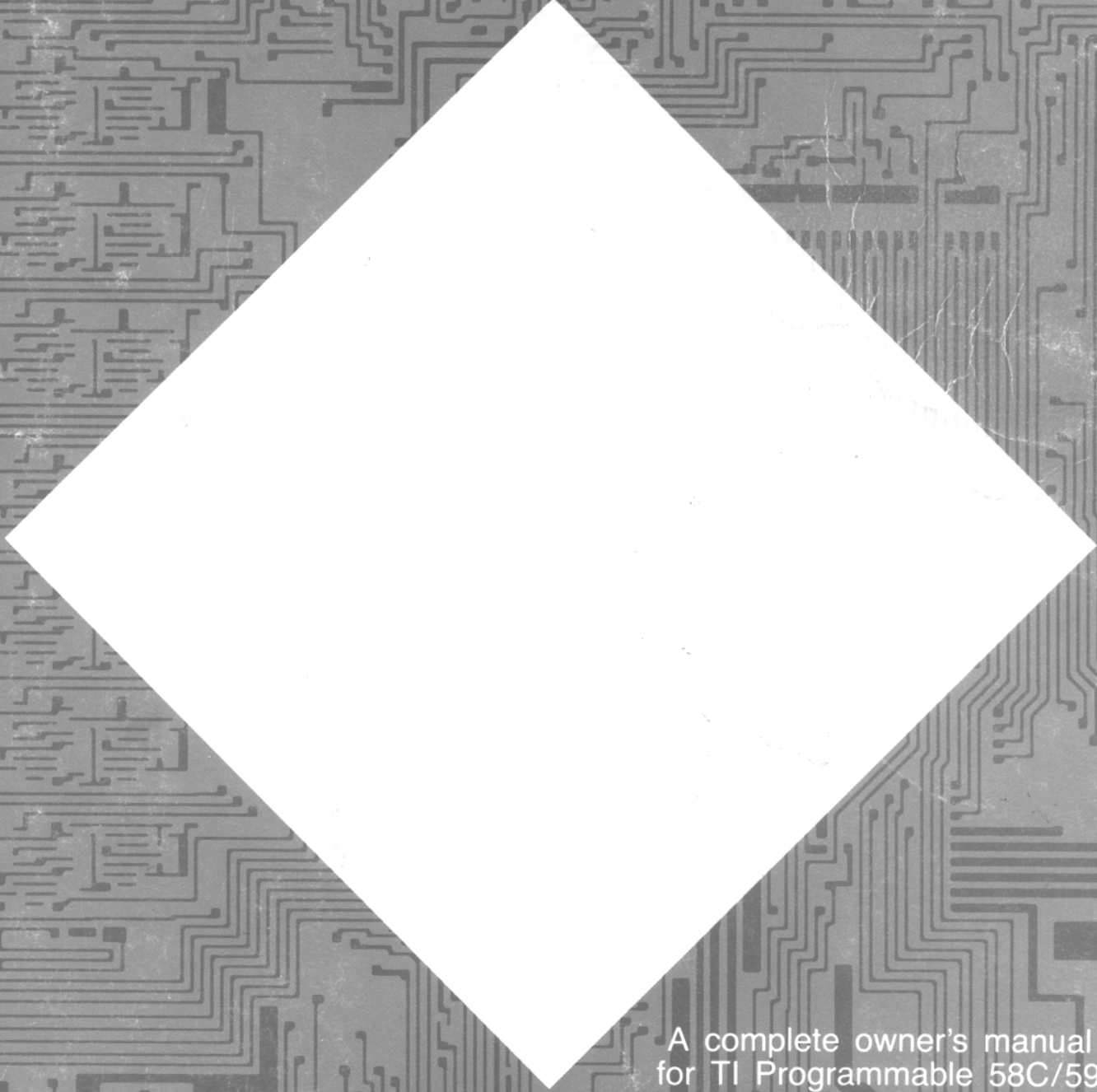


Personal Programming

A complete guide to a whole new dimension in problem
solving ease and power: handheld programming



A complete owner's manual
for TI Programmable 58C/59

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KEY INDEX

This indexed keyboard provides a quick page reference to the description of each key.

A'	V-55	B'	V-55	C'	V-55	D'	V-55	E'	V-55
A	V-55	B	V-55	C	V-55	D	V-55	E	V-55
2nd	V-3	INV	V-3	log	V-16	CP	V-3, 43	CLR	V-3
				Inx	V-16	CE	V-3		
Pgm	III-1	P→R	V-30	sin	V-17	cos	V-17	tan	V-17
LRN	V-43	x↔t	V-30	x²	V-20	√x	V-20	1/x	V-15
Ins	V-52	CMs	V-3, 23	Exc	V-26	Prd	V-24	Ind	V-68
SST	V-48	STO	V-23	RCL	V-23	SUM	V-24	y^x	V-21
Del	V-51	Eng	V-8	Fix	V-8	Int	V-20	|x|	V-20
BST	V-48	EE	V-5	(	V-12	)	V-12	÷	V-10
Pause	V-44	x=1	V-62	Nop	V-51	Op	V-27	Deg	V-16
GTO	V-56	7	V-2	8	V-2	9	V-2	X	V-10
Lbl	V-55	x≠1	V-62	Σ+	V-32	x̄	V-33	Rad	V-16
SBR	V-58	4	V-2	5	V-2	6	V-2	-	V-10
St flg	V-65	If flg	V-65	D.MS	V-30	π	V-2	Grad	V-16
RST	V-44	1	V-2	2	V-2	3	V-2	+	V-10
Write	VII-2	Dsz	V-63	Adv	VI-3	Prt	VI-2	List	VI-4
R/S	V-43	0	V-2	.	V-2	+/-	V-2	=	V-10

Refer to Appendix A and the inside back cover for service and warranty information.

IMPORTANT

Record the serial number from the bottom of the unit and purchase date in the space below. The serial number is identified by the words "SERIAL NO." on the bottom case. Always reference this information in any correspondence.

TI PROGRAMMABLE — _____

Model No.

Serial No.

Purchase Date

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Personal Programming

A complete owner's manual
for TI Programmable 58C/59

This book was developed by:

The Staff of the Texas Instruments Learning Center:
Roger F. Farish
Charles D. O'Grady
Dr. Ralph A. Oliva, Educational Software Director

With contributions by:

Peter L. Bonfield
Lane L. Douglas
Danny J. Enzone
Delores A. Hackney
Charles L. McCollum
Henry M. Meltzer
Arthur L. Norrington, Jr.
Stavro E. Prodromou
Sydney W. Poland

*Artwork and layout were coordinated
and executed by:*

Gaither and Davy Design Studio, Inc.

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I

GETTING ACQUAINTED

A QUICK LOOK

INTRODUCTION

Today's handheld calculators can make it easy to utilize math in handling the problem situations that arise in many professional fields. A new speed, accuracy and confidence can now be part of our everyday life situations involving numbers and math from the routine to the most complex.

Initially, "the basics" — addition, subtraction, multiplication and division — were the only calculator capabilities available — and at the time, they were a revolutionary development. Next evolved calculators with more powerful math functions — squares, square roots, logarithms, trig functions, etc. These not only replaced the need for volumes of tables and charts, but also greatly increased the speed and accuracy possible in handling and solving the problems that arise in technical disciplines.

Now — a new dimension! Programmability in a handheld calculator opens the gateways to vast new problem solving areas — areas that only a computer could enter before. This manual has been specifically structured to start you programming right away. You'll see "hands on" how easy it really is to access the power of your TI Programmable calculator.

This manual is written for both the TI Programmable 58C and 59. These two calculators differ by the following.

	Data Registers	Program Steps	Special Feature
TI Programmable 58C	Up to 60	Up to 480	<i>Constant Memory™</i>
TI Programmable 59	Up to 100	Up to 960	Magnetic Cards

Both calculators provide the option to store data and program information for long periods. The TI Programmable 59 has magnetic cards which can be used to record information. The cards can later be read by the calculator to restore the information to the data and program memories. The TI Programmable 58C has a *Constant Memory* feature which prevents the data and program information from being lost when the power is switched off. This feature of the TI Programmable 58C also allows the battery pack to be changed or removed for installing the calculator on the optional printer without losing a program or stored data. Be sure to read Sections VI, VII and Appendix A for more details about the special features unique to your calculator.

Most other calculator functions and operations are identical. Where the operations of the calculators differ, special notes have been made in the text. This book is organized like this:

- We'll start right in with some quick illustrations of just how easy using and programming your machine can be.
- After that we'll follow with a tour of the key's features and functions of your machine.
- Then we'll go into a step-by-step discussion of programming.
- Later in the manual we'll cover some of the more advanced programming features of your calculator, with a variety of application examples from various fields.
- The final section of the manual is a detailed and complete analysis of all calculator keys showing the full operating limits of the machine in various calculating situations. (If you are already quite familiar with calculators and programming and just want all the facts and details right away — you may want to skip directly to that section and review your machine in technical detail.)



Getting Acquainted

A QUICK LOOK

POWER UP

The battery pack furnished with your calculator was charged at the factory before it was sent out to you. However, due to self-discharging that happens in all batteries, the battery pack may require some charging before initial operation. If while you're first using your machine, the display becomes dim or erratic, the battery pack needs to be charged. Just turn the machine off, plug in your charger and wait a few minutes. Then proceed. You can be using your calculator while the battery pack is being charged.

Note that the TI Programmable 58C has a *Constant Memory* feature which will save the program and data memory contents when turned off and for short periods with the battery pack removed. See Appendix A for complete battery and charging information.

Slide the ON/OFF switch to the ON position and you should see a single zero in the display. This shows that the battery is charged and the calculator is ready for action. Turning the calculator ON automatically clears the TI Programmable 59. However, the *Constant Memory* feature of the TI Programmable 58C retains the program and data memory contents, the partitioning, and the fix-decimal status that existed when last turned off. To check your calculator's display, press the decimal point $\boxed{\cdot}$ and the change sign $\boxed{+/-}$ keys, then press eight repeatedly to fill the display. An eight lights all segments of each digit position in the display. Note that the decimal point and minus sign progress to the left each time an eight is pressed. You can enter up to 10 digits into your calculator at any one time for either positive or negative numbers. All digit entries made after the tenth are simply ignored.

Whenever you exceed the limits of the display or ask the calculator to do something it cannot do, the calculator lets you know by flashing the display. This flashing is stopped by pressing \boxed{CE} .

We'll be taking you on a "guided tour" of your machine, but remember that there's no substitute for just sitting down and exploring it on your own. This is one of the best ways to get to know what a versatile and powerful device it is. The more you learn about its far reaching capabilities, the better it is able to serve your needs.

TYPES OF OPERATIONS

Basically, there are 3 types of operations your calculator can handle for you:

You can easily use one of the many *Solid State Software*™ programs built right into your machine to handle complex problems with a few keystrokes — OR —

You can teach your calculator your own problem-solving methods, and it can remember and execute them for you whenever you want — OR —

Your machine always stands ready to work as a high-powered manual calculator — ready to immediately handle "around-the-house" math as well as more intricate calculations with its advanced professional features.



Running Library Programs

Without knowing anything about how to personally program your calculator, you can run many useful programs. A master library of prewritten *Solid State Software* programs is contained in a small module already inserted in the back of your calculator. This interchangeable module (other modules are available) contains a variety of general purpose programs described in the *Master Library Manual*. Through use of the program key **Pgm**, each program can be “called-up” and used according to the writeup in the manual. To illustrate how easy these programs are to use, let’s play the “Hi-Lo” game.

The object of the game is for you to guess a secret number in as few guesses as possible. The calculator chooses a number in the range from 1 to 1023. The calculator responds to each of your guesses with a “too low,” “too high,” or “correct”. Your score (number of guesses) is tallied by the calculator. Follow the User Instructions and play.

USER INSTRUCTIONS				
Step	Procedure	Enter	Press	Display
1	Select program		2nd Pgm 21	
2	Key in a series of random digits (1 to 199017)	Your Number	A	Your Number
3	Generate secret number		B	0.
4	Enter your guess (1 to 1023) Clue: -1. guess is low 1. guess is high flashing 0. guess is correct	Guess	C	Clue
5	Repeat Step 4 as needed			
6	Display score (number of guesses)		D	Score

Most prerecorded programs are as easy to use as this. Actually dozens of program steps have been executed, but these are automatically handled for you. All you have to do is enter the numbers you want to work on, and start the program.

