TEKSCOPE

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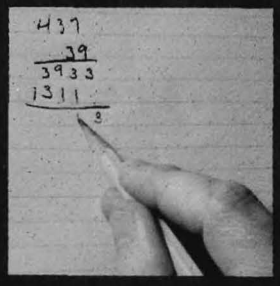

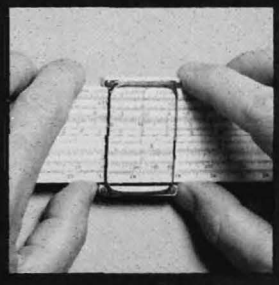

TEKSCOPE

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committed to
technical excellence

Contents

Cover: Man, from earliest times has used his fingers for counting. He's still using them today. Only now they count vast numbers simply by pressing the keys of a scientific programmable calculator such as the TEKTRONIX 31.

The Tektronix Calculator —It All Adds Up

With this issue of TekScope, Tektronix announces its new calculator line, featuring the TEKTRONIX 21 and 31 programmable calculators.

We're going to the great length of a TekScope issue to introduce these calculators, because many people, seeing their low prices, might assume them to possess far less capability than they actually have. And, to make descriptive problems worse, it's the kind of sophisticated capability that a specifications brochure can only begin to impart (although an excellent brochure *is* available on the 21 and 31).

So, in addition to designing, manufacturing and servicing the calculators, we have accepted the added task of helping new users, and potential users, discover their great usefulness, through various means.

Catch phrases like "natural math format" and "keyed-in programming" help spread the word that these calculators *are* a time-saving pleasure to use.

But there's another story. For, beyond doing the most commonly useful tasks uncommonly well, the Tektronix calculators will also do a wide range of tasks commonly thought of as impossible for machines in their price range.

With the components and accessories of the Tektronix calculator line, users can custom-fit their price/performance requirements, up to a very powerful level of sophistication. Options in memory capacity and silent printers can easily add up to the flexibility and power of a minicomputer, and yet sit compactly at deskside, to do as much as the user's ingenuity can demand.

Tektronix is committed to helping users tax their calculators to the utmost. Our specially inducted, experienced calculator sales people have gained an expertise *cum laude* in calculator capability. New and potential users will be encouraged to lean on them.

Additionally, a user's newsletter, called ArithmaTEK, will provide valuable access to the latest applications and ideas from the field.

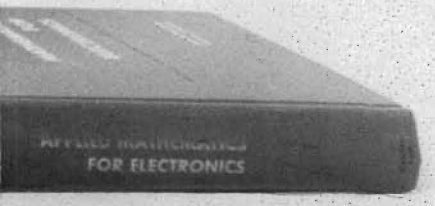
As you read the following articles, we think you'll find that the contributions to this endeavor from all the Tektronix areas of expertise, add up to a calculator line worth looking into—even a whole issue's worth.

Larry Mayhew, Vice President
Information Display Division

The Calculator and You

Long before we trotted off to our first day at school we were being taught the rudiments of mathematics. Ask a little fella how old he is and he'll usually respond by proudly holding up two fingers. If perchance he is three, there may be a moment's hesitation while he decides which three fingers to unfold.

It didn't take long for the problems we encountered to outstrip our ability to count and display them using our fingers; even with the capacity added by removing our shoes and socks. And so we turned to machines. The abacus, perhaps the oldest known model, was invented in pre-Christian times and is still in use in many countries. Much more recently, in the last century, Charles Babbage built the first true forerunner of today's computer, a mechanical "analytical engine." Today, through the miracle of solid-state technology, we have fantastic calculating ability right at our fingertips. These new machines are called scientific programmable calculators—programmable meaning the calculator can



remember and execute operations or keystrokes previously entered, and scientific referring to the mathematical capability of the machine.

There is just one problem—you can't walk up to one of these machines and solve even a basic equation without some special training. The first scientific calculators were developed by men who had previously built computers. Their approach produced a kind of "minicomputer" rather than a mathematical machine, and required special techniques for entering equations.

Now, two new calculators from Tektronix, the TEKTRONIX 21 and 31, offer a fresh approach to solving your problems. These machines have an easy to use language that follows the same rules of algebra that you learned in high school. Equations are entered into the calculators just as you would write them on the blackboard. Let's look at a few examples:

Here is how you write the mathematical expression on paper—	Here is how you write the mathematical expression on the Tektronix keyboard (after pressing [CLEAR]).
EXAMPLE: $4-3\times 2=-2$	[4] [−] [3] [×] [2] [=] −2.
EXAMPLE: $\frac{(2+3)\times 5}{(4+6)}=2.5$	[(] [2] [+] [3] [)] [×] [5] [÷] [(] [4] [+] [6] [)] [=] 2.5
EXAMPLE: $5\times 4\ (.25+5/4)=40.$	[5] [×] [4] [×a] [(] [.] [2] [5] [+] [5] [÷] [4] [)] [=] 40.

You will note that the calculator observes mathematical heirarchy in solving each equation.

Coupled with the ease of problem entry is unequalled ease in programmability. This means your problem solving capability is not limited to those programs supplied by the calculator manufacturer. It's easy to write your own programs and enter them into the machine. In fact, with the "user definable" capability, discussed later, you can modify your calculator at will to communicate in terms unique to any discipline—be it mathematics, statistics, engineering, banking, physics or whatever.

Now let's take a closer look at these new calculators.

Data Entry

The data entry portion of the keyboard looks similar to that on any other scientific calculator. But there the similarity ends. With the TEK 21/31 keyboard you have perfect freedom to enter numbers using scientific notation, floating point, or you can mix them. The machine will accept and display them in whichever format you choose.

