THE T.I. PROGRAMMABLE 59

BY TUDOR JONES

The T.I. Programmable 59 electronic calculator is a product of one of the giants of the computer industry, Texas Instruments Inc. of Dallas, Texas. It is distributed through a variety of stores at prices that appear to vary between $350 to less than $300.

Including a library module it weighs 10½ ounces. The instruction books for the calculator, master library module, and surveying module are each 11" x 8½", collectively contain 425 pages, and weigh 2¾ pounds.

It is T.I.'s top-of-the-line hand held programmable. It is extremely versatile, and features up to ten registers directly available for looping, incrementing and decrementing, ten flags, conditional and unconditional branching, six levels of sub-routines, flexible addressing, complete program editing, magnetic cards for recording custom programs and data register contents, over 175 separate functions and operations, together with the capability of storing 960 program steps in memory. 800 of the program steps can be traded off with 100 storage registers.

The optional PC 100C print/security cradle provides hard copy printouts of data entered and calculated.

The calculator serves as an excellent back-up or stand-by to larger desk-top mini-computer systems costing up to thirty times as much.

In fact, if a person was to consider purchasing a desk-top system, such a system would have to compare very favourably with the T.I. 59 or similar hand-held calculator. If it only equalled it in power and capacity, and cost $8,000, then in effect the computer part of the desk-top calculator would be worth $300, and the case it comes in would cost the remaining $7,700.

Anyone contemplating replacing, augmenting or up-grading their present equipment should carefully consider the hand-held micro-computers available today.

The T.I. 59 calculator is equipped with the "Algebraic Operating System" method of entering problems, as opposed to the "Reverse Polish Notation" system as used by some others. Mathematical
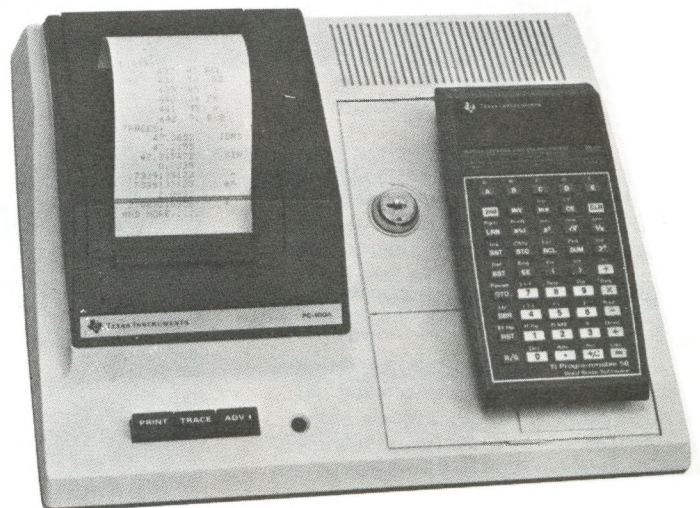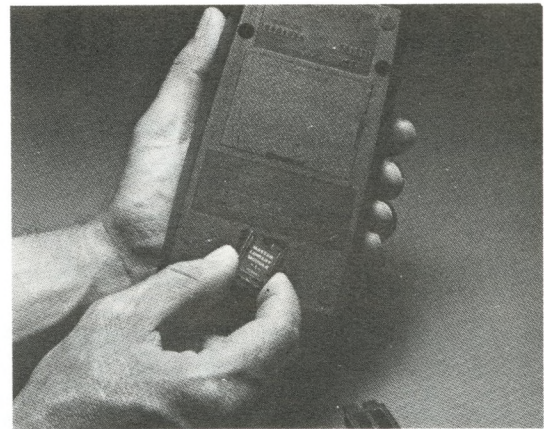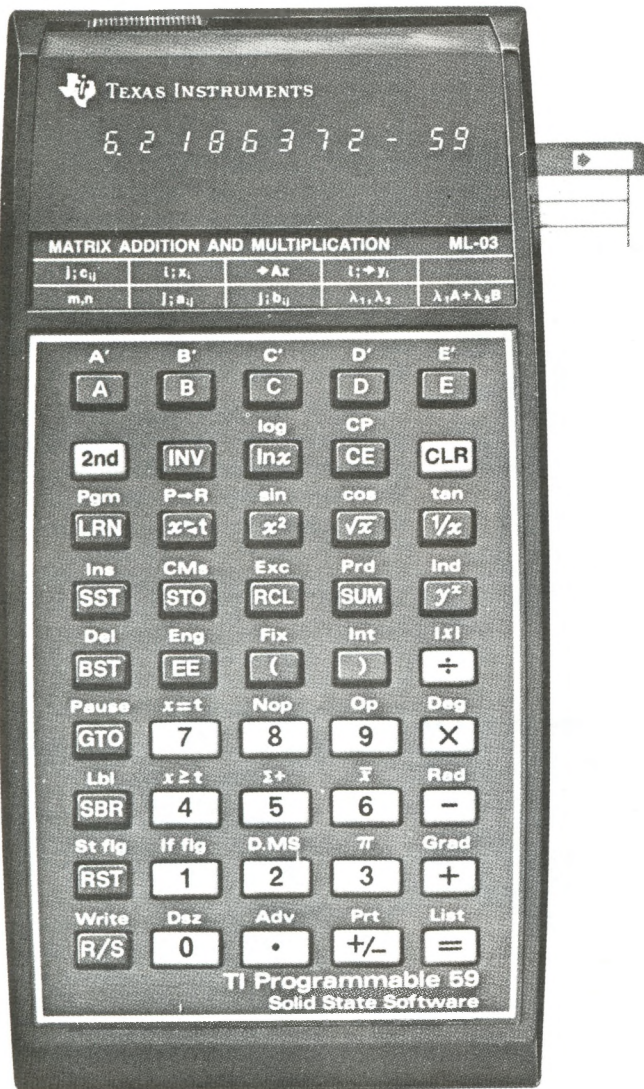
problems are solved by entering them into the calculator in the order they are written, left to right. The calculator sorts the operations as they are entered, and applies them to the data in the correct order. Up to nine sets of parenthesis, allowing up to eight pending operations, are available. Additional control over the order of interpretation is provided through the use of parenthesis keys.