Here’s an important point — the key to using any of the *Solid State Software* programs is the library manual. All of the ins, outs and details you need to get the most out of each library program are included in the manual. So, refer to it whenever you’re using any prerecorded program. It might be a good idea to glance through your *Master Library Manual* right now. Get a feel for the programs that are already at your disposal — ready to help handle problems for you.



Getting Acquainted

I

A QUICK LOOK

Calculations From the Keyboard

Your advanced TI calculator is equipped with AOS™ method of entering problems, one of the most straightforward entry methods yet devised. Problems are easily solved by entering them directly into the calculator in the order they are written, left to right. For instance, to convert 100°C, 36°C, and -4°C to Fahrenheit, you need to multiply the Celsius reading by 9/5 and add 32. $^{\circ}\text{F} = ^{\circ}\text{C} \times 9/5 + 32$.

Press	Display
100 \times	100.
9 \div	900.
5 $+$	180.
32 $=$	212.

You can repeat this sequence to find $36^{\circ}\text{C} = 96.8^{\circ}\text{F}$ and $-4^{\circ}\text{C} = 24.8^{\circ}\text{F}$. (More will be said about the AOS entry method and the calculating power it gives you later in the book.)

Writing Your Own Programs — An Example

Once a calculation sequence has been determined and you have several values that need the same sequence, you can press the **LRN** (learn) key and teach the calculator the sequence. For the above example, press **LRN** then key in the following:

\times
9
 \div
5
 $+$
3 2
 $=$
R/S (to stop and display answer)

Press **LRN** once more after the sequence — this tells the calculator to stop “learning” the keystrokes you enter. The calculator now remembers this sequence and is ready to perform this series of operations on any number (here, any Celsius reading) that you may enter into the display.



You're now ready to have your machine do the Celsius to Fahrenheit calculations on any number you enter.

- Key in your Celsius value
- Press **RST** (reset) to tell the calculator to start at the beginning
- Press **R/S** (run/stop) to begin program execution

Press	Display
100 RST R/S	212.
36 RST R/S	96.8
4 +/- RST R/S	24.8

This is all you need to do to convert any Celsius reading to a Fahrenheit equivalent. Writing your own program can be just as easy.

This ability you've just seen in action — the ability to execute a program you have created — is one of the most powerful aspects of your calculator. Once a program is stored and you have tested it to verify its accuracy, you can use it over and over again simply “at the touch of a key.”

PRINTING CAPABILITIES

Your calculator is compatible with the PC-100A or PC-100C printing units. The printer can record the displayed value on paper whenever you tell it to. When solving problems directly from the keyboard, you can selectively print any or all desired intermediate results or provide a complete listing of a stored program. When executing a program, print instructions encountered in the program cause automatic printing of the quantity in the display register. These printing features allow you to run a program while recording multiple answers. The trace option on the printer prints all steps performed and the corresponding numerical results.

Through use of the special control operations you can assemble and print any messages you need to identify segments of the listing or for titles. Up to 20 characters can be printed per line, made up from a master set of 64 characters.

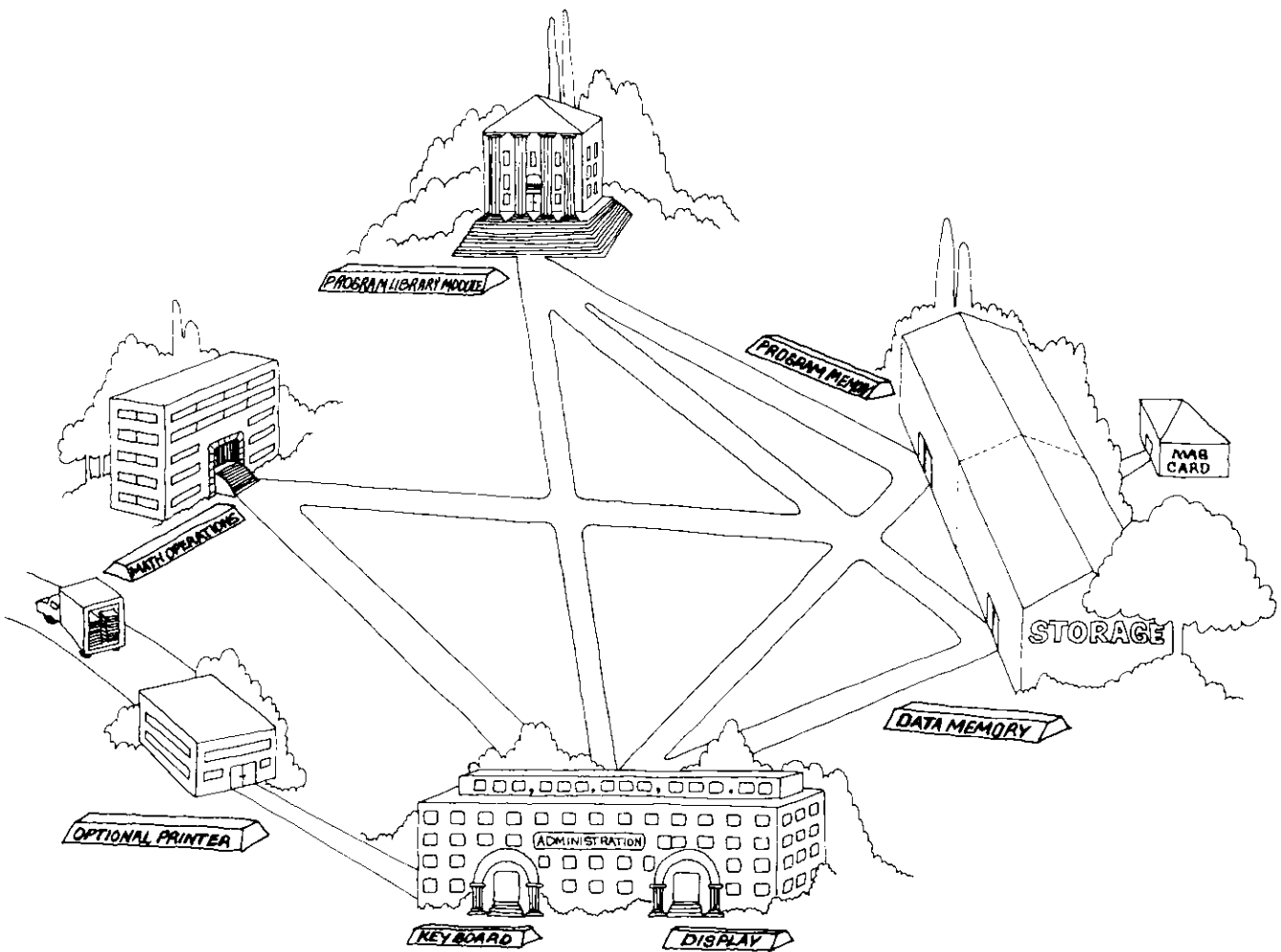


Getting Acquainted

A QUICK LOOK

CALCULATOR CAMPUS

Your new calculator has many powerful structures that work together to form a “community of benefits” all designed to work as an easy to use problem-solving system. In this section you’ve had a very quick look at some of these features in action. In the next section we’ll take a brief “guided tour” of this working community in a little more detail, and then get right on into the business (and pleasure) of programming.





II

A “GUIDED KEY TOUR”

A LOOK AT THE FEATURES AND FUNCTIONS

Before you plunge into some of the more advanced features of your machine, it will be useful to come along on a brief tour of the main features and functions available on the keyboard. This is particularly true if this is your first experience with an advanced calculator. Many calculator owners never fully access all the power available in their machines — simply because they’ve never taken the time to see each key in action. In this section you’ll get a quick key review — requiring only about 10-15 minutes of your time. This will generally familiarize you with the main keyboard features — so that as you move on in to programming, you’ll be able to take full advantage of all that the machine can do.

A note to various users:

If you’re already familiar with advanced calculators with AOS entry method, you may want to skip this key tour section and get right into programming (Section IV).

For a *specific and detailed* description of all the calculator’s various operations and capabilities, refer to Section V for an in-depth discussion of each key and feature.

As you proceed through this tour, be sure your calculator is out and handy. Check out each key and feature as it’s discussed. The best way to learn about your machine is to use it!



A “Guided Key Tour”

A LOOK AT THE FEATURES AND FUNCTIONS

KEYBOARD BASICS

Clearing the Display — **CE**, **CLR**

There are two procedures that allow you to clear the display register of your calculator depending upon your needs as you proceed through a problem.

CE CLEAR ENTRY — The clear entry key clears the last number you entered into the display (provided that a function or operation key has not been pressed). Use of this key does not affect calculations in progress. (So, if you accidentally hit 5 instead of 6 in the middle of an entry, just press **CE** and enter the complete correct number). The **CE** key may also be used to stop a flashing display created by an error condition.

CLR GENERAL CLEAR — The clear key clears the contents of the display register and any calculations in progress. If an error condition exists when this key is pressed, it too is removed.

Data Entry Keys — **0** – **9**, **.**, **+/-**, **π**

Numbers are entered into the machine with the data entry keys **0** – **9** **.** **+/-**. As you enter any number, the decimal point stays to the right of your entry until the decimal point key is pressed. The fractional part of the number is then keyed in, and the decimal point floats to the left with it. To change the sign of a number in the display just push the change sign key **+/-** once. (Pressing **+/-** again changes the sign back again).

Pressing **2nd** **π** places the first 10 digits of π in the display 3.141592654. 13 digits are carried in the internal display register, 3.141592653590. **CE** does not remove this entry.

Basic Operation Keys — **+**, **-**, **X**, **÷**, **=**

Basic arithmetic is handled with the 5 basic operation keys **+** **-** **X** **÷** and **=**.

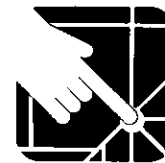
Your calculator has a powerful feature called AOS entry method which makes problem solution with these keys exceptionally easy. Basically, you just key in the problem the way it's written, press **=** and get your result. The amazing feature of the AOS entry method is that it automatically sorts out mixed operations in a problem for you, and applies them in the correct order as it calculates your result. (We'll say more about the AOS entry method on the next page.)

When you press the **=** key, all pending operations (things waiting to happen inside your calculator), are completed. You get your result, and the calculator is cleared — ready to start on the next problem.

Example: Calculate $15 + 7 \times 31 - 4 = ?$

Press: 15 **+** 7 **X** 31 **-** 4 **=** Display: 228

NOTE: Observe that AOS entry method instructed the calculator to interpret the expression as $15 + (7 \times 31) - 4$, where 7×31 is calculated, then added to 15 and 4 subtracted from this.



II

A “Guided Key Tour”

A LOOK AT THE FEATURES AND FUNCTIONS

The AOS Entry Method

Mathematics is a science which adheres to a clearly defined set of rules. One such rule is that it never permits two different answers to the same series of operations. Because of this requirement — one solution for any computation — mathematicians have established a universally accepted set of rules when mixed operations are used in one calculation. For example: the problem:

$$3 + 10 - 2 \times 14 \div 7 = ?$$

has only one right answer! (Know what it is? It's 9.)

You can key this problem directly, left to right into your calculator and you'll get the correct answer. The algebraic hierarchy of the calculator sorts the operations you enter, applies them in the correct order, and lets you see what it's doing along the way. Your calculator performs operations it received from you in the following universally accepted order:

- 1) Special Single Variable function keys — act on the displayed number immediately — as soon as you push the key. (We'll talk more about each of these keys later in the “tour” — but they include all the keys for the trig and log functions and their inverses, as well as square and square root, reciprocal, and conversions.)
- 2) Powers and Roots (y^x and $\sqrt[y]{y}$) are handled next (we'll discuss these further in this section.)
- 3) Multiplications and divisions are completed, followed by
- 4) Additions and subtractions.

This algebraic hierarchy applies to each set of parentheses.

Finally, the equals key completes all operations.

There are cases in problem solving where you want to be the one who specifies the order in which an expression is evaluated. In these cases you can control the order with the parentheses keys, $()$, which are discussed in the next section. Parentheses demand a special first level of attention in mathematics — and they're treated that way by your calculator.



A “Guided Key Tour”

A LOOK AT THE FEATURES AND FUNCTIONS

Parentheses Keys — (,)

In a variety of problems, you may need to specify the exact order in which expressions are evaluated, or the way in which numbers are grouped, as a problem is solved. Parentheses give you a way to cluster numbers and operations. By putting a series of numbers and operations in parentheses you tell the calculator “Evaluate this little problem first — down to a single number result, then use this result for the rest of the calculation.” Within each set of parentheses, your calculator operates according to the rules of algebraic hierarchy. You should use the parentheses if you have any doubts in your mind about how the calculator will handle an expression. Your calculator can have as many as 9 parentheses sets open at any one time with as many as 8 operations pending. The following is an example of this full capability.

$$(((2 \times (2 \times (2 \times (2 \times (2 \times (2 + 2) \times (2 + .2)) - (2 + 2)))))) \div 2) \div 2)$$

As you key in this sequence, note that no calculations take place until the first closed parenthesis is keyed in. Your calculator remembers all instructions keyed in and interprets them when it's supposed to.