Data entry is limited to a ten-digit mantissa. However, the calculator performs all mathematical calculations with a twelve-digit mantissa in order to maintain accuracy and reduce round-off errors. The twelve-digit mantissa is maintained in the working registers of the calculator and rounded to ten digits for display. The two extra mantissa digits are known as "guard digits."

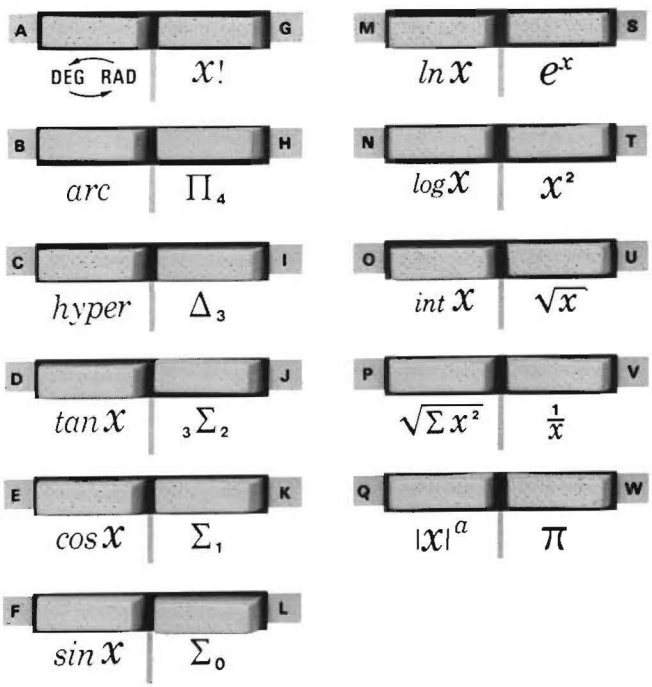
The Display and You

You can enter up to twelve digits in the display; ten digits in the mantissa and a two-digit exponent. And the display warns when you're in trouble—it will flash if you exceed the range of the calculator, if you ask it to perform an undefined math operation, or if a power failure occurs. The status lamps are another vital part of the display. They tell you if the calculator is working in degrees or radians, is in the learn mode, busy, stopped waiting for data, or if an address is incomplete.

The Math Keys—and More

The math keys, ordinarily used in performing math operations or in evaluating mathematical expressions within the capability of the calculator, are pictured at right.

The math keys are the same on the TEKTRONIX 21 and 31. However, on the 31 you'll find them doing double, or even triple, duty. By using a keyboard overlay, these twenty-four keys become user-definable. This means you can label your own subroutines in terminology familiar to you and execute them simply by pressing their respective keys. And you don't lose the math functions covered up by the overlay. They're instantly available by lifting off the overlay.



Alpha, too

The math keys, and all other programmable keys on the TEKTRONIX 31, have another function. In conjunction with the optional thermal printer, they provide alpha capability including a full set of punctuation, plus other symbols. They're available just by depressing the ALPHA key. And the alpha keys can be used to label subroutines, too.

The TEKTRONIX 21 Memories

The TEKTRONIX 21 data registers and program memory are separate entities. The data portion consists of the ten "K" registers, each capable of storing any number within the range of the calculator. By double use of the K key (K_{K_0}), the registers can be addressed indirectly permitting, for example, simplified loading routines.

The basic program memory can handle 128 program steps or key strokes. You can expand to 256 or 512 steps with available options. The memory is continuous but may be addressed at eight equally spaced points using the f_0 through f_7 keys.

For permanent program storage the TEKTRONIX 21 comes standard with a Mag-Card reader. Each card can store 256 program steps. You can transfer programs from the card into the calculator, and vice versa, in an easy, straightforward manner.

The TEKTRONIX 31 Memories

The TEKTRONIX 31 offers considerably greater memory capacity. Here, again, the data registers and program memory are separated.

In addition to the ten "K" registers, the basic TEKTRONIX 31 has 64 data registers called "R" registers. Options are available to expand to 1000 "R" registers.

The basic program memory consists of 512 program steps, and you have a variety of options to choose from providing up to 8,192 steps.

Program control in the 31 differs from the 21 in that the f-key feature is replaced by a single program memory with subroutine capability.

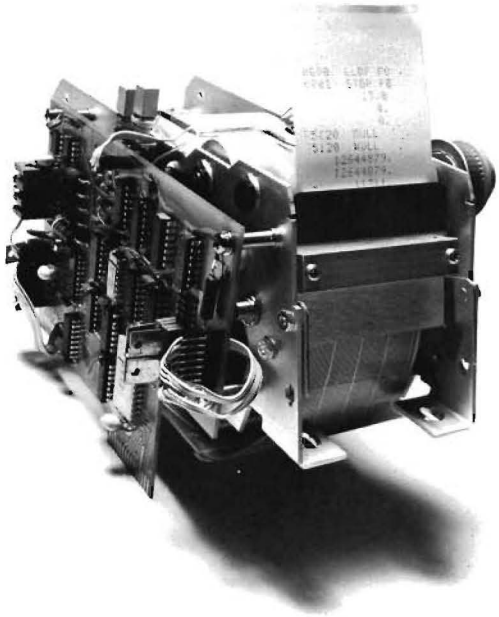
MEMORY OPTIONS FOR THE TEKTRONIX 31						
STEPS	REGISTERS					
	128	192	256	448	640	1000
1024	Option 2					
1536		Option 3				
2048			Option 4		Option 5	Option 8
3584				Option 6		
5120			Option 7		Option 9	
8192			Option 10			

Permanent storage capability for the 31 comes in two forms. An endless-loop tape cartridge storing up to 6000 program steps provides easy transfer of programs to or from the calculator.