A feature of the T.I. 59 is a selection of programs, in read-only memory form, in convenient plug-in modules.

The Surveying Library Module has 24 programs ranging from a compass rule balance of a traverse, through the usual co-ordinate geometry (bearing-bearing intersect, etc.) to earthwork volumes and triangle and curve calcs. Each of these programs is accessible immediately via a few keystrokes, and can be used as sub-routines within custom programs.

For modification, these library programs can be down-loaded into the program memory of the instrument, and manipulated and amended there as necessary. These amended programs would have to be stored on magnetic cards - the amended programs cannot be placed back in the library module, of course.

Some library modules contain proprietary programs and are protected from downloading.

Following are brief descriptions of the operations carried out by some of the keys on the keyboard.

Keys A and A' through E and E' access a particular segment in a program. Along with most other keys they can be used to head up sub-routines in custom programs. For example, a particular custom program calculates a closure or missing course, and area from lats., deps., D.M.D.'s, and double areas. After entering all bearings and distances, Key A calculates and prints total lats. and deps., and the relative accuracy, or Key B calcs. and prints lat., dep., bearing and distance of the missing course; Key C calcs. and prints the enclosed area.

CP clears all program memory locations, CMS clears all data registers by storing zeros therein.

In the learn mode, INS and DEL enable new instructions to be inserted into a program, or unwanted instructions to be deleted. In either case, all following program steps are moved up or down as the case may be to accommodate the change.

DMS converts degrees, minutes and seconds to degrees and decimal degrees. Older, and less sophisticated, computers require about sixteen program steps to carry out this single function.

When the INV key precedes another key, the purpose of that key is reversed. For example, INT discards the fractional part of the number in the display register. INV.INT discards the integer portion and keeps the fractional part.

