpublished results).
14. Sasisekharan, V. and Gupta, G., *Curr. Sci. (Ind.)*, 1980, **49**, 43.
15. Sundaralingam, M., *Biopolymers*, 1969, **7**, 821.

SOME MORE KEYS AND RULES FOR A PROGRAMMABLE CALCULATOR

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ABSTRACT

The standard system of keys[1] has been enlarged to incorporate the various concepts of programming. A set of rules governing arithmetic operations and display is also given.

The Blank Key

THIS key, designated as β, is a null key which does nothing other than passing the control to the next step.

Effect of a DR Control Key Followed by the I or D Key

In such cases, the machine will first perform the indicated operation on the memory whose address is given by the content of the concerned IR and *then* increment/decrement its content. Hence SIϕ is equivalent to SRϕ Iϕ and SDϕ to SRϕ Dϕ. The other keys F, M and Z also work similarly.

Relational Operators

These are keys which cause the machine to take a decision depending upon the relation between two numbers. They are $\leqslant$ and $\equiv$ which stand for *less than or equal to* and *equal to*. The role of $\leqslant$ has already been defined[1]. In view of the convenience to the programmer, we redefine its role and similarly define the role of $\equiv$. Both the keys will cause the display to be copied in the internal register. The general form of these keys are $a \leqslant b$ $(sss \ldots s)$ and $a \equiv b$ $(sss \ldots s)$, where a and b are the displays before and after encountering the operator key. $sss \ldots s$ is a sequence of steps which will be executed only if the indicated relation is true. The bracket need not be put if there are only four steps inside it.

The Inverse Key

The inverse key V performs the inverse/complement operation of the key succeeding it. Hence V $\leqslant$ stands for *not less than or equal to* and V $\equiv$ for *not equal to*.

These ideas are illustrated in the example given below:

Example 1. Write a programme for finding the greatest absolute value of $x_1, x_2, \ldots x_n$.

The programme is given in Table I. The inputs are $n, x_1, x_2, \ldots, x_n$ and output, the greatest absolute value. Spaces have been provided at appropriate places.

TABLE I

Programme for finding the greatest absolute value

	Programme steps	Comment
ϕϕϕ	AG4 HP Sϕ = A	n is stored in DRϕ
ϕϕ9	1 Tϕ 3 T1	
ϕ15	HP SI1 Iϕ	Steps ϕ15 to ϕ3ϕ
ϕ22	Rϕ $\leqslant$ Mϕ → ϕ15	form a loop to store $x_1, \ldots, x_n$ in DR3 onwards
ϕ31	3 T2 ϕ S2 =	DR2 is initialised to zero
ϕ38	ϕ V$\leqslant$ MI2 (±)	Nos. are called one by one
ϕ47	V$\leqslant$ M2 E S ϕ2	Sign of a negative no.
ϕ55	R1 V$\leqslant$ R2 → ϕ38	changed and compared with the content of DR2. The greater no. being retained in it
ϕ65	A M2 P	
ϕ69	Halt	End of programme

Two Special Combinations of Keys

The combination DS is used to *D*elete *S*ign from the displayed number, *i.e.*, for getting the absolute value; and IN, to display the *IN*tegral part simultaneously storing the fractional part in the internal register. (N is one of the subroutine keys to be defined below.) The programme in example 1 can be shortened by means of the DS combination.

Input/Output Using an Auxilary Storage Device (ASD)

Data can be stored on an auxilary storage device which can be subsequently used as input. An ASD is divided into blocks which are serially numbered. Each block contains as many storage locations as there are data registers. Each storage location is serially numbered and can hold a number at a time.

The Write Key

The write key W is used for output on an ASD and the combination VW, for input from an ASD. The general form of an output statement is *a.b* W *c.d* and input statement, *a.b* VW *c.d* where *a* stands for the number of data registers/storage locations involved; *b*, for the starting DR address; c, for the block number and *d*, for the starting storage location number in the block.

The Subroutine Keys

A subroutine is a sequence of steps which forms part of a programme called the main programme. If the sequence is required several times in the main programme, its inclusion every time will consume a lot of steps. Such duplication of steps can be avoided by making use of the subroutine keys. These are the J (*i.e.*, *J*ump subroutine) and N (*i.e.*, retur*N*) keys. The J key must be followed by the step number of the first key of the subroutine. The J key together with this step number is called the calling statement. The J key passes control to the step number following it, and the N key returns control to the main programme; to the first key after the calling statement. The J and N keys must occur in pairs and can be nested. The use of these keys are illustrated in the example given below.

Example 2. Write a programme to evaluate the expression:

$$(5x^2 + 8x + 2)^2 (y^3 + 8y + 6)/(z^4 + 6z^2 + 4z + 5)$$

for different values of x, y and z.

This involves evaluation of polynomials and hence steps ϕϕϕ to ϕ71 of the polynomial evaluation programme[1] can be used as a subroutine. For this, step ϕ72 is to be changed to N. The main programme can be started from step 1ϕϕ onwards. It is given in Table II.