Note: an important point when using parentheses. You may often see equations or expressions written with parentheses to imply multiplication: $(2 + 1)(3 + 2) = 15$. *Your calculator will not perform implied multiplications.* You have to key in the operation between the parentheses:

$$(2 + 1) \times (3 + 2) = 15.$$

Here's an example using parentheses:

Evaluate: $\frac{8 \times (4 + 9) + 1}{(3 + 6 \div 2) \times 7}$

In problems of this type — you want the calculator to evaluate the entire numerator, then divide by the entire denominator. You can be sure of this taking place by placing an extra set of parentheses around the numerator and denominator as you key in the problem.

Press	Display	Comments
CL	0	Clear any calculations in progress.
(8 X (4 + 9)	13.	(4 + 9) is evaluated.
+ 1)	104.	8 × (4 + 9) is evaluated.
÷ ((3 + 6 ÷ 2)	105.	The value of the numerator.
X 7)	6.	(3 + 6 ÷ 2) is evaluated.
=	42.	The value of the denominator.
	2.5	The result.



A LOOK AT THE FEATURES AND FUNCTIONS

Dual Function Keys — $\boxed{2nd}$, \boxed{INV}

Your calculator is equipped with numerous functions designed to save you time and increase the accuracy of your calculations. To allow you access to all of this power without loading the machine with keys, many of the calculator keys perform more than one function. The first function is printed right on the key. To use the first function of a key — just press it. To use the second function (written above the key), just push the $\boxed{2nd}$ key followed by the key right below the function.

For example, to find the natural logarithm of a number, press $\boxed{\ln x}$. To find the common logarithm of a number, press $\boxed{2nd} \boxed{\ln x}$. In order to distinguish the second function key, this manual shows it as $\boxed{2nd} \boxed{\log}$. First function operations, therefore, are indicated by $\boxed{}$. Second functions are indicated by $\boxed{2nd} \boxed{}$.

The inverse key \boxed{INV} also provides additional calculator functions without increasing the number of keys on the keyboard. When you press the \boxed{INV} key before a particular function or key, the purpose of that function or key is reversed. The \boxed{INV} key works together with quite a few keys on your calculator to provide extra functions, or to reverse an operation.

The $\boxed{2nd}$ and \boxed{INV} keys allow 108 different keyboard operations to be performed using only 45 keys. For use with specific keys, see *Dual Function Keys* in Section V.



A “Guided Key Tour”

A LOOK AT THE FEATURES AND FUNCTIONS

Memory Keys — **CMs**, **STO**, **RCL**, **Exc**

Each time you turn on your TI Programmable 59 there are 60 data registers for you to use. The number of data registers available on your TI Programmable 58C depends on the number last selected, even though the calculator has been turned off. Actually, the number of data registers available versus the amount of program memory is variable. (See *Selection of Memory Size* in MEMORY CAPABILITIES of Section V for complete details.) Data registers are special locations in the calculator where you can store numbers you may need to use later. The TI Programmable 58C retains numbers stored in the data registers even when the calculator is turned off.

Because there is usually more than one data register available for your use, you must indicate which register you want to use by specifying its two-digit number **XX**. For example, **STO 08**.

The **CE** and **CLR** keys do not affect what is in the memories; however, pressing **2nd CMs** clears all data registers simultaneously (places a 0 in all registers).

STO XX — STORE — This instruction stores the number held in the display register into data register **XX**(00-99) without disturbing the contents of the display register. (Any number previously stored in register **XX** is cleared out first.)

RCL XX — RECALL — This instruction simply brings the contents of data register **XX** to the display register. Again, the contents of data register **XX** are not disturbed.

2nd Exc XX — MEMORY EXCHANGE — The exchange sequence simply swaps whatever is in data register **XX** with the contents of the display register. (The display register value is stored in register **XX** while the number stored in memory is called to the display register.) This key is handy in many situations allowing you to make a quick check or use what is in memory without losing what’s in the display register.

Example: Store and recall 3.21.

Press	Display	Comments
3.21 STO 08	3.21	Store 3.21 in register 8
CLR	0	Clear display
RCL 08	3.21	Recall contents of register 8

II



A “Guided Key Tour”

A LOOK AT THE FEATURES AND FUNCTIONS

Example: Evaluate: $(A + 2) + A(A + 2)$ for $A = 9.3069128$.

Press	Display	Comments
CLR	0	Clear any calculations in progress.
9.3069128 STO 12	9.3069128	Stores A in register 12.
+ 2 +	11.3069128	$A + 2$ is evaluated.
2nd Exc 12	9.3069128	Stores $A + 2$ in register 12 and calls A to the display register.
X RCL 12	11.3069128	Recalls $A + 2$ to the display register. (Note that a X must be between A and $A + 2$)
=	116.5393643	Completes all pending operations to arrive at the final result.

Note that the long value of A only had to be entered once, saving time and possible errors. The exchange key performs the task of a store and a recall also saving calculation effort.

Memory Arithmetic Keys — **SUM**, **Prd**

There is also a series of key sequences that let you operate on the numbers stored in memory without affecting other calculations in progress:

SUM XX — MEMORY SUM — This sequence allows you to add whatever is in the display register directly to what's stored in register XX. The result of the addition is stored in the memory while the display register is unaffected. Similarly, the sequence **INV SUM XX** subtracts the value in the display register from the contents of register XX.

2nd Prd XX — MEMORY PRODUCT — This sequence causes the contents of register XX to be multiplied by the display register value while **INV 2nd Prd XX** divides register XX by the number in the display register. Again the result is left in memory and the display register is undisturbed.

These instructions perform similar to the way basic arithmetic operations do in normal keyboard calculations, except that results are accumulated in a data register instead of the display register.

Example: Find the total cost of items of \$28 and \$6.60 with 5% sales tax.

Press	Display	Comments
28 STO 01	28.	Store 28 in data register 1
6.6 SUM 01	6.6	Add 6.6 to data register 1
1.05 2nd Prd 01	1.05	Multiply data register 1 by 1.05
RCL 01	36.33	Total Cost



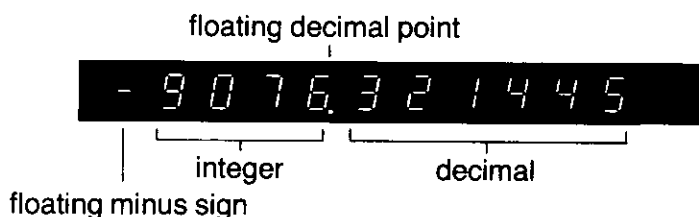
A "Guided Key Tour"

A LOOK AT THE FEATURES AND FUNCTIONS

DISPLAY CONTROL

Standard Display

The display provides numerical information complete with negative sign and decimal point and flashes on and off for an overflow, underflow, or error condition. (A complete list of error conditions is found in Appendix B.) An entry can contain as many as 10 digits. All digits entered after the tenth are ignored.



The terms display and display register are not synonymous. *Display* refers only to the digits you see in the calculator's display window. The *display register* is the internal register that retains results to 13 digits.

If a number is too large or too small to be handled by the standard format, the calculator automatically displays the number using scientific notation.

For example, when 400,000 and 2,000,000 are multiplied together you get 800,000,000,000, a number too large for the 10-digit display. So, it is displayed as $8. \times 10^{11}$.



Scientific Notation Key — **EE**

In many applications, particularly in science and engineering, you may find yourself needing to calculate with very large or small numbers. Such numbers are easily handled (by both you and your calculator) using scientific notation. A number in scientific notation is expressed as a base number (mantissa) times ten raised to some power (exponent).

$$\text{Number} = \text{Mantissa} \times 10^{\text{Exponent}}$$

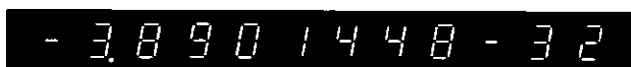
To enter a number in scientific notation

Enter the mantissa using up to 8 digits — (then press **+/-** if it's negative).

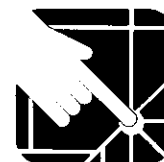
Press **EE** (Enter Exponent) — "00" appears at the right of the display.

Enter the power of 10 (then press **+/-** if it's negative).

A number such as $-3.8901448 \times 10^{-32}$ looks like this in your display:



In scientific notation the power of ten tells you where the decimal point would have to be if you were writing the number out in longhand.



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A “Guided Key Tour”

A LOOK AT THE FEATURES AND FUNCTIONS

A positive exponent tells you how many places the decimal point should be shifted to the right, a negative exponent — how many places to the left.

Example: $2.9979 \times 10^{11} = 299,790,000,000$
(Move decimal 11 places to the right and add zeros as needed)
 $1.6021 \times 10^{-9} = 0.0000000016021$
(Move decimal 9 places to the left and add zeros as needed)

Once you initiate the scientific notation format it stays there until you deliberately remove it. If you press **INV** **EE**, the calculator returns to standard display format as soon as the value in the display is within the range of the standard display. **CLR** removes this format when it clears the display.

Engineering Notation Key — **Eng**

Engineering notation is a modified form of scientific notation. The power (exponent) is always adjusted to a multiple of three (10^{12} , 10^{-6} , etc.). As a result, the mantissa may have one, two, or three digits to the left of the decimal point. This feature allows the calculator to display results in units that are easily used by the scientist, engineer or technician (such as 10^{-12} for picofarads, 10^{-3} for millimeters, 10^3 for kilograms, 10^{-6} for microseconds). **CLR** does not remove engineering notation.

The display may be converted to engineering notation at any time by pressing **2nd** **Eng**. **INV** **2nd** **Eng** returns the display to standard display format.

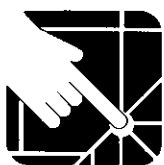
Example: Evaluate $8 \times 98 \times 30$ in Engineering Format

Press	Display
CLR 2nd Eng	0. 00
8 X 98 X	784. 00
30 =	23.52 03
INV 2nd Eng	23520.

Fix-Decimal Control — **fix**

This convenient feature allows you to choose the number of digits you'd like to appear in the display to the right of the decimal point as you go through your calculations. Just press **2nd** **fix**, then press the desired number of decimal places (0 to 8). The calculator then rounds all subsequent results to this number of decimal places for display only. However, you may still make entries with as many digits as you like as the calculator retains its own internal (13 digit) accuracy. **INV** **2nd** **fix** removes fix-decimal. **The TI Programmable 58C retains the fix-decimal selection, even while turned off.**

Press	Display
CLR 2 ÷ 3 =	.666666667
2nd fix 6	0.666667
2nd fix 2	0.67
2nd fix 0	1.
INV 2nd fix	.666666667



A “Guided Key Tour”

A LOOK AT THE FEATURES AND FUNCTIONS

ALGEBRAIC FUNCTIONS

Square, Square Root, Reciprocal Keys — x^2 , \sqrt{x} , $1/x$

These three easily accessible keys are essential for speedy handling of a variety of equation solving situations. All three of these keys act immediately on the number held by the display register without affecting other calculations in progress.

x^2 — SQUARE — Calculates the square of the number, x, in the display register.

\sqrt{x} — SQUARE ROOT — Calculates the square root of the number, x, in the display register.

$1/x$ — RECIPROCAL — Divides 1 by the display register value x.

Here's an example putting them all together: $\sqrt{4} \div (1/5)^2 = 50$

Press	Display	Comments
CLR	0	Clear any calculations in progress.
4 \sqrt{x}	2.	$\sqrt{4}$
\div 5 $1/x$	0.2	1/5
x^2	0.04	$(1/5)^2$
$=$	50.	The result

Powers And Roots — y^x

This powerful key allows you to raise any positive number to a power. You may also use this key to find the roots of a positive number.

For Powers (y^x)

- Enter the number (y) you want raised to a power.
- Press y^x .
- Enter the power (x).
- Press $=$ (or any operation key).

Example: Calculate 2^6 .

Press	Display
CLR	0
2 y^x 6 $=$	64.

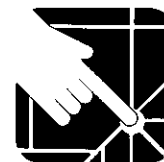
For Roots ($\sqrt[x]{y}$)

- Enter the number (y) you want to find a root of.
- Press INV y^x .
- Enter the root (x).
- Press $=$ (or any operation key).