The speed of some of the operations, contrary to what one would expect, is surprisingly slow in some instances.

Sines and cosines, at the touch of the appropriate key, appear to be generated in less than a second. A latitude and departure calculated by program from a keyed in bearing and distance both together take about six seconds.

As a test, an area of a figure bounded by twenty courses, using the program previously referred to, was calculated from lats. and deps. already in storage. From pressing Key C to the print-out of the square feet, took an incredible 95 seconds.

This length of time may be due in part to inefficient programming, even though the program is structured with the sub-routines listed first to cut down search time. However, an earlier desk-top machine with the same data, and with basically the same program, takes less than four seconds to do the same amount of work.

The optional PC 100C Print/Security Cradle provides quiet, high speed printing for convenient hard copy print-outs. It prints over 60 characters per second using a non-impact thermal print-head.

It is particularly useful, and certainly earns its cost, when programming and debugging complex problems.

Alpha-numeric printing of 64 characters is possible. Each character is entered by means of a 2-digit address code which, on the one hand, tends to eat up available program steps in a hurry, but on the other hand makes for a sharp looking tape. Maximum line length across the 2½" wide paper is 20 characters.

It cannot merge alpha characters with calculated answers, e.g. N23° 45' 30"E is not attainable. The best it can practically do is something like:

23.453	BRG, or
23	DEG
45	MIN
30	SEC.

As calculated data is sooner or later generally annotated onto a sketch for the drafting room, whether this data needs to be copied from a printout tape, or directly from the display, is a $175 question to be answered by each user. If the data on the sketch is questioned, a tape is always to hand and verification can soon be made, whereas the calc. would have to be done over again to confirm that the display reading was copied correctly.

Following are a few notes on the display and a central processing unit. This may, or may not, be of interest due to the nature of the subject.

In 1961, researchers at Texas Instruments found that a gallium arenside diode or transistor when conducting current gave off an infra-red light. This material now forms part of the transmitter in many E.D.M. instruments.

The gallium arenside was modified later so that it would produce light in the visible region instead of infra-red; and the so-called light-emitting diode came into being.

Early L.E.D. displays were handmade and very expensive. Hybrid construction of the individual segments of a digit array was difficult and unsatisfactory, as the eye can perceive very minute misalignments in each segment.

Monolithic displays are now manufactured wherein all seven bars required for each digit are a part of one semiconductor device. The price of the modified gallium arenside is high, so to reduce the cost of such an L.E.D. display, the digits are made small and then magnified. The penalty to be paid for this scheme is a reduced viewing angle.

An unmagnified L.E.D. can normally be read over a viewing angle of 65° to 70° from the vertical, or normal. The display on the T.I. 59 begins to disappear at an angle of 25° from the vertical, and at 30° cannot be seen at all. When working alone with the machine, this restriction causes no problem; when discussing results with one or two other people, it creates some inconvenience.

The L.E.D. display may be driven, or turned on, by simply connecting it across a flashlight battery. Forming digits this way requires one wire per segment, plus one wire for each decimal point, plus one common wire. For the T.I. 59 display, with ten digits, there would be 81 connections required to the display.

The nature of L.E.D. displays, however, are such that they can be multiplexed, or scanned. This reduces the number of connections to both the integrated circuit and the display to nineteen.

The connection of the display in a multiplexed system is shown in Fig. 1. There is a connection to each digit that allows the integrated circuit to choose which digit will be turned on. Similarly

positioned segments on each digit are then connected together so that, for example, to turn on the top segment of the second digit, power would be applied between terminal 2 and terminal B.
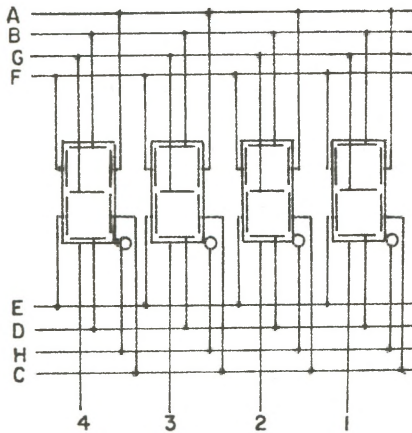

FIG. 1

The display is turned on one digit at a time. For the first digit, terminal 1 would be closed and power applied to terminals A through G as needed to form the desired character. This would then be repeated with the second, third digits, etc. Although only one digit is ever turned on at any one time, the speed of going from digit to digit is such that all digits appear to be on at the same time.