This is augmented by PROM's (Programmable Read Only Memories). PROM's give you the capability to define your calculator the way you want it, instead of the way someone else thinks you want it. For example, by sending Tektronix the programs (in any form: cards, listings, etc.) you want incorporated in a PROM, you can define up to twenty-four keys as your own special set of keys. And with the User Definable Overlay you can label these keys with any nomenclature you choose. The PROM's and overlay sets can be exchanged in a matter of seconds to completely redefine your calculator.

The Printer is Optional

A compact thermal printer is available as an integral part of either the TEKTRONIX 21 or 31. The one for the 31 is a bit smarter—it gives you full alphanumerics plus a complete set of punctuation marks. The 21 is numeric only. Executing a program on the 31 is a breeze when you have the alphanumeric printer option. The calculator can tell you what to enter and how, or label the results in terminology you understand.



Summing It Up

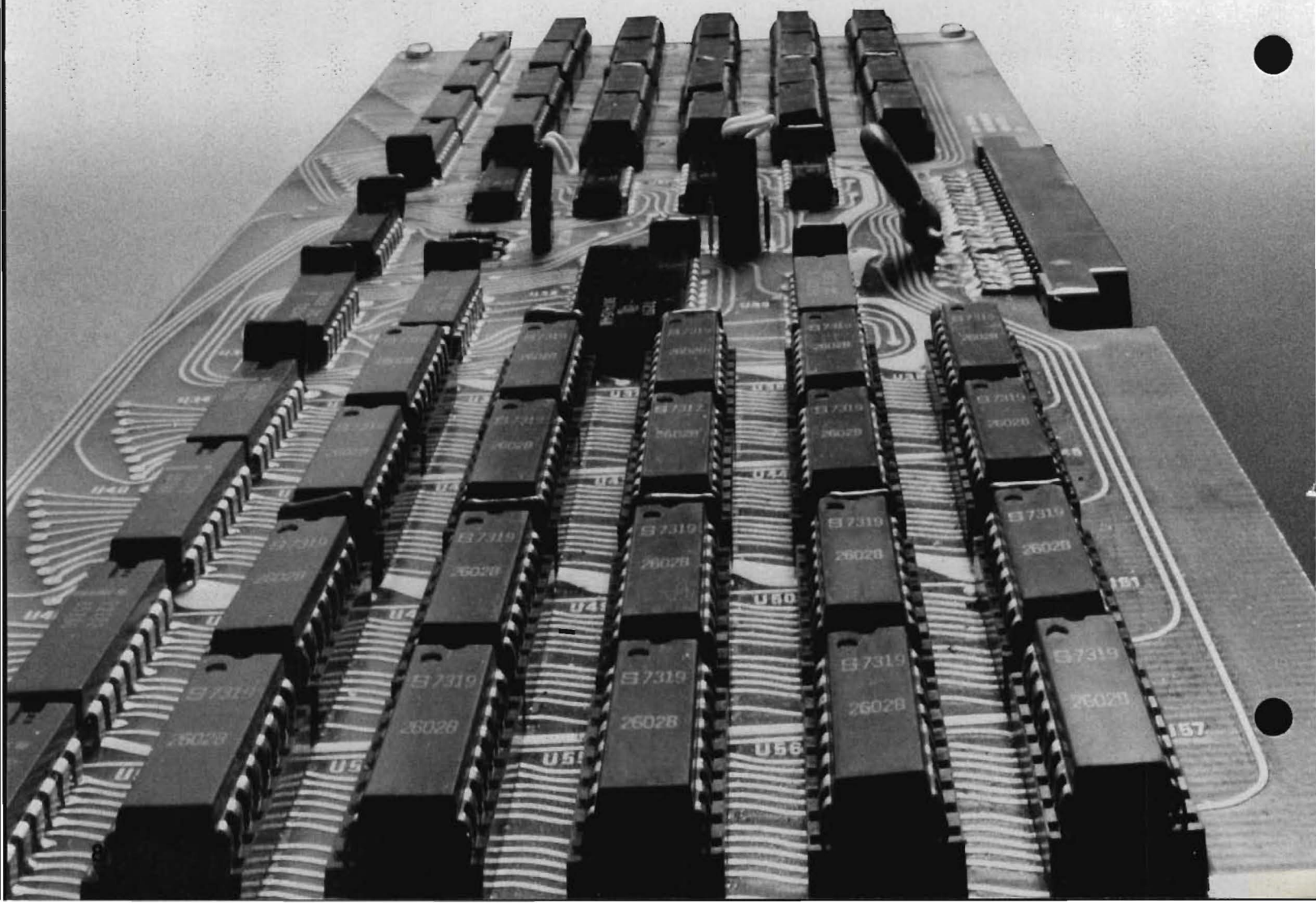
The TEKTRONIX 21 and 31 Calculators are designed to communicate in a language we all know—mathematics. You can walk up to them and start a "conversation" without need for an "interpreter." Whether your level of mathematics is elementary or sophisticated, you'll find them able to understand your problems, and come up with the right answer—every time.