Example: Calculate $\sqrt[6]{64}$.

Press	Display
CLR	0
64 INV y^x 6 $=$	2.

NOTE: You should only enter positive values for y, a flashing display results for negative entries.



A LOOK AT THE FEATURES AND FUNCTIONS

Logarithms — $\ln x$, \log

Logarithms are mathematical functions that enter into a variety of technical and theoretical calculations. Basically, if $x = y^2$, then $\ln x$ (to the base y) = 2. The keys discussed below give you immediate access to the logarithms of any positive number — without affecting calculations in progress — and without having to deal with bulky tables.

$\ln x$ — NATURAL LOGARITHM — Immediately calculates the natural logarithm (base $e = 2.718281828459$) of the number held in the display register. (A flashing display results if this number is negative or zero.) The antilogarithm of the natural log (e^x) is found using the sequence $\text{INV} \ln x$.

$2^{\text{nd}} \log$ — COMMON LOGARITHM — Immediately calculates the common logarithm (base 10) of the display register value (Again, the value in the display should be positive). The antilogarithm of the common log (10^x) is found by pressing $\text{INV} 2^{\text{nd}} \log$.

Example: Calculate the natural logarithm of ($e^{2.7} + 10^{1.2}$).

Press	Display	Comments
CLR	0	Clear any calculations in progress.
$(2.7 \text{ INV } \ln x$	14.87973172	$e^{2.7}$ is evaluated.
$+ 1.2 \text{ INV } 2^{\text{nd}} \log$	15.84893192	$10^{1.2}$ is evaluated.
$)$	30.72866365	Pending addition is completed.
$\ln x$	3.425195888	The result.



A “Guided Key Tour”

A LOOK AT THE FEATURES AND FUNCTIONS

Angular Mode Keys — **Deg** , **Rad** , **Grad**

Your calculator is equipped to handle a variety of calculations that involve angles — notably the trigonometric functions and polar/rectangular conversions. Angles can be measured in degrees, radians or grads. Your calculator always powers up in the degree mode; however, you may select any one of three common units for angular measure using the key sequences below:

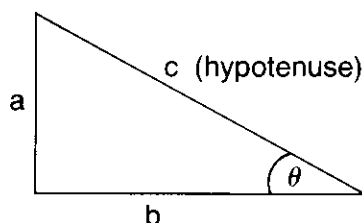
2nd Deg — SELECT DEGREE MODE — In this mode all entered and calculated angles are measured in degrees, until another mode is selected. (One degree = $1/360$ of a circle — a right angle equals 90° .)

2nd Rad — SELECT RADIAN MODE — In this mode all angles are measured in radians (one radian equals $1/(2\pi)$ of a circle — a right angle equals $\pi/2$ radians).

2nd Grad — SELECT GRAD MODE — In this mode all angles are measured in grads (one grad equals $1/400$ of a circle — a right angle equals 100 grads).

Trigonometric Keys — **sin** , **cos** , **tan**

These functions immediately calculate the sine, cosine, and tangent of the angle held in the display register. The angle is measured in the units of the selected angular mode.



$$\sin \theta = \frac{a}{c}$$

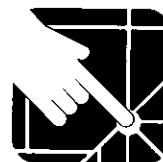
$$\cos \theta = \frac{b}{c}$$

$$\tan \theta = \frac{a}{b}$$

where: a, b, and c are the lengths of the sides.

The sequences **INV sin** , **INV cos** , and **INV tan** are used to calculate the inverses of these functions. The resulting angles are displayed in units corresponding to the selected angular mode.

In the degree mode, all angles are interpreted in decimal format. (See Degree Format Conversions in Section V.)



A LOOK AT THE FEATURES AND FUNCTIONS

CONVERSIONS

Degree Format Conversions — **D.MS**

There are two ways of representing an angle in degrees.

One method is to use the decimal degree format DDD.dd. Here DDD represents the integer portion of the angle while .dd denotes the fraction portion written as a decimal. (You may use as many as 10 digits.)

The second method is to use the degree.minute-second format DDD.MMSSsss. Again, DDD represents the whole angle. MM represents minutes and SS denotes seconds. If greater accuracy is desired, fractional seconds may be entered in the sss position. Observe that the decimal point separates the degrees from the minutes.

To convert from the degree.minute-second format to decimal degrees enter the angle into the display (DDD.MMSSsss) and press **2nd** **D.MS**. Pressing **INV** **2nd** **D.MS** reverses the conversion process and converts decimal degrees to degrees, minutes and seconds.

Two digits should always be submitted for minutes and two for seconds as the calculator looks at the fractional part of the entry two digits at a time. Trailing zeros need not be entered. Consider this example.

Example: Convert 54°02'09.6" to its decimal equivalent and back.

Press	Display	Comments
54.02096 2nd D.MS	54.036	DD.ddd
INV 2nd D.MS	54.02096	DD.MMSSs

This same process can be used to convert between hours, minutes and seconds and decimal hours.

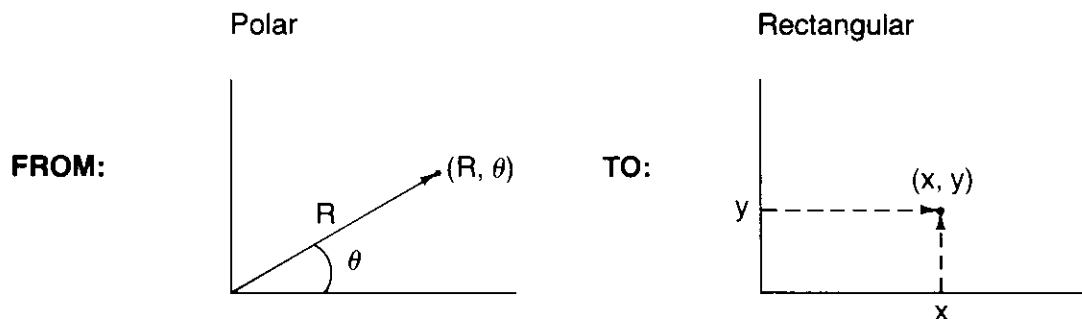


A “Guided Key Tour”

A LOOK AT THE FEATURES AND FUNCTIONS

Polar/Rectangular Conversions — **P→R**

This is an especially handy feature of your calculator that is particularly useful in science and engineering applications. Working with the **$x \leftrightarrow t$** key — it’s fast and easy to convert from polar to rectangular coordinates, or vice versa. Just follow the key sequences illustrated below:



To convert from polar to rectangular coordinates:

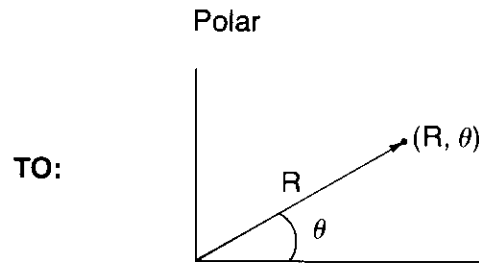
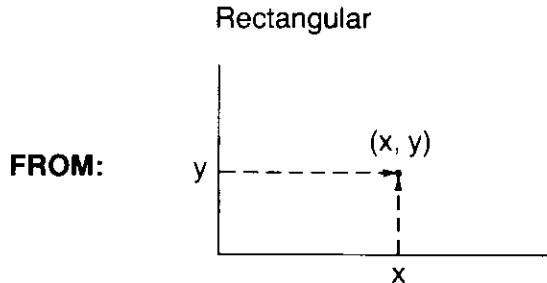
- Enter your value for “R”
- Press **$x \leftrightarrow t$**
- Enter your “ θ ” value (be sure angular mode is correct)
- Press **2nd** **P→R** to display “y”
- Press **$x \leftrightarrow t$** to display “x”

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A "Guided Key Tour"

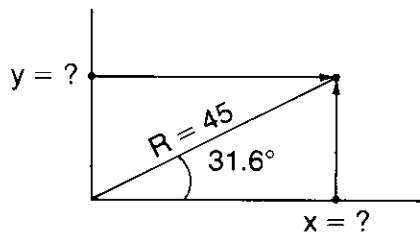
A LOOK AT THE FEATURES AND FUNCTIONS



To convert from rectangular to polar coordinates:

- Enter your "x" value
- Press $\boxed{x \leftrightarrow t}$
- Enter your "y" value
- Press $\boxed{\text{INV}} \boxed{2\text{nd}} \boxed{P \rightarrow R}$ to display " θ " in selected angular units
- Press $\boxed{x \leftrightarrow t}$ to display "R"

Example:



Convert $R = 45$ meters, $\theta = 31.6^\circ$
into rectangular coordinates

Press	Display	Comments
$\boxed{\text{CLR}} \boxed{2\text{nd}} \boxed{\text{Deg}}$	0	Clear any calculations in progress and <i>select degree mode</i> .
45 $\boxed{x \leftrightarrow t}$	0.	*Place R in the T-register
31.6	31.6	Place degrees in display
$\boxed{2\text{nd}} \boxed{P \rightarrow R}$	23.57936577	Convert to rectangular coordinates and display y.
$\boxed{x \leftrightarrow t}$	38.32771204	Display x. (y is now in the T-register)

*NOTE: This conversion uses a special register known as the T-register accessed through the $\boxed{x \leftrightarrow t}$ (x exchange t) key. The special applications of this register are discussed in various programming sections.



A “Guided Key Tour”

A LOOK AT THE FEATURES AND FUNCTIONS

STATISTICAL FUNCTIONS ON KEYS

Mean, Variance and Standard Deviation

You may find yourself handling large sets of data points describing some particular factor or parameter of a large number of items. (These data could be test scores, sales figures, etc.) The most commonly used statistical calculations used to boil down such data to a few representative numbers are the mean, variance, and standard deviation. The mean is the *average* value of your data — a measure of the central tendency of your data. The variance and standard deviation give you a feel for how variable the data are; a measure of how far the data differ from the mean.

Refer to *Statistics* in Section V for a complete discussion of how to use these powerful functions.



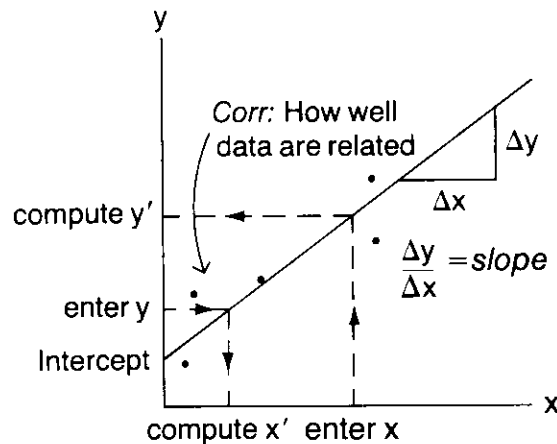
A LOOK AT THE FEATURES AND FUNCTIONS

Linear Regression

Linear regression may sound like a highly technical or threatening title to you — but it’s a process that your calculator makes very easy to use. And it’s one that deals with one of the oldest problems in the world: predicting future events.

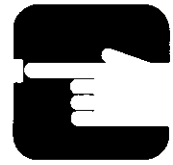
In the linear regression situation you usually have data expressed as pairs of variables that you could plot on a graph. We usually label a pair of points like this with the letters x, y (x may be dollars in advertising while y is unit sales, or x may be a test score and y a performance record in the field, etc.). You want to make a prediction for some x value that you select — what will happen to y (or vice versa)? Your calculator can do this for you by mathematically drawing the “best straight line” through your data points. You may then use the straight line to make predictions.

Once the data are entered your calculator is ready to draw the best straight line through your points and give you the following information from it:



Statistics involving non-linear curve fits, exponential population plots for example, can also be accommodated by the calculator.

The use of these and other features is detailed in *Statistics* in Section V.



ACCESSING SOLID STATE SOFTWARE PROGRAMS

The term "software" may or may not be familiar to you — and actually it has a variety of definitions. Basically, it refers to the instructions and programs — things that usually can be written on paper — that tell a computer or calculator what to do, and a user like yourself how to use them. Your calculator has a provision for an assortment of easy-to-use but extremely powerful programs to be inserted into the calculator and used by you at the touch of a key. These programs — especially written to handle user needs in a variety of fields — are stored in a special library module in back of your machine. This module can be easily replaced with a different module. The program information is all contained in a tiny solid-state "chip" of silicon — similar in construction to the silicon integrated circuit that is the heart and brain of a calculator. Hence the term "*Solid State Software*" programs. There's a lot of "software" — programs with easy-to-use features stored for you in your *Solid State Software* module. The advantages

- a lot of program capability is packed in little space — easy to carry and use.
- library programs are accessible from keyboard anytime.
- the library programs are especially written to be easy to use, even by the beginning calculator user.