TABLE II

Programme to illustrate the use of subroutine keys

Programme steps		Comment
1ϕϕ	AG4	
1ϕ3	Jϕϕϕ	The subroutine is called. Control goes to ϕϕϕ to evaluate $5x^2 + 8x + 2$. The result is stored in DR2. Upon reaching the N key, control comes back to 107 of the main programme.
107	× = S8 Gϕ	$(5x^2 + 8x + 2)^2$ is stored in DR8.
113	Jϕϕϕ	The subroutine is called to evaluate $y^3 + 8y + 6$.
117	× M8 = S8 Gϕ	The numerator evaluated and stored in DR8.
125	Jϕϕϕ	The subroutine is called to evaluate $z^4 + 6z^2 + 4z + 5$.
129	A ÷ M8 E = PA	The value of the expression is printed.
137	Halt	End of the programme.

Rules Governing Arithmetic Operations, Display and Internal Register Contents

Every operation in a calculator is governed by *exact* rules. A knowledge of them is essential for the efficient utilisation of the machine. Some rules related to arithmetic operations, display and storage in the internal register are given below. These are illustrated in Table III.

1. Change of display will cause the previous display to be stored in the internal register.
2. The pressing of any arithmetic/relational operation key will cause the display to be copied in the internal register.
3. A binary arithmetic operation command will prevail in the machine until it is cleared or a new command is given.
4. If an operand is missing, the content of the internal register will be taken as operand. If the operator is missing the prevailing operator if any will be taken as operator. In such cases rule 1 is applicable after inserting the missing terms.

5. A binary arithmetic operation is performed by treating the content of the internal register as operand and the display as the number to be operated upon. The display will then be replaced by the result.

TABLE III
Illustration of rules relating to arithmetic operations and display

Key	Display	Internal register content	Comment
6	6	..	
+	6	6	rule 2
3	3	6	rule 1
×	9	3	rules 1, 5
2	2	9	rule 1
=	18	2	rules 1, 5

TABLE IV
Evaluation of $x^2 + xy + y^2$

Key	Display	Internal register content	Comment
$x \times =$ Sφ	x^2	x	x^2 stored in DRφ
E	x	x^2	
$\times y =$ Fφ	xy	y	xy added to DRφ
E	y	xy	
$\times =$ Fφ	y^2	y	y^2 added to DRφ
Mφφφ	x^2+xy+y^2	y^2	Expression evaluated

By virtue of rule 4, the sequence $6 + 5 \times - \div 2 =$ is equivalent to $6 + 5 \times 5 - 5 \div 2 =$ and the sequence $6 + 5 \times 7 = 8 = 9 =$ is equivalent to $6 + 5 \times 7 =$, $8 \times 7 =$, $9 \times 7 =$. Raising to powers can be done either by $\times = = \ldots\ldots$ or $\times \times \times \ldots\ldots$

These rules can save memories and steps as illustrated in the following two examples. The x and y have to be replaced by their numeric values.

Example 3. Give the sequence of keys to evaluate the expression:

$$[2x^2 + (y \div x^2)]/3$$

The required sequence is $x \times \div yE + + \div 3 =$. Note that the value of x is entered only once and no memory is used.

Example 4. Evaluate the expression:

$$x^2 + xy + y^2.$$

The required sequence is given in Table IV.

From the above examples we see that the E key *is* a very powerful one. Its potential is yet to be understood by many users.

For easily distinguishing negative numbers, they may be printed in red colour.

In this and the earlier paper[1], most of the concepts of programming have been discussed with reference to a calculator. Any person well experienced with ordinary calculators can comprehend them without much difficulty. In colleges, programming courses can be taught using a calculator, because many colleges can afford it. With this background, students can study programming languages quickly. In program*ming it is not the machine that matters*; but what matters is the logic or the organisation of the programme. The programmer's thoughts can be given expression both in a calculator and in a computer, subject to the limitations of the machine. This job is fairly quick in a sophisticated computer whereas in a calculator, this sophistication is to be matched by the programmer's ingenuity.

Calculator programming can be recommended as a profitable hobby.

APPENDIX

The symbols β, V, J, N, DS and IN are equivalent to R/D, INV, JSB, RTN, GOLD 2 and GOLD 3 in Micro 2200 of the HCL[2]. The JSB key is to be followed by a four-digited step number. There are no equivalent keys for ≤, V≤, ≡ and V≡. But their effects can be produced by manipulating the E key and one or more of X≤Y, X = Y, X>Y and →. The D key should not follow a DR control key, *i.e.*, a combination like MDφ is not acceptable. But MIφ is acceptable. In machines with MAM, the effect of W key can be produced by manipulating the SILVER key and one or more of the blocks of the floppy disc.

1. Abdurazak, M. P., *Curr. Sci.*, 1980, 49, 3.
2. Anonymous, *Instruction Manual, Micro* 2200, Hindustan Computers Limited, Lucknow, 1978.