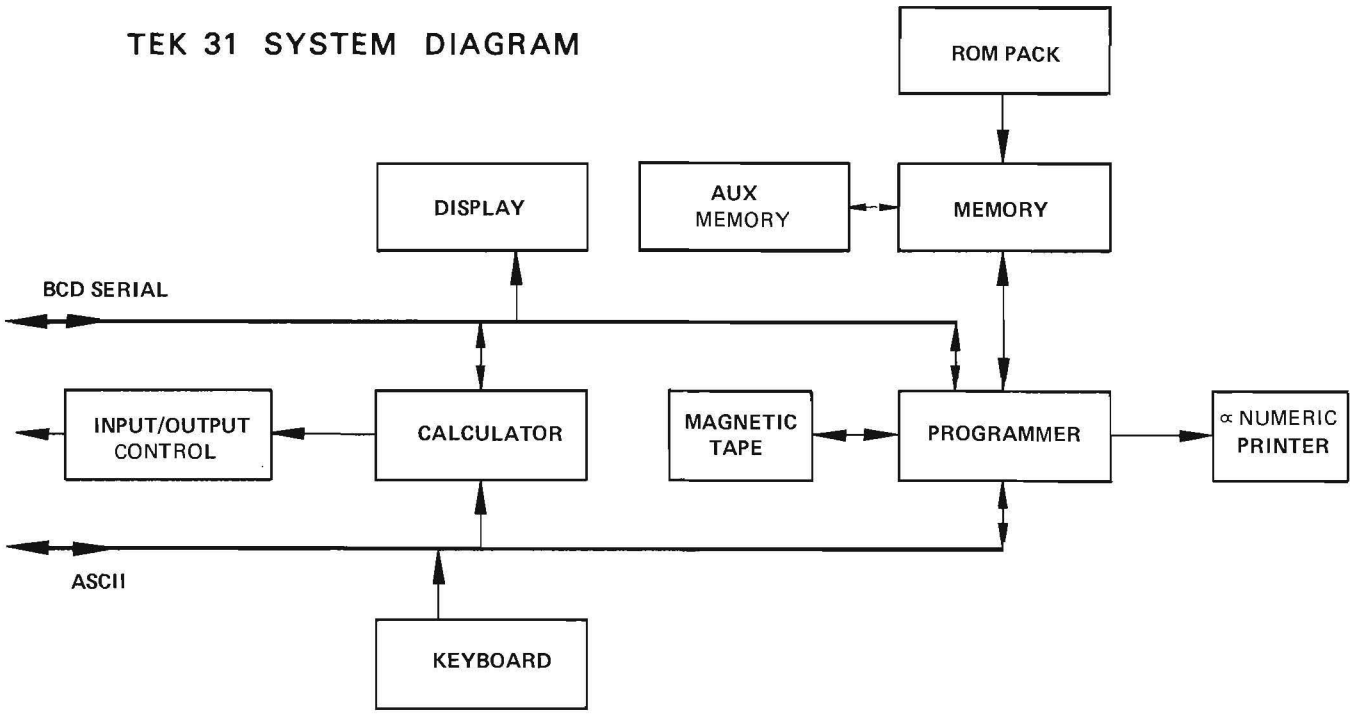
A Close-up Look

What's one of the first things you do when you're looking over a new car? Trip the latch and see how much power they've crammed under the hood. Let's "lift the hood" on the TEKTRONIX 21 and 31 Calculators and see how they stack up.

MOS LSI

You'll find the latest in MOS LSI design used in the calculator portion of the machine. Fifteen new MOS chips developed by Tektronix include a BCD arithmetic and logic unit, working registers, K storage and microprogram control ROM's.





Modular Construction

Another feature, apparent at first glance, is the limited number of printed circuit boards in the calculator; ten to be exact. This means fewer board interconnects for improved reliability. And service time is reduced by simplifying board replacement. Because calculators are less expensive to build using the large board concept you receive a double benefit—lower acquisition cost and lower maintenance cost.

Magnetic Storage

Standard equipment on the TEKTRONIX 21 and 31 includes a magnetic storage transport mechanism. The 21 uses a magnetic card while the 31 uses a continuous-loop tape with the added capacity it affords.

Options—More Than Frills

You can add horsepower as well as operating convenience to your calculator with the variety of options available for the TEKTRONIX 21 and 31. Among the most useful are the quiet thermal printers. The mechanism is the same in both machines with added electronics in the 31 providing alpha as well as numerics. Printing is accomplished by applying power to a row of 80 hybrid resistors deposited on the edge of a ceramic substrate. The resistors are arranged in 16 groups of 5 dots each. Seven cycles of applying power and advancing the stepping motor drive to the paper results in sixteen 5 x 7 dot-matrix characters printed across the paper.

Plug-in PROM's are available for both the 21 and 31. You can have your favorite programs kept inviolate and ready for use at a moment's notice without tying up the flexible magnetic storage portion of the calculator.

And, finally, a wide range of memory options lets you expand the capability of your machine as your needs expand. For example, in the 31, by simply plugging in IC's and changing a few jumpers you can have up to 8192 program steps and 256 registers or 2048 steps and 1000 registers.