To complete the effectiveness of each module, there is a library manual. All information peculiar to each program is found in an easy-to-use format in this manual.

PROGRAM LIBRARIES

A Master Library that is a basic assortment of useful programs comes with your calculator. Other professional libraries can be obtained from most TI retailers or ordered directly from Texas Instruments. Each library contains a selection of programs that make it easy to use some of the powerful mathematical techniques of the various professional fields. A library consists of a program library module, a manual explaining in detail the use of each program in that library, a storage case and a set of program label cards. Any *Solid State Software* library designated for the TI Programmable 58 and 59 is also completely compatible with the TI Programmable 58C.

PROGRAM LIBRARY MODULE

The programs of each library are stored in library modules, one module for each library. A module can be easily inserted into the back of the calculator and used immediately. Modules are durable devices, but should be handled with care for long life.

CAUTION

Be sure your body is free of static electricity before handling any module.

This is especially true when the charger is connected because this grounds the calculator. Just touch some metal object to electrically discharge your body. The contents of a module can be severely damaged by static discharges. See Appendix A for more on maintaining the modules.

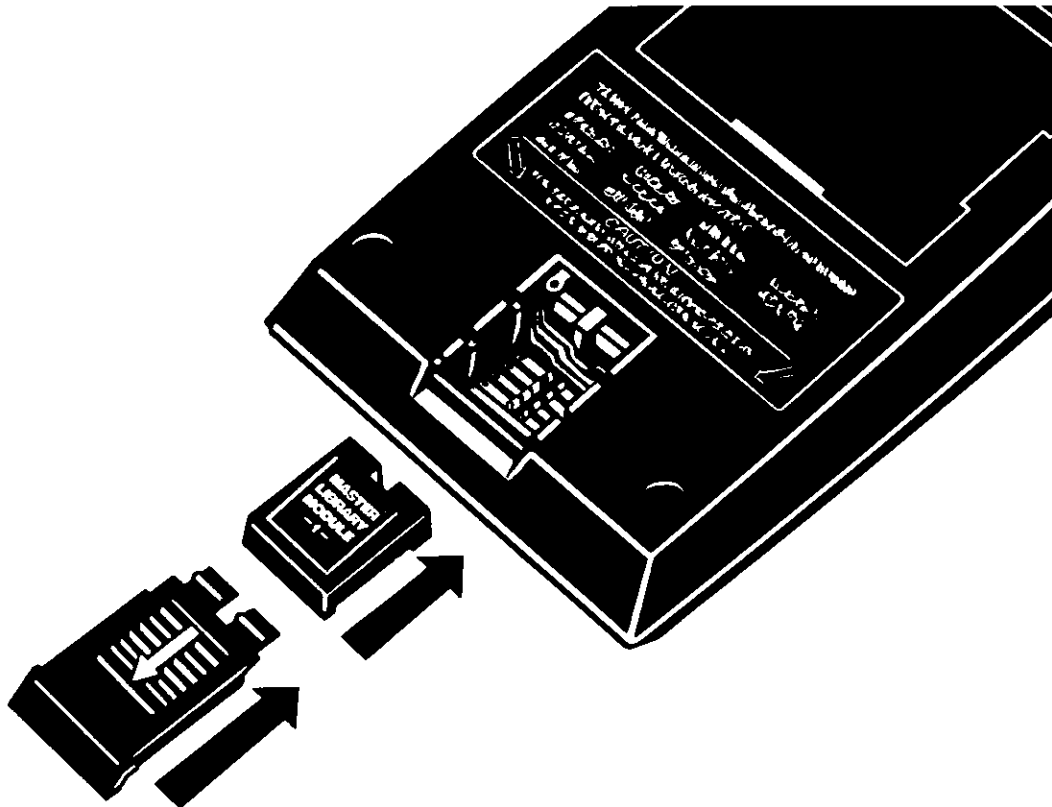


Using "Built-In" Problem Solutions

ACCESSING SOLID STATE SOFTWARE PROGRAMS

The Master Library module is installed in the calculator at the factory, but can easily be removed or replaced with another. It is a good idea to leave the module in place in the calculator except when replacing it with another module. Be sure to follow these instructions when you need to remove or replace a module.

- 1) **Turn the calculator OFF.** Loading or unloading a module with the calculator ON may cause the keyboard or display to lockout. Also, shorting the contacts can damage the module or calculator.
- 2) Slide out the small panel covering the module compartment at the bottom of the back of the calculator. (See Diagram below) Again, eliminate all static charges before handling the module.
- 3) Remove the module. You may turn the calculator over and let the module fall out into your hand.
- 4) Insert the module, notched end first with the labeled side up into the compartment. The module should slip effortlessly into place.
- 5) Replace the cover panel, securing the module against the contacts.



Avoid any action that could bend, contaminate or otherwise damage the contacts.



Using "Built-In" Problem Solutions

ACCESSING SOLID STATE SOFTWARE PROGRAMS

RUNNING LIBRARY PROGRAMS

Once a library module has been loaded into the calculator, calling a particular program is done simply by requesting it by its number (each program in a library has its own number). The required sequence is **2nd** **Pgm** **mm**, where **mm** is the two-digit number assigned to the program you have chosen to run. If **mm** is not in the current module, the display flashes.

To use a program, carefully follow the instructions in the library manual. A program label card is included for each program. This nonmagnetic card specifies the user-defined key assignments and can be fitted into the window above these keys once it is separated from the sheet of labels.*

Example: What is the value of \$1000 after 20 years of compounding at an 8% interest rate?

The Compound Interest program in the Master Library can readily solve this problem.

Press	Display	Comments
CLR 2nd Pgm 18	0.	Calculator goes to Compound Interest Program (PGM 18)
2nd f	0.00	Initialize
20 A	20.00	Enter number of periods
8 B	8.00	Enter interest rate
1000 C	1000.00	Enter present value
0 D	4660.96	Calculate future value

You can use this program over and over once you are there without having to use the PGM instruction again. Press **RST** or **2nd** **Pgm** **00** to return to program memory and keyboard operation or you can run another library program through use of the **Pgm** key.

Library programs can also be called by other programs as explained in *Subroutines* in Section IV. This feature greatly expands the programming capabilities of your calculator.

If you want to find out which library is in the calculator at any time without having to open the module compartment, press **2nd** **Pgm** **1** **SBR** **2nd** **Write** (**2nd** **Pgm** **1** **SBR** **2nd** **R/S**) for the TI Programmable 58C) and the module number is displayed (and printed along with the module name if you have the calculator on a PC-100A or PC-100C).

*Note that the blank label cards are provided as a convenience for labeling user-defined keys of personal programs using the TI Programmable 58C.



Using “Built-In” Problem Solutions

ACCESSING SOLID STATE SOFTWARE PROGRAMS

ANALYZING LIBRARY PROGRAMS (DOWNLOADING)

Normally, library programs are confined to their module for ready access, whenever needed. When a program is used, processing actually enters the module and performs its task. To gain access to the library program, you can bring it into program memory. Now all the calculator's programming tools can be used to analyze the individual steps and alter the program to your particular needs if necessary. Actually, only a copy of a program is brought into program memory, the module contents can never be changed. The procedure to “download” a program is easy.

- 1) Verify that there is sufficient program memory space available for the incoming program. See *Partitioning* in the next section.
- 2) Press **2nd** **Pgm** **mm** to designate which program to download.
- 3) Press **2nd** **Op** **09** to download the program.

This procedure places the requested program into program memory beginning at program location 000. The downloaded program writes over any instructions previously stored in that part of program memory. Therefore, a program in program memory cannot download a module program.

Once in program memory, the program can be manipulated for whatever purposes you need. You cannot, however, place the altered program back into the library module. If you need to preserve the “new” program, you can write down each step on a coding form, record it onto a magnetic card (or cards) if you have a TI Programmable 59 or list it if you have an optional printing unit. The TI Programmable 58C will retain a program until changed or until battery power is lost for an extended period.

A library module containing proprietary programs is protected from downloading. A request to download one of these programs flashes the display.

If a library module does not perform as expected, see Appendix A.

IV

PROGRAMMING CONSIDERATIONS



WHAT IS PROGRAMMING?

Computers are having such an impact on everyday life that we've become familiar with terms such as *computer-programmers*, *programming the computer*, *programming language*, or just plain *programming*. For some people, these terms conjure up visions of super-sophisticated individuals dealing in a highly complex field, and just the thought of becoming a programmer seems beyond the realm of possibility, at least without a great deal of training.

Not so; the era of personal programming is here. In fact, calculator programming is simple, and most intriguing is the fact that anyone can be programming calculators after a couple of easy lessons. Texas Instruments programmable calculators are designed to make programming simple and easy. Your calculator is versatile enough to allow you to enjoy the speed and power that programming offers — whether you are someone using just basic arithmetic, or an aerospace engineer working with extremely complex mathematics. The calculating power is there for everyone, but use only what is required for your application. You'll be amazed at how quickly and easily time-consuming problems can be solved with simple arithmetic and simple programs working together.

Programming is logical thinking. In simplest terms, a program is a set of instructions telling a machine or a person how to do something. A *calculator program*, therefore, tells a calculator how to do something, in particular how to perform calculations. When you want your calculator to do a job all you really need to do is to tell it exactly what you want it to do and how you want it done. A *program* is a list of precise instructions in specific order to be executed faithfully in a literal way.

A *language* is merely the means by which you can communicate with your calculator. There is even a language to communicate with the simplest four-function calculator. Applied to programming, a language is a necessary means to communicate your program to your calculator.

A *calculator language* is heavily weighted toward common sense and the use of arithmetic. If, therefore, you have experience in carrying out arithmetic calculations, either with pencil and paper or on a calculator, you already know most of your calculator's programming language. The functions explained in this manual for keyboard operation can be used in the same way in programs.

A calculator (like any computer) performs with literal faithfulness those and only those instructions given it. This characteristic makes working with these machines a mixed experience. The result is that you, the programmer, have to be careful what you tell the calculator to do and the order in which you tell it to complete the instructions. A calculator does exactly what you instruct it to do, regardless of whether you want it done that way or not. The techniques we discuss here will allow you to start realizing the potential of your calculator and make you a functional part of the era of personal programming.



ELEMENTARY PROGRAMMING

Placing a Variable in a Program

Consider the following simple expression:

$$A + B = C$$

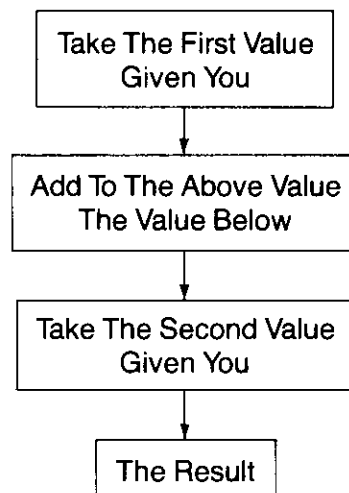
When using a basic four-function calculator, the values of A and B cannot be identified at a later time, they must be known at the time the expression is keyed in. After this first expression is keyed in and a result is obtained, to change either or both values you have to key in the entire expression again. With the programmable calculator you may key in the instructions leaving the values undefined and then get an answer at a later time by keying in only the values to be changed.

Now with the simple arithmetic expression above, the four-function calculator may be just as fast to use as a programmable calculator. The real advantage of the programmable calculator can be seen in an expression like the one below. Let's say you're in a situation where an answer is needed for ten different values of A, assuming B and C do not change.

$$A \times (B \div (1 + A)^{-C}) = \text{RESULT}$$

You'd like to be able to enter the equation just once, then change only the value of A for each calculation. With your programmable calculator it's easy to do just that.

Let's go back and work with our simple expression again. Consider how to give instructions to the calculator. First, write the instructions as if to instruct another person, and then convert them to calculator instructions.

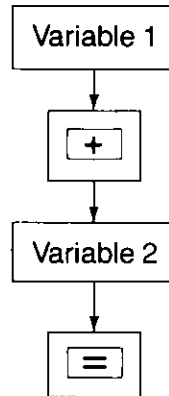


A and B are values that can be anything — they can vary. These values are often called variables.