The terms display and display register as used in connection with this instrument are not synonymous. Display refers only to the ten digits seen in the calculator's window. The display register is an internal register that retains results to thirteen digits. Any results in this register are rounded for the display only.

One curious anomaly that occurs as a result of this, is that if the numeral one in the display is divided by three, and then the result is multiplied by three, the surprising answer is a numeral one in the display. The reason for this is that the expected, computed answer of 0.999 (recurring) is in the display register, and the rounded off value of it is in the window.

The actual execution of an instruction in an electronic digital computer can be divided into four distinct parts. First, the instruction must be fetched from memory. Then, it must be interpreted, or decoded. Next, the operand or operands must be fetched from memory. Finally, the instruction must be executed.

Most elementary texts, including some school text books, on the internal working of such a computer depict the bits of information being processed as, for example, a train of box cars travel-ling along a track, with some box cars marked with ones, and the remainder with zeros, or perhaps as black and white tennis balls rolling along the inside of a transparent pipe of appropriate diameter. The tracks and pipes have junctions and switches in them, and are supposed to represent the internal logic of a central processing unit. Very little time in these texts is spent on how the switches are operated, and under what authority they are changed. These, and other difficult questions, seem to be ignored.

A consideration of the timings within a computer will soon illustrate that the above analogies are not very good and in my opinion contribute very little to the understanding of these machines.

Light travels at approximately 186,000 miles a second, or at about twelve inches per nano-second. Electricity travels along its conductors at about two thirds this speed, or eight inches per nano-second.

Let us assume that the central clock in the computer emits 4,000 pulses per second. This is not unrealistic.

Earlier mini-computers operated on 1kHz clocks. A recent product of a computer firm in England, the F.P.S. 100, has a 4MHz clock and two central processing units working in parallel, and it fires off its synchronous machine cycles at 250 nano-second intervals for a throughput potential of eight million floating point operations every second.

Incidentally, the British have always been at the forefront of computer technology. They wrote the world's first computer program which ran in June, 1948, built the first computer to be offered for commercial sale, ahead of the Univac in February, 1951, and when the Atlas went into operation in December, 1962, it was the most powerful computer at that time - roughly four times more powerful than a contemporary IBM. It would appear from the F.P.S. 100 that they do not appear to be slowing down any.

To revert to our typical small computer creaking along at 4kHz, each cycle will last 250,000 ns. Let each pulse last 100,000 ns with a 150,000 ns pause between pulses.

The leading edge of the pulse will only take about 3 ns to reach its full potential.

From one end of the calculator to the other is less than eight inches, so even if it has to double back on itself several times, then given a clear path, the signal is going to reach the most distant part of the circuitry within a very short time.

Some gates take a little while to get through, and parts of the memory cannot be reached for perhaps three or four hundred nano-seconds. But certainly within 1000 ns the leading edge of the pulse is going to be at its objective.

This circuit will now be fully energized for the remaining 99,000 ns.

At the end of this time, the clock will terminate the pulse, and the trailing edge (in this technology) will come flashing along the lines, tripping flip flops, and setting gates as it goes.

All will now be quiet for 150,000 odd ns until another pulse is generated.

Certain switches, however, that were in an off position, will now have been switched on, others will have been switched off, counters will have incremented, formerly dead terminals will now be "live", and amongst other things triggers within delay circuits will have been set.

Additionally, electrostatic charges representing information in the capacitors of the semi-conductor memory are quietly dissipating, and soon will have to be refreshed.