How It Fits Together

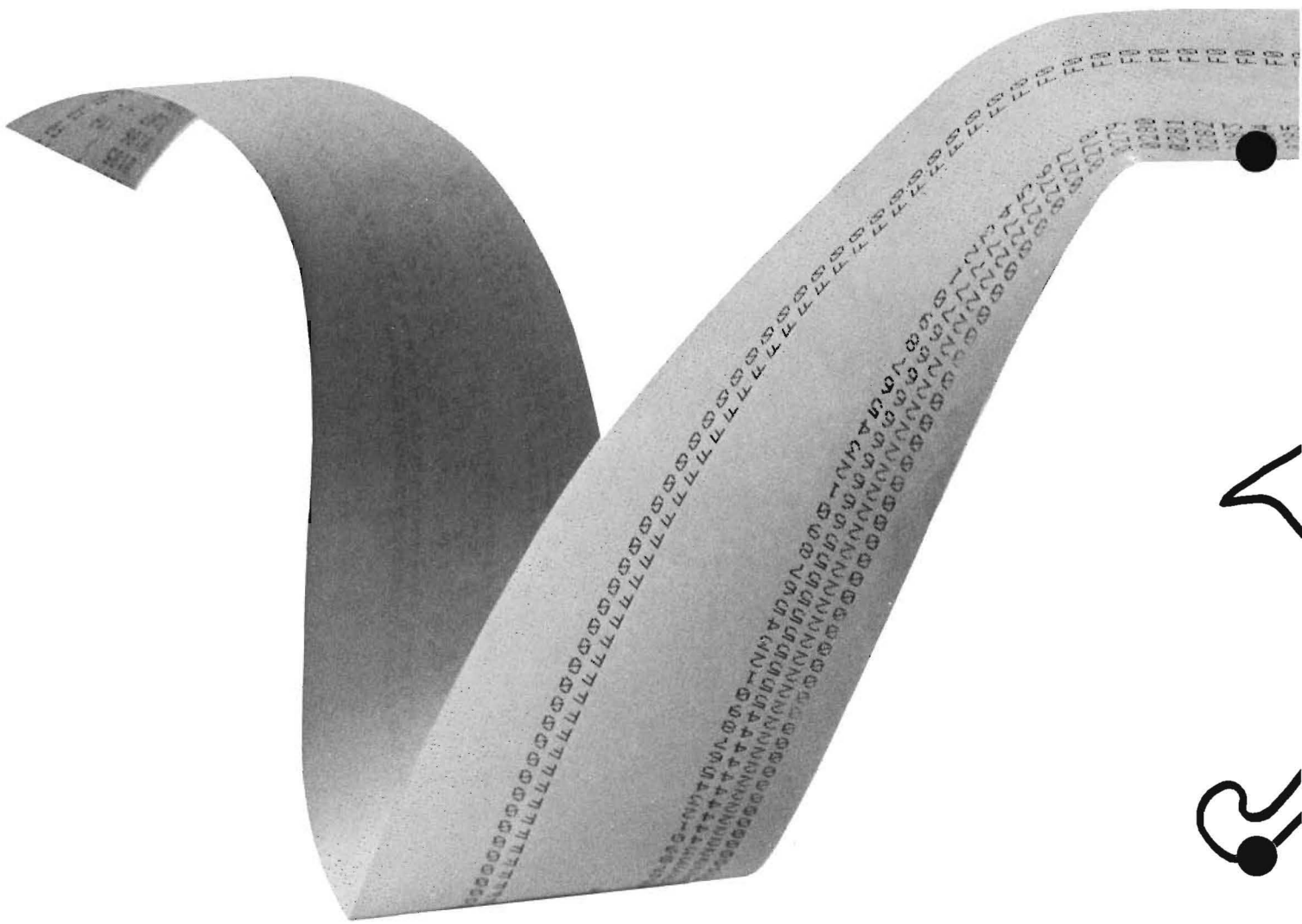
The diagram above shows the main communication paths in the TEKTRONIX 31. In the 31 the ASCII bus can be used for direct memory access as well as for alpha and control. The transfer into and out of the programmer's memory can be at a megabaud rate—comparable to that in the minicomputer and fast enough to make external disk storage feasible. The single I/0 port provides for a variety of peripherals to be connected to the 21 and 31 including the TEKTRONIX 4010 Graphics Terminal.

Summing It Up

Every feature of the TEKTRONIX 21 and 31 is designed to provide you with a high performance, highly reliable, expandable calculator at the most reasonable cost achievable today.

PROGRAMMING—As Easy As Writing a Formula

An important measure of calculator performance is the ease with which you can enter numbers or variables. Equally important is the ease of programming. You don't need a course in computer language to program the TEKTRONIX 21 and 31 Calculators—they understand plain mathematics.



The TEKTRONIX 21

Let's look at how you would program the TEKTRONIX 21 for solving a simple equation.
The problem is:

$$\frac{A}{(1-B)} = C \quad \text{with} \quad \begin{array}{l} A \text{ stored in } K_1 \\ B \text{ stored in } K_2 \\ C \text{ stored in } K_3 \end{array}$$

To program the solution, you would press:

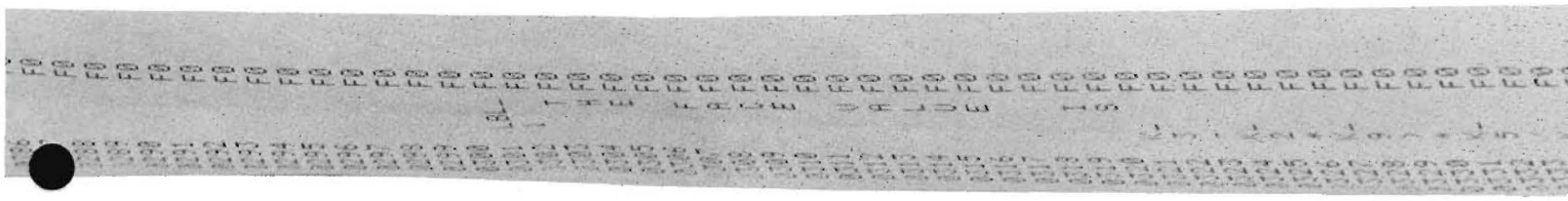
GO TO f_0 LEARN
K 1 ÷ (1 − K 2) = K 3 END
LEARN