IV



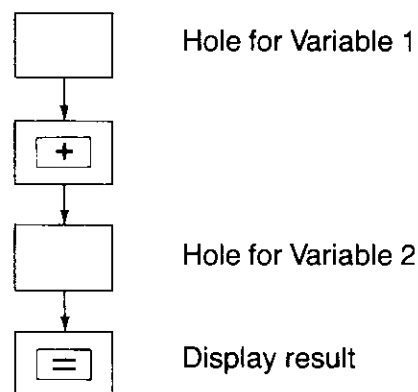
Programming Considerations



As far as the calculator is concerned, if you don't enter the variable as part of the program, two things must be done:

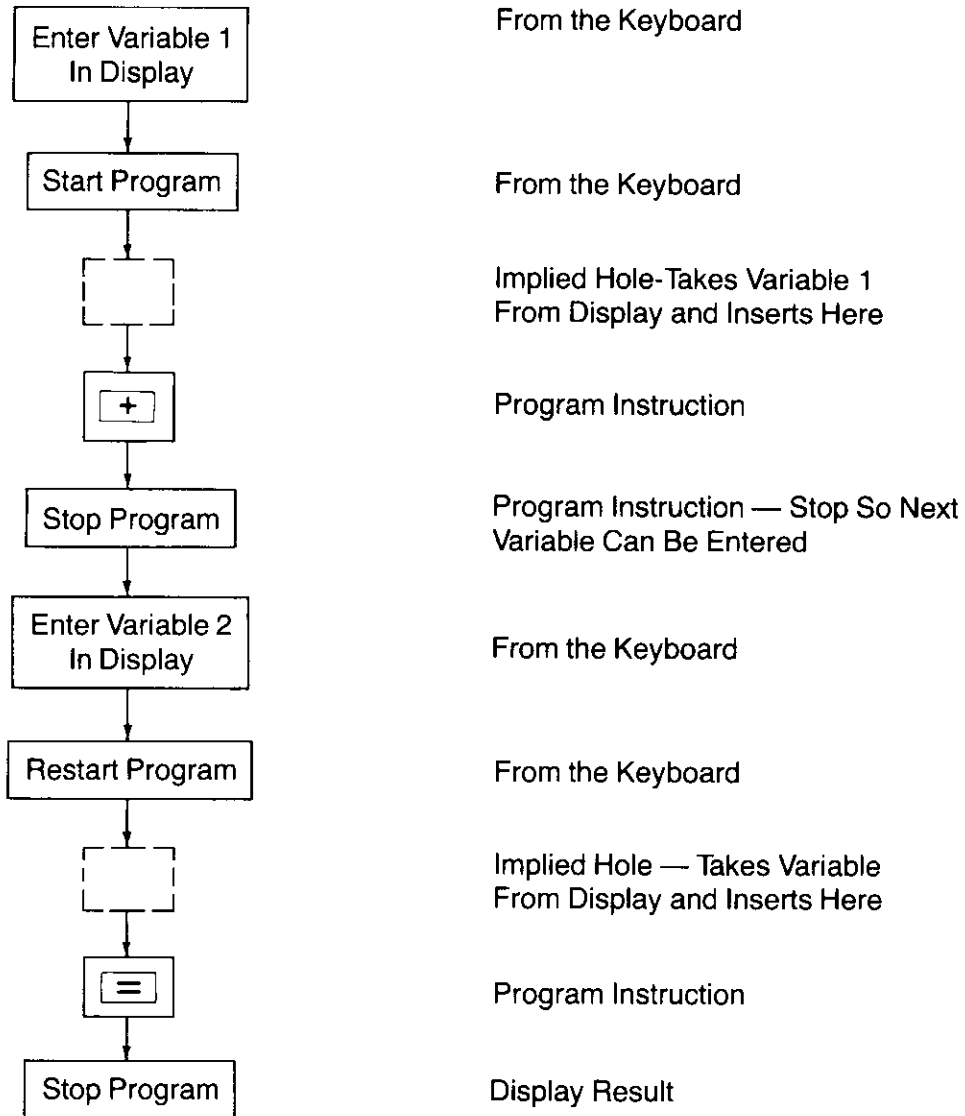
1. Leave a *hole* at the right spot in your instructions where you can place the variable at a later time.
2. Tell the calculator where to look for the variable value when it needs it. You can instruct the calculator to look for a variable either in the display or in one of its data registers.

Here we'll redraw the instruction sequence, leaving *holes* where the variables should be inserted.



Now, if the calculator needs to use a displayed number as a variable, leave the hole empty. When the calculator starts running through a program, whatever value is in the display is placed in the first hole. A value for the second variable must also be found in the display, so we'll need to stop the program just before the variable is needed and enter it into the display. Then when the program is restarted the calculator takes the displayed value and continues.

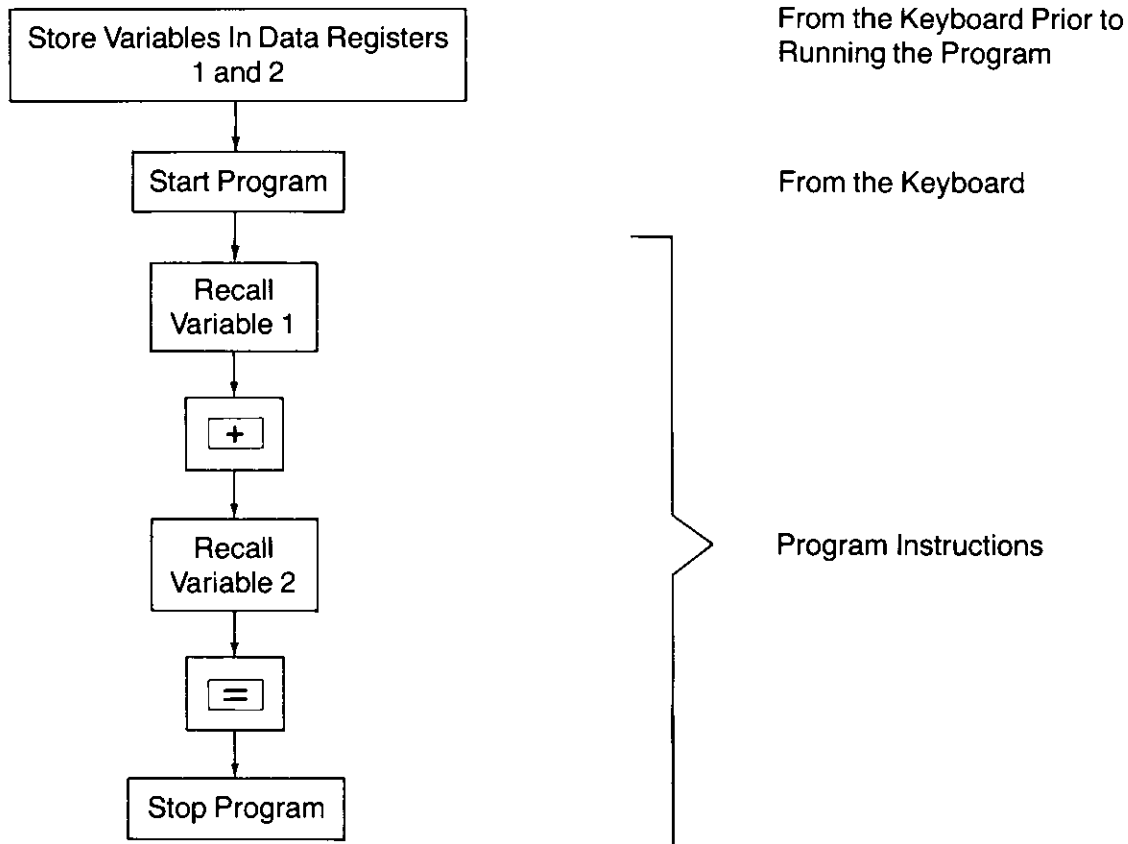
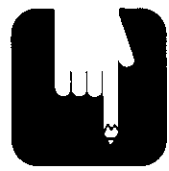
One technique that lets you leave holes in your program for new entries or data is to simply stop the program at that point with the **R/S** (Run/Stop) key. You're just telling the machine to *hold everything* so that you can key the next value it needs into the display. (We can call this an *implied hole* since no gap is actually left between program instructions. By stopping execution at some point in the program we're implying that we want to do something at that point — make a data entry.)



Variables in the Display Flow Chart

The above method (stopping the program to enter data) is ideal when a completely new set of variables is to be used each time the program is run. You may find another technique preferable when only one value needs to be changed. In this procedure you use the calculator's data registers to store the variables.

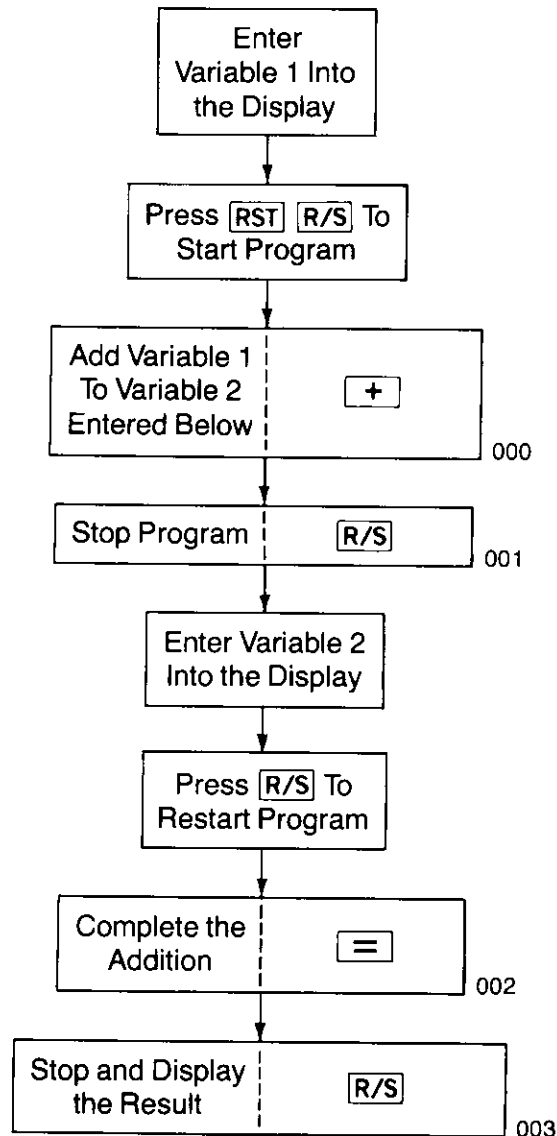
If you want your calculator to find a variable in its memory, place the instruction to recall the variable from the appropriate data register right in your program. For example, recalling a variable stored in data register 1 is performed by the sequence **RCL 01**.



Variables in Data Memory Flow Chart

Let's briefly review what we've accomplished thus far. First, we identified a problem and then considered two methods for entering the variables (one with memory and the other without memory). Third, we developed a simple flow diagram for each method. Notice that a flow diagram is originated by graphically separating the problem into individual steps or actions which solve the problem when performed from top to bottom.

The next important step is to use the flow diagram to help determine the keystrokes required to instruct the calculator to solve the problem. Notice in the two following examples that the **[RST]** key must be pressed before actually running the program. This assures that the program begins with instruction number 000 when the **[R/S]** key is used to start the program. The following example shows the keystrokes required to instruct the calculator to look for the variables in its display register.



Variables in the Display Program

The centered blocks in each flow diagram explain what *you* must do to run the program once you have keyed the program instructions into program memory. These instructions or keystrokes are found in the right halves of the blocks divided by dotted lines. The numbers outside these blocks are the instruction numbers corresponding to the keystrokes inside the blocks. These keystrokes or program instructions may be keyed into program memory by placing the calculator in the learn mode.

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Programming Considerations

Here's the procedure for getting a program into your calculator.

1. Press **2nd** **CP** to clear the program memory.
2. Press the **LRN** key to enter the learn mode. You will know you are in this mode by a unique display format 000 00.
3. Press each key shown in the flow diagram beginning at the top. Press only the keys shown. If you make a mistake, press **LRN** and start over with step one. Changes in the display are explained below.
4. Press the **LRN** key a second time to exit the learn mode and the unique display disappears leaving a single zero displayed. You are now ready to run the program.

The three digits in the left of the display should change as you enter a program. These three digits show you at what program location or instruction number the *program pointer* is located. The program pointer is an internal device used by the calculator to determine which instruction it should perform next when executing a program. In the learn mode the program pointer simply points to the next unfilled location in the program memory.

Now you and your calculator can try out the program with the variables coming in through the display.

1. Turn the calculator ON and press **2nd** **CP** .
2. Press the **LRN** key to enter the learn mode.
3. Enter the program by pressing the sequence shown below.

+ **R/S** **=** **R/S**

4. Press the **LRN** key to exit from the learn mode.

You have just programmed the calculator. Now solve the problem $227 + 34 = ?$ by running the program.