You will see, though, that in no way can you have two box cars on the same track, or two tennis balls in the same pipe, at one and the same time.

$$
\begin{array}{r}
0\ 1\ 1\ 1 \\
+0\ 0\ 1\ 1 \\
\hline
1\ 0\ 1\ 0 \\
\hline
\end{array}
$$

Binary arithematic follows the same rules as decimal arithematic. In the addition 7 plus 3 shown in the example, one plus one equals ten, zero down, carry one; one plus one plus the carried one equals eleven, one down, carry one;

TRUTH TABLES.						
IN	OUT		LOGIC STATES			
'AND'	A	0	1	0	1
A ⊐ C	B	0	0	1	1
B	C	0	0	0	1
'EXC. OR'	A	0	1	0	1
A ⊐ C	B	0	0	1	1
B	C	0	1	1	0
'INHIBIT'	A	0	1	0	1
A ⊐ C	B	0	0	1	1
B	C	0	0	1	0

FIG. 2

one plus one equals ten, zero down and the carry goes into the 2^3 slot, giving an answer of binary ten.

The same addition is done electronically in the adder in Figure 3. The adder is equipped with three shift registers, four "and" gates, two "exclusive or" gates, two "inhibit" gates, and a delay circuit.

The operation of the various gates can be adduced from the truth tables in Figure 2. The delay circuit does just that, accepts a pulse on one cycle, and generates a pulse on the next. Heavy lines in the diagrams indicate live, or energized, conductors.

The diagrams are supposed to indicate the conditions in the circuits during four consecutive clock cycles. The last 1 in the sum register has been written in before the trailing edge of the last pulse to save an extra diagram. The two arrows represent diodes that pass current in one direction, but not in the other. I don't think that any further explanation is required.

This example, of course, is quite absurd, as no account is made of any plus or minus signs, floating decimal points or mantissas and characteristics, parity bits, etc. etc. Some idea of the complexity of the actual circuits can be appreciated when one realizes that to merely change the sign of a number in an advanced micro-computer requires somewhere in the order of four hundred separate operations to effect the alteration.

ACSTTO
Office Policy

In the last issue of the Quarterly, an office policy regarding ACSTTO was printed. This statement outlined the policy regarding AOLS employers regarding advertising and hiring of technical staff etc. The following firms have indicated that they have approved the policy as a policy of their firm:

Pierce & Lyons Inc. Peterborough
Yates & Yates Limited, Toronto
Horton & Wallace Ltd. Whitby
E. W. Petzold Limited, Toronto
Smith & Smith (Kingston) Limited
E. C. Brisco, Chatham
Bishop & Wilson Limited, Haliburton
George B. Macaulay, Brantford
William J. Setterington Limited, Leamington
H. A. Smith, Fort Frances
Humphries & Burgham Limited, Kingston
Dearden & Stanton Limited, Orillia
Baird & Mucklestone Limited, Toronto
John L. Sylvester Limited, Port Hope
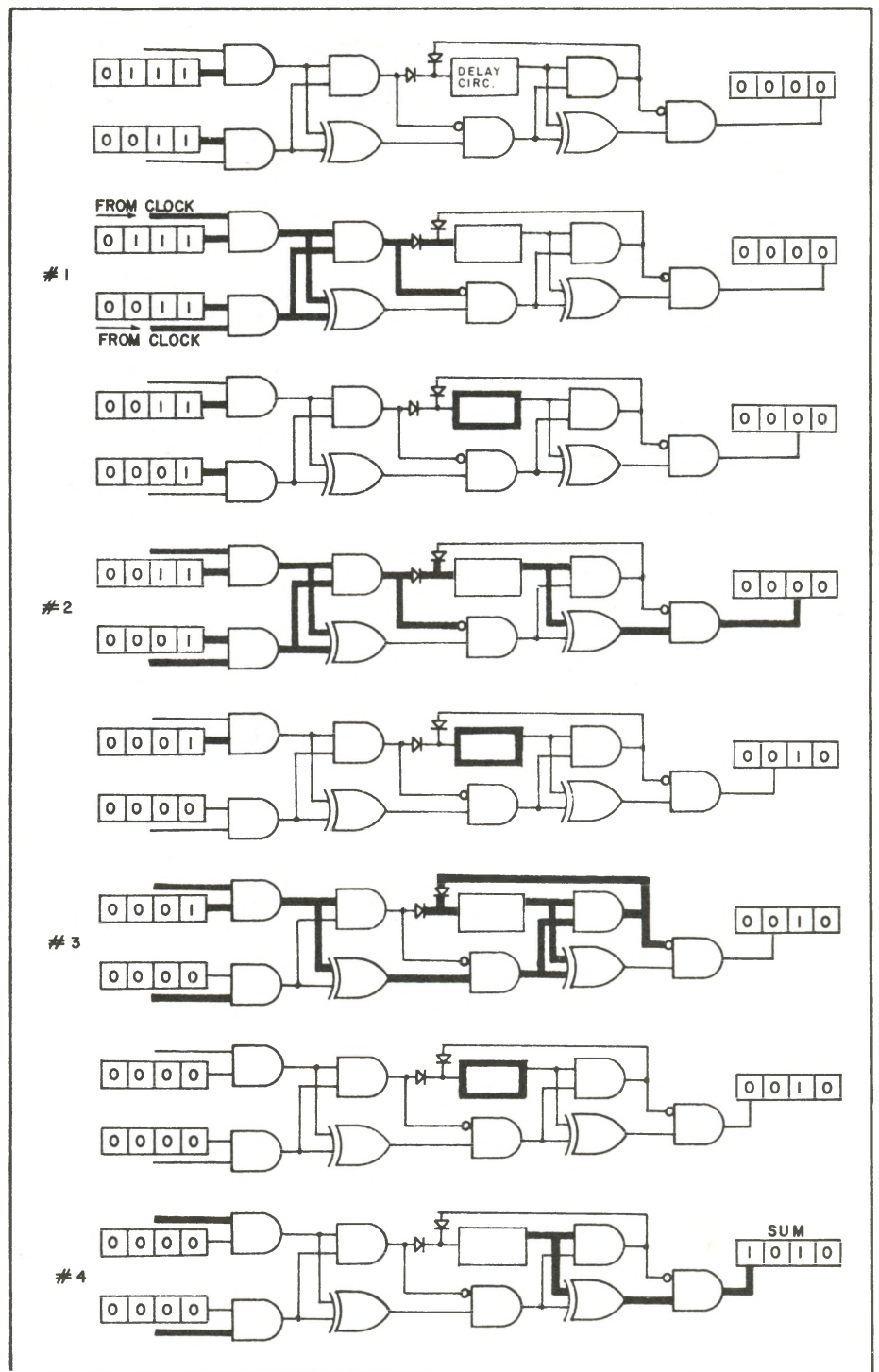J. F. Weston, Tillsonburg
D. J. Cullen Limited, Orangeville

FIG. 3

H. Sutcliffe Limited, New Liskeard
Annis & O'Sullivan Limited, Ottawa
Donald E. Roberts Limited, Scarborough
Nesbit, Robertson, Milway, Sarnia
Maurice W. Fitzmaurice Limited, Bracebridge
Charles P. O'Dale Limited, Midland
H. R. Whale Inc. Hanover
L. U. Maughan Co. Ltd., Parry Sound
Donevan & Fleischman Company Ltd., Pickering

If further firms wish to endorse this policy we will be pleased to add their names to our list.

FEBRUARY SEMINAR
ADVANCE NOTICE

Highways, roads, lanes, foot-paths, cow-trails — Do they cause you a problem?

Then attend the seminar dealing with "Roads in Ontario" on Wednesday, February 20, 1980 at the Harbour Castle Hotel in Toronto (this is the day preceding the annual meeting).