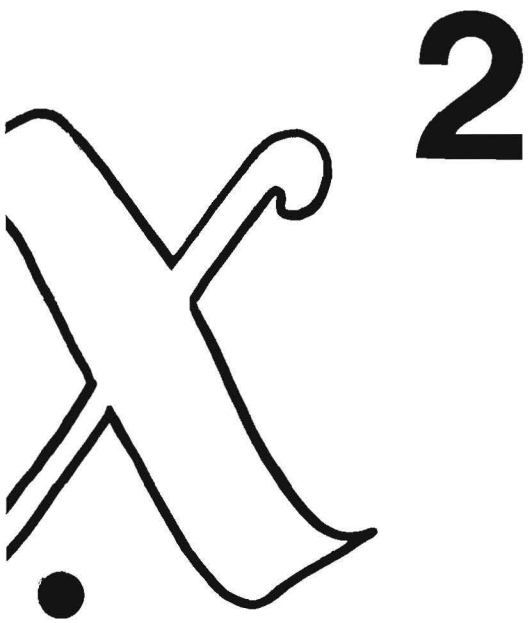
The GO TO f_0 LEARN steps puts the calculator in the LEARN mode at the beginning of block f_0. Then you simply key in the formula. The END step follows to branch back to the beginning of f_0 and to display the result. The last LEARN brings the calculator out of the LEARN mode. As you can see, the procedure for programming an equation amounts to little more than just keying it into the machine.

To run this program, you store the values of A and B in K_1 and K_2 and press f_0. Storage is done by pressing = and then the register. For example, you press CLEAR 6 = K 1 and CLEAR 3 = K 2 to store 6 in K_1 and 3 in K_2. Addressing a register without the preceding = recalls the stored contents into the display.

While this simple program lets you solve the equation, you would normally want to do more. You usually perform data entering as part of the program, and, if your calculator has the optional thermal printer, you usually want to print the data and the results. With these additional operations you would key in:

GO TO f_0 LEARN
CLEAR STOP = K 1 PRINT CLEAR
STOP = K 2
PRINT K 1 ÷ (1 − K 2) = K 3
PRINT
PAPER FEED END
LEARN





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When the program is being executed, it stops for data A at the first STOP and data B at the second STOP. This data is printed, and then the calculated result C is printed. The PAPER FEED is inserted for formatting the print-out.

To run this program, press:

f_0
6 CONT (value of A)
3 CONT (value of B)

There are eight keys designated f_0 through f_7. Depending on the length and complexity of your programs, these keys can provide direct access to eight separate programs, or, on the other extreme, provide eight programmable branch points in a large program. The basic calculator has 16 steps per f-block; options are available to expand this to 32 or 64 steps per block.

So far we have dealt with an example programmed in f_0 and perhaps extending into block f_1 on the basic machine. On the following page is a typical engineering problem which requires six blocks to program. The program includes conditional branching (the IF≥0 f_1 sequence) and also indirect addressing (the K K 8 sequence). The example also illustrates how the solution is translated directly into program steps.

DETERMINANT OF A COMPLEX 2 x 2 MATRIX

Calculating the determinant of a complex 2 x 2 matrix is often performed in engineering, usually as a step in doing parameter conversions. For example, converting 2-port "y", parameters to "z" parameters is a matrix inversion operation which involves calculating the determinant.

This problem is programmed here, not because it is particularly difficult, but because it illustrates some of the programming features that make the Tektronix 21 a powerful, yet simple to use calculator.

The determinant is calculated by the formula-

$$\det \begin{bmatrix} K_0 + iK_1 & K_2 + iK_3 \\ K_4 + iK_5 & K_6 + IK_7 \end{bmatrix}$$

$$= K_0K_6 - K_1K_7 - K_2K_4 + K_3K_5 + i(K_0K_7 + K_1K_6 - K_2K_5 - K_3K_4)$$

In the program, values are first entered into the K-registers. Then the real and imaginary parts of the determinant are calculated as written above and these results are printed and stored.

Example:

$$\det \begin{bmatrix} 1 + i & 2 + i3 \\ 4 + i5 & 6 + i7 \end{bmatrix} = 6 - i9$$

PROGRAM STEPS

		0	1	2	3	4	5	6	7	8	9
f0	00	CLR	=	K	8	PF	f1				
f1	10	CLR	STOP	=	K	K	8	PRNT	K	8	+
	20	1	=	K	8	+/–	+				
f2	30	7	)	IF≥0	f1	K	0	x	K	6	–
	40	K	1	x	K	7	–				
f3	50	K	2	x	K	4	+	K	3	x	K
	60	5	=	K	8	PF	PRNT				
f4	70	K	0	x	K	7	+	K	1	x	K
	80	6	–	K	2	x	K				
f5	90	5	–	K	3	x	K	4	=	K	9
	00	PRNT	CLR	PF	END						

COMMENTS

K_8 is a subscript that is set equal to zero initially.

STOP = K_{K_8} Each matrix element is entered and stored in K_0 through K_7. $K_8 + 1 = K_8$. The subscript is increased by 1.

If ≥ 0 f_1. These steps and the steps just preceding are to test whether K_8 and the remainder of the program can be executed. (If not, the program branches back to the beginning of f_1 so that the next matrix element can be entered).

Program performs the computations just as written in formula above.

With indirect addressing, the contents of one register serves as the subscript of another. For example, if 5 is stored in K_8, then pressing [K] [K] [8] displays the contents of K_5 (K_{K_8} is K_5).

The operations and procedures presented thus far demonstrate how easily you can program the TEKTRONIX 21. In addition, most of the math routines you normally use in problem solving are already in the machine and available at the press of a key.