1. Press **CLR** to clear any calculations in progress.
2. Press **RST** and enter **227** for variable 1.
3. Press **R/S** . The number **227** remains in the display.
4. Enter **34** for variable 2 and press **R/S** again. The answer **261** is displayed.

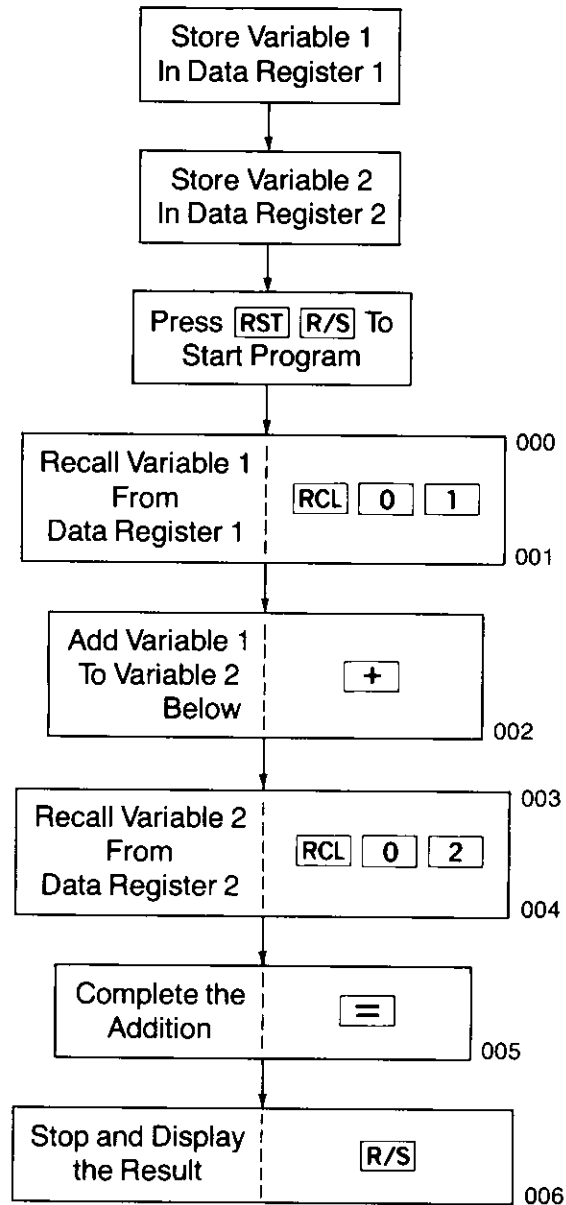
Before running any program, it is a safe practice to press the **CLR** key to ensure that there are no pending calculations left to cause erroneous results. Each time these keys are pressed, the program adds the values in data registers 1 and 2 and displays the result. Enter numbers of your own and run the program again.



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Programming Considerations

Now let's use data registers to hold our variables and write a new program.



Variables in Data Memory Program

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Programming Considerations

Perform the following sequence to enter this program into your calculator.

1. Turn the calculator ON and press **2nd** **CP** .
2. Press the **LRN** key to enter the learn mode.
3. Enter the program by pressing the following sequence.

RCL
0
1
+
RCL
0
2
=
R/S

4. Press the **LRN** key again to exit from the learn mode.

This program looks for the variables in data registers 01 and 02. Therefore, store 227 in register 01 and 34 in register 02 as follows.

- | | |
|-----------------------------|----------------------------|
| 1. To Store 227 in memory 1 | 2. To Store 34 in memory 2 |
| Enter 227 | Enter 34 |
| Press STO 01 | Press STO 02 |

As noted in the flow diagram comments, the only keyboard operation needed to run the program is to press **RST** **R/S** . After pressing these keys, the answer 261 appears in the display and the problem is solved.

Notice that entering the variables from the keyboard into the display took fewer programmed keystrokes or instructions to the calculator, consequently less space was used in program memory. By using the data registers to store the variables, more instructions are placed in program memory, but the calculator computed the result from start to finish with no intermediate stops. Choosing one method over the other depends on your needs.

You should remember that flow diagrams can be very useful, particularly in helping to organize and lay out the approach to solving a particular problem. A flow diagram consists of what is happening while the program is running, and includes not only the instructions or program placed in the calculator's program memory, but also explains what you need to do manually at the keyboard to make the program run, like starting the program and inputting variables. The keystrokes shown are instructions the calculator recognizes and will follow. These keystrokes are stored in the calculator's program memory when the calculator is in the learn mode; essentially they are the program.



Programming Considerations

Mechanics of Programming

The versatile arithmetic language permits both simple and complex programming. Simple programs may be entered, checked, and run with little effort or difficulty. Even though the language is designed to be as straightforward as possible a complex program requires forethought and planning.

If you have done little programming, you will find the following ideas useful. If you are familiar with programming concepts, the ideas will serve as a review and orient you toward calculator programming. You should interpret the following only as a list of suggestions since you will undoubtedly develop your own programming style.

1. **Define the problem very clearly and carefully.** Identify the formulas, variables and desired results. What is known? What is to be determined? How are the known and the unknown related?
2. **Develop a method of solution** (sometimes called an **algorithm**). Define the operation sequence of the numerical approach you want to use keeping in mind the calculating and programming capabilities of the calculator. (Remember, strictly speaking, calculators do not solve problems, you do. Your calculator carries out your solutions precisely the way you tell it to!)
3. **Develop a flow diagram.** It is often useful to develop drawings that help you visualize the flow of the program. Here, you can picture interactions between various parts of the solution. It may even be possible to simplify the program structure after it is flow charted.
4. **Begin making data register assignments.** Assign data registers to the numerous things you'll be operating on. You'll continue this task throughout the programming process. It is a good idea to never store a quantity in memory without making a written note that the data register in question contains that quantity.
5. **Translate the flow diagram into keystrokes.** The coding forms are provided to help you here. It is useful to list all labels and memory registers in the space indicated on the form. Use the comments column for easy reference to various segments of the program.
6. **Enter the program.** Press **2nd** **CP** **LRN** and key in the complete program from the coding form. When entry is complete, press **LRN** to remove the calculator from the learn mode.
7. **Test the program.** Check out the program using test problems representing as many cases as practical.
8. **Correct errors.** Correct the coding form for any errors discovered while testing the program.
9. **Edit the program.** Place the calculator in the learn mode, complete the required corrections and press **LRN** to return to the keyboard operation. See page IV-21 for more information.
10. **Retest the program.** Repeat steps 7-9 as needed.
11. **Record the program.** If your calculator has magnetic card capability, record the program on magnetic cards. See Section VII for more information.
12. **Document user instructions.** It's always a good idea to carefully write down step-by-step instructions describing how to use your program. Even the most powerful programs are useless if you don't remember how to use them. Fill out a User Instructions form, detailing information required to run the program.



Using User-Defined Keys (Labels)

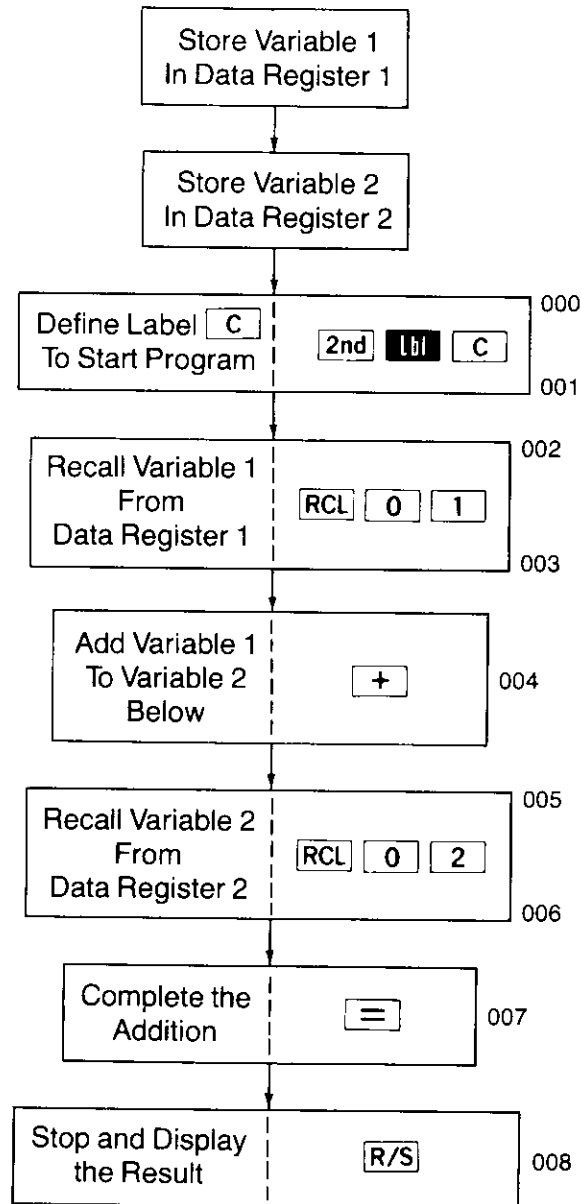
In running the previous sample programs, you used the **RST** and **R/S** keys each time. Since **RST** returns the program pointer to instruction number 000, you may have concluded that every program must start at the beginning of program memory. As you gain programming experience, you will discover that this is not always practical. Your calculator has *user-defined keys* that may be used as *labels* to provide easy access to any location within a program. *Labels* are placed in a program as reference points.

When a user-defined key is placed in a program, pressing this key causes the program pointer to locate the label. The calculator then automatically begins running the program, starting calculations from the first instruction following the label. These keys are **A** through **E** and their second functions **2nd A** through **2nd E** which allow you to identify and access up to ten different reference points (programs or parts of programs). For example, with a minor addition to the first program example, the **RST R/S** key sequence used to start the program could simply be **C** or any other user-defined key. Since the **C** key is user-defined, the addition to the program is simply to label the start of the program with **C** using the **2nd Lbl** or label key as shown in the following diagram.



Programming Considerations

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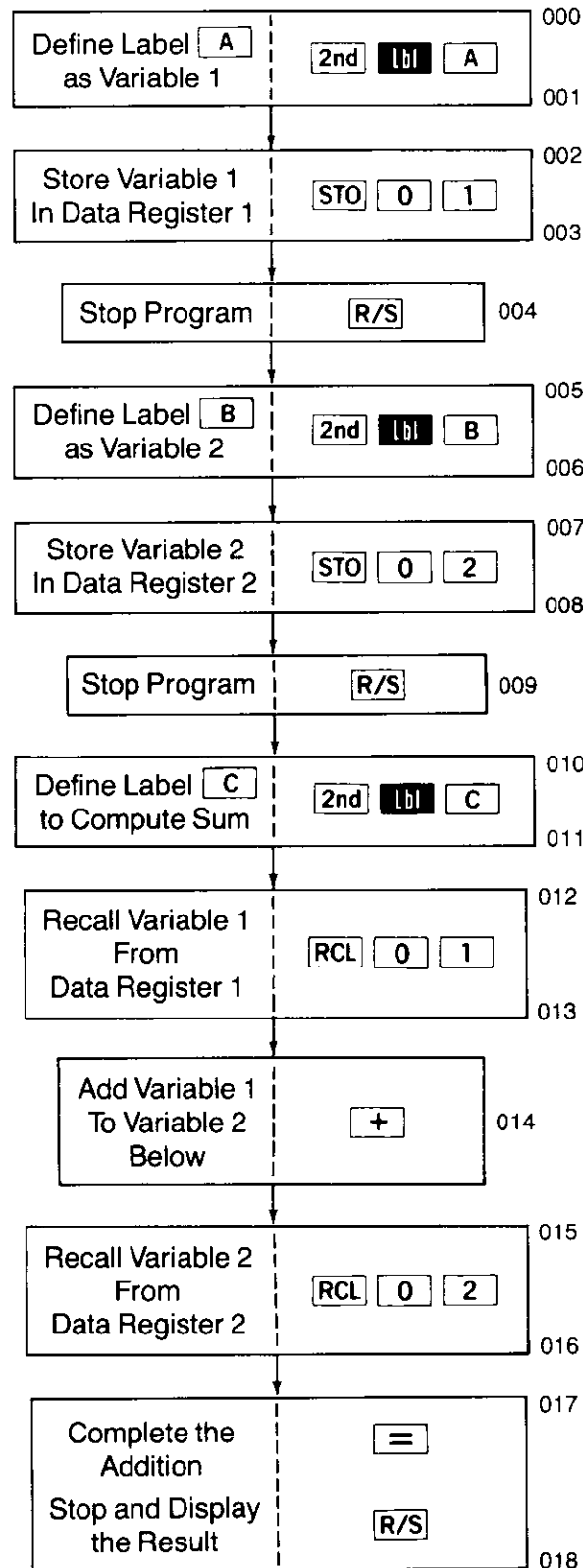
Enter the learn mode just as before and key in the keystrokes shown. Exit the learn mode and store 227 in data register 1 and 34 in data register 2. Now press **C**. The answer 261 is displayed because pressing **C** tells the calculator to find where **Lbl C** is located in program memory and then begin executing the instructions or keystrokes following **Lbl C**.