Supporting the TEKTRONIX 21 are mathematics and statistics program libraries. Mathematics programs range from simple triangle solutions through solutions of third order matrix equations, manipulation of vectors and complex numbers, and numerical integration and solution of differential equations. Included in the Statistics library are programs for means, standard deviations, analysis of variance, tests and distributions (X^2, t, F, etc.), and curve fitting (linear, parobolic, 3-variable curve fitting, etc.).

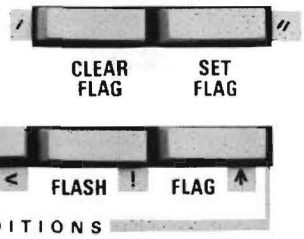
The TEKTRONIX 21, with its programming capability, optional thermal printer and built-in magnetic card reader, can serve the scientific, educational and business communities very effectively.

The TEKTRONIX 31

For those of you with more sophisticated needs, there is the TEKTRONIX 31—one of the most powerful calculators on the market today. It has the same easy-to-use mathematical language and the same mathematical keys as the 21. But the TEKTRONIX 31 offers more capability in several areas.

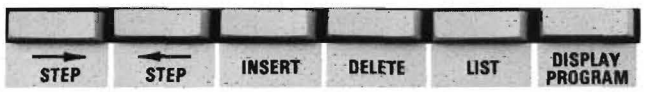
Considerably more program steps and data registers are available to you through options. And continuous-loop magnetic tape cartridges can hold up to 6000 program steps per cartridge for unlimited program storage.

Five "if" conditions provide branching based on whether the condition is satisfied. Three keys detect whether the display is ≥ 0, $=0$, or <0. Another key de-



tects whether the flag is set, and another detects whether the display is flashing as caused, for example, by taking the square root of a negative number. Thus, the FLASH key can be used to detect whether the roots of a quadratic equation are real or complex.

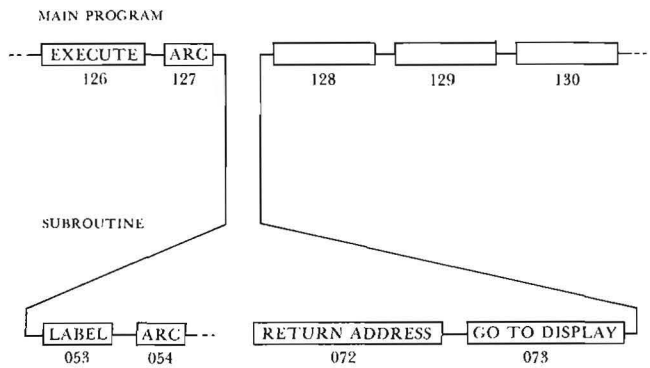
Full editing capability is provided in the 31. You can step forward or backward, delete, insert, list the program, or display the program.



The alphanumeric capability provided by the thermal printer is a powerful programming tool enabling you to include printed instructions in your programs. And you can use alpha to greatly extend the number of program labels available. You can have up to 151 labels in the 31—lots of flexibility for even the most complex programs.

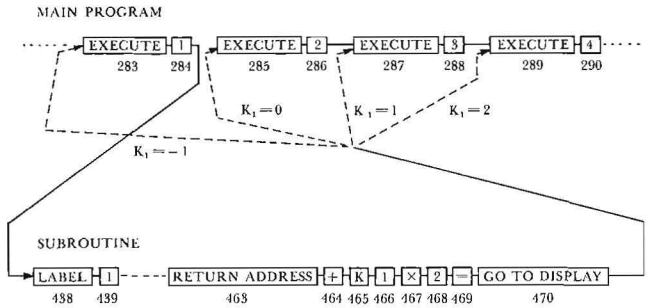
Any part of a program may be labeled by using LABEL and another key for the symbol. This part of the program is then executed by pressing EXECUTE and the appropriate symbol. Labeling provides branch points for "if" conditions or can be used to denote the beginning of separate, independent programs.

You may also use labeling to create subroutines. Usually a subroutine is called from a main program. Upon completion of the subroutine the calculator returns to the main program at the proper location. To accomplish this on the 31, the RETURN ADDRESS GO TO DISPLAY sequence is programmed at the end of the subroutine as follows:



Return address stores 128.

One very useful feature of the TEKTRONIX 31 is that the most recent return address can be displayed, stored in a data register, or become part of a mathematical expression. Even logic within the subroutine can be used to determine where to branch to next. For example, a program may look like this:



Here the stored return address is 285, but a value of K_1 other than 0, either established before executing subroutine 1 or else established by logic within subroutine 1 causes the subroutine to branch back to the main program at locations other than 285.

Conclusion

The ease with which you can program the TEKTRONIX 31 belies its outstanding problem solving capability. The large program step and register memory, plus the "if" conditions and subroutine capability enable you to do operations on the 31 that were formerly relegated to computers—and for considerably less money. Mathematics and statistics libraries are available to put the 31 right to work for you. With the ability to interface with sophisticated peripherals such as the TEKTRONIX 4010 Graphics Terminal, under program control, the TEKTRONIX 31 can serve as the "heart" of a complete system.

Reliable by Design

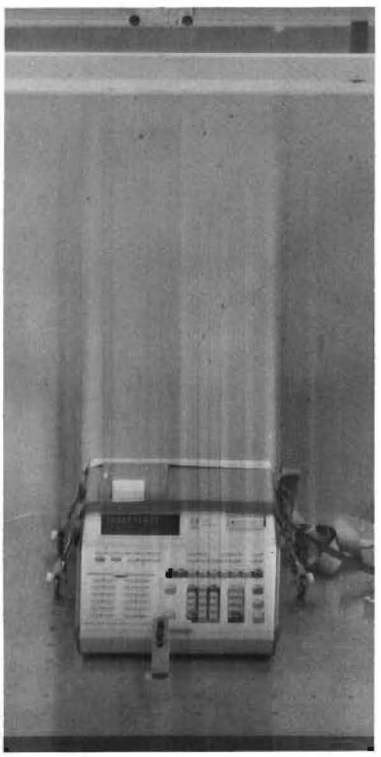
In the early days of electronic equipment, some manufacturers operated under an illusion. They believed users would be nice to their products. So they engineered and built accordingly. But customers had other ideas. Equipment was being carried off to jungle, mountain and desert on plane, truck and pack mule. Product performance was not enhanced by this treatment. Cases cracked, coronas flared, cables broke and connections corroded. Users were unhappy.

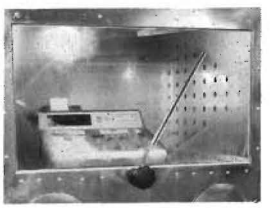
Consequently, the "kick-it-and-maybe-it'll-work" syndrome was born. But kicking didn't help nor did cussing out the manufacturer. It was not the golden age of electronics.

Early in the game, we at Tektronix learned about all the strange places people want to set up shop, and reliability testing became a routine part of the design process for every product. Today, over 5,000 square feet of engineering area are dedicated to punishment, and six engineers and their assistants devote full time to heaping abuse on brand new products. We think our products should operate accurately under all environmental conditions and if there's a design flaw, we want to be the first to know. That's why every new machine is subjected to a series of severe operating conditions. This electronic obstacle course reveals the physical durability of the equipment and the reliability of all operating functions.

Tek's new calculators are no exception.

Because they're not only new products but of a new compact design, the 21 and 31 are prime candidates for rough handling. As a result, they are subjected to the same rigorous reliability testing as our other products. Test parameters involved are heat, humidity, altitude, shipping simulation and just plain old dropping. These take place individually and in combination.





Shake, Rattle and Roll

Features and functions don't mean much without sound structural engineering. The "shake table" highlights undesirable mechanical resonance or flexing. The table provides a 0.015" vibration from 10 to 50 c.p.s. in three axes. If anything has a tendency to slip or shift it will do it now.

Turn Up the Heat!

Heating and cooling can have a devastating effect on electronic components. Parts could swell, connections crack or circuits short. Thermal cycling in the test oven usually reveals this kind of problem. For thirty hours the calculators endure 0° to 50° C. cycling. During the test, actual machine operation is observed. The engineers can immediately pinpoint any failure or erroneous results. But what if something was weakened but is still operating perfectly? Back to the shake table. A part with hidden thermal damage will usually make itself known during this second vibration test.

Taking a Fall

The survival rate of transported goods is a sometimes thing. Dropping, banging, squeezing and carelessness take their toll. This stage in reliability testing gives our engineers an answer to the question of product self-defense. TEK's drop test plunges the calculators into a fall ending with a 30 G stop. A sample of each model is then secured in its own special packing case and banged up and down on its corners. As if this weren't enough abuse, the packaged products are then dumped into an ersatz truck bed and bumped, shoved and pushed around for several hours as they would be under actual trucking conditions.

Up, Up and Away

Next, a session in the altitude chamber. TEK guarantees flawless product operation up to 15,000 feet. This test provides both you and Tektronix with the confidence. To make sure a non-operating product will survive even higher, chamber air is pumped out til pressure equals that at 50,000 feet. There's a reason. Planes often reach that height and most cargo holds aren't pressurized.

Sweating It Out

Moisture does strange things to electronic devices. It'll carry impulses to the wrong places, fool around with resistance, change voltage levels and give equipment other bad habits. A run through the "Wet Box" socks each calculator with 90% humidity for five days. For variety, a 30° to 50° C. cycle occurs every 24 hours. If the 21 and 31 survive this man-made moisture, they'll survive the stuff from mother nature.

Super Sauna

After a product clears the reliability testing hurdles, proves itself capable of all specs through a range of heat, height and moisture, and does so while staying in one piece, there's still one lingering question. How will it do in actual use? To answer that question as accurately as possible, Tektronix has constructed a special sauna bath. Samples of the new products are operated here at 50% humidity, 50° C., for 24 hours a day, seven days a week. This process is aptly called "accelerated life testing" and can continue for months. What does this mean to you? A TEK calculator in your employ has come off the line with built-in experience. Costly down-time has been designed out.

Beating the System

TEK's insistence on thorough reliability testing has a positive effect on our design engineers. They build equipment to survive the test range. An example? Take a close look at the 21 or 31. To build machines that keep the faith, TEK engineers have replaced many construction/design traditions with a spectrum of innovations.

Innovation: The TEKTRONIX 21 and 31 cases are heavy gauge aluminum, eliminating the possibility of twisting and distortion which sometimes takes place in plastic cases.

Innovation: Components are operated well below their rated capacity giving quality parts an added margin of reliability.

Innovation: TEK-designed thermo-chemical tape printers replace noisy mechanical devices. In addition to providing a quiet operation, these integral printers utilize only 70% of the space previously required.

Not all the calculators rolling off the assembly line get a run at the test series, but each and every 21 and 31 goes through a 96-hour "burn-in" prior to delivery. This session, equivalent to a month's actual operation, eliminates the majority of early failures and prevents you from inheriting those annoying little problems.

Conclusion

We expect the TEKTRONIX 21 and 31 calculators to be valuable tools for your problem solving. We've designed and built them with portability and rough handling in mind. We're confident that they're ready to do the job, anywhere you are.

TEKTRONIX®
committed to technical excellence