Now that you have an idea about how user-defined keys work, consider a second addition to the previous program allowing variable 1 to be stored in data register 1 by pressing **A** and variable 2 to be stored in data register 2 by pressing **B**. Then, **C** is again used to obtain the answer.

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Programming Considerations





Programming Considerations

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Place your calculator in the learn mode and enter the program instructions. Press **LRN** again to exit the learn mode and try out the program. Note that variables 1 and 2 may be entered in either order.

Although this change increases the size of the program it is now much easier to use. The following comparison of these three programs provides an overall view of how the user-defined keys improve the usability of a program. Clearly, the third version is the easiest to use.

First Version

Enter **227**
Press **STO** 01
Enter **34**
Press **STO** 02
Press **RST** **R/S**
Display **261**

Second Version

Enter **227**
Press **STO** 01
Enter **34**
Press **STO** 02
Press **C**
Display **261**

Third Version

Enter **227**
Press **A**
Enter **34**
Press **B**
Press **C**
Display **261**

Labels may be placed anywhere in a program instruction sequence without altering the meaning of that sequence. They are simply ignored during instruction processing except for the purpose of locating a desired point in program memory and do not affect pending operations. This statement is not intended to mean that a label can interrupt a sequence such as **RCL** 14 where more than one program location is involved in defining a single processing action.

You should include needed labels in your original program design rather than add them as an afterthought. Then key your labels into program memory along with the rest of your code, just as though they were any other instructions.

Of course, even the use of labels does not make practical a program that simply adds two numbers together as the number of keystrokes required for the operation is increased rather than reduced. It should be evident, however, that labels can be used as valuable tools in more sophisticated programs.



Short Form Addressing

Up till now we have always used a two-digit address to access data registers. That is, recalling a variable stored in data register 1 for example, has been accomplished by using the sequence **RCL 01**. In some cases, however, leading zeros are not needed to access data registers 0-9. This type of addressing, often called *short form addressing*, may be used *whenever a nonnumeric keystroke immediately follows the register address*.

Example: Store 227 in data register 1 and 34 in data register 2, then recall these values and compute their sum.

Press	Display	Comments
227 STO 01	227.	Since the next entry is to be a numeric keystroke, the full address must be used.
34 STO 2	34.	Short form addressing may be used in the last three occurrences since each address is followed by a nonnumeric keystroke.
RCL 1 +	227.	
RCL 2 =	261.	

Observe that when short form addressing is used the instruction is not completed until a nonnumeric key is pressed. That is, just as 227 is not recalled until **+** is pressed, 34 is not stored until **RCL** is pressed.



Keying in Your Program

Programming is the technique of determining what your instructions to the calculator are going to be. However, once you have prepared these instructions you need to know how to enter them into the calculator. You have already been exposed to the learn mode; but this section covers it in depth.

Programs are developed through a logical organization of the problem. Although you don't need a calculator to develop the programs, you will want to try each program as it is presented in this manual. Therefore, this section is placed here with the intention of familiarizing you with the learn mode and hopefully assist you in bridging the gap between *writing* a program and *using* a program.

Your calculator can receive program instructions from the keyboard only when it is in the learn mode. Conversely, any keystroke (except the four discussed in *Editing Programs* a few pages later) made when the calculator is in the learn mode is received by the calculator as an instruction. This is an extremely important fact because it means instructions should be entered with care and that keyboard calculations cannot be performed in the learn mode.

If you make a mistake while keying in an instruction, you don't need to start all over reentering the entire sequence of instructions. Your calculator has keys that make it possible to correct a keystroke entered by an erroneously pressed key, to delete instructions, and to add instructions. These keys are discussed in *Editing Programs*.

Following these simple steps should allow you to enter any program.

1. From the keyboard, press **2nd** **CP** to position the program pointer at location 000 and clear all of program memory.
2. Press **LRN** to place the calculator in the learn mode. (Refer to *Displaying the Program* on the opposite page for an explanation of the display format.)
3. Key in your program, not forgetting any necessary **2nd** prefixes.
4. Make sure your program does not exceed the program memory size. If too many instructions are entered, the calculator switches to keyboard control, and the learn mode display format is conspicuously absent.
5. Switch from the learn mode to the keyboard control by pressing **LRN**.
6. Run test problems and correct or edit your program according to the procedures outlined in *Editing Programs*.

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Programming Considerations

Displaying the Program

The display format of the learn mode is designed to show you where the program pointer is positioned and the instruction presently found at that location. Turn your calculator on and press **LRN** to enter the learn mode. A unique display consisting of two groups of zeros should appear in the display.

000 00

The group of three digits on the left shows you where the program pointer is positioned in program memory. When writing a program, assign each instruction to a location in program memory. This not only allows you to keep track of instructions, but tells the calculator the order in which to complete the instructions as well.

Since your calculator can only understand numbers, each key is assigned a two-digit code number known as a *key code*. The group of digits on the right displays the key code corresponding to the instruction stored in the program memory location indicated on the left. The general rules for coding the keys are:

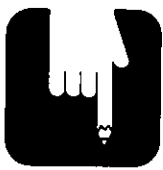
1. All *numeric keys* are represented by their appropriate number, thus key **7** is coded as "07."
2. All other *first function keys* are assigned key codes relative to their location on the keyboard. The first digit denotes in which of the nine rows (numbered 1-9 from top to bottom) the key is located. The second digit establishes the column location (numbered 1-5 from left to right). In the learn mode, a **\sqrt{x}** instruction (row 3, column 4) stored in program memory location 073 would appear as in the display below.

073 34

3. *Second functions* are coded by adding five to the column position. The row number is not changed. For example, **2nd** **COS**, located above **\sqrt{x}** (key code "34"), is coded as "39". **2nd** **TAN**, however, located above the **1/x** key (key code "35"), is represented by "30" rather than "40" as the row number remains the same.

You may use the key code overlay supplied with your calculator to help acquaint yourself with these codes. Key code charts are also found in *Instruction Codes (Key Codes)* in Section V.

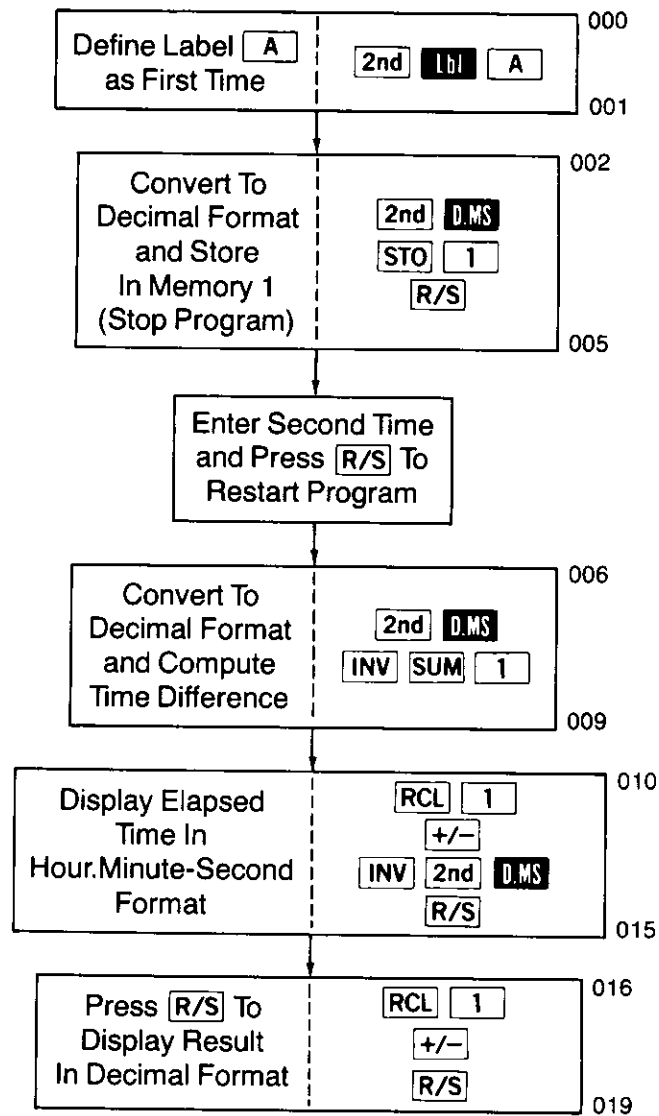
In special cases the instructions may be combined and stored in one program location. When this happens, the key codes are also combined or *merged* into a single two-digit code. **RCL 12** for example, is stored in two program locations. **RCL** is stored in the first location and the sequence **1 2** is merged and stored in the second. In this example, the key codes are merged into the two-digit code "12". Here, "12" is not interpreted as the user-defined key instruction **B** as any memory operation tells the calculator to translate the next instruction it encounters into a data register address. Other special cases are discussed as they arise.



Programming Considerations

Elapsed Time Program

Write a program that may be used to determine the elapsed time between two specified times. You may enter the time in hour.minute-second format (e.g., 3:16:03 = 3.1603) and convert to decimal format for computation using **2nd** **D.MS**. See the discussion of this conversion in *Degree Format Conversion* in Section II.



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Programming Considerations

Let's perform this exercise using the following procedure. First, press **2nd** **CP** to clear program memory and to place the program pointer at location 000 and then enter this program according to the procedure outlined below.

Press	Display
LRN	000 00
2nd Lbl	001 00
A	002 00
2nd D.MS	003 00
STO	004 00
1	*004 00
R/S	006 00
2nd D.MS	007 00
INV	008 00
SUM	009 00
1	*009 00
RCL	011 00
1	*011 00
+/-	013 00
INV	014 00
2nd D.MS	015 00
R/S	016 00
RCL	017 00
1	*017 00
+/-	019 00
R/S	020 00

Since you initially cleared program memory using **2nd** **CP** all key codes are displayed as 00 as you enter this program. This is because once a program location is filled the program pointer advances to the next location and displays the key code of the instruction stored there — not the instruction just entered.

*These displays do not appear consistent; however, observe that short form addressing is used here. What happens is that the calculator is waiting for the data register address to be completed. In the first occurrence, for example, if **STO 01** were pressed 005 00 would appear in the display. In the above, however, the nonnumeric keystroke **R/S**, tells the calculator that the address stored in 004 is complete and instructs it to store **R/S** in 005. The pointer then automatically advances to 006 as location 005 is filled.



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Programming Considerations

Follow this procedure to verify that you have entered the program correctly. If you have a PC-100A or PC-100C Printer, just press **RST** **2nd** **List** to obtain this listing. Press **R/S** to stop listing.

Press	Display	Corresponding Keystrokes
RST LRN	000 76	2nd Lbl
SST	001 11	A
SST	002 88	2nd D.MS
SST	003 42	STO
SST	004 01	1
SST	005 91	R/S
SST	006 88	2nd D.MS
SST	007 22	INV
SST	008 44	SUM
SST	009 01	1
SST	010 43	RCL
SST	011 01	1
SST	012 94	+/-
SST	013 22	INV
SST	014 88	2nd D.MS
SST	015 91	R/S
SST	016 43	RCL
SST	017 01	1
SST	018 94	+/-
SST	019 91	R/S
LRN		

Now that you have correctly programmed your calculator, run this program using 2:15 for the first time and 3:42:54 for the second.

Enter	Press	Display	Comments
2.15	A	2.25	t_1 (H.MMSS) \rightarrow t_1 (H.hh)
3.4254	R/S	1.2754	t_2 (H.MMSS) \rightarrow Δt (H.MMSS)
	R/S	1.465	\rightarrow Δt (H.hh)

The elapsed time is 1 hour, 27 minutes, and 54 seconds, or 1.465 hours.

If in running this program you obtain an output such as 6.396 in the hour.minute-second format interpret this result as 6 hours, 39 minutes, and 60 seconds which is equivalent to 6 hours and 40 minutes.



Editing Programs

While in the learn mode you have the following capabilities:

1. Display the instruction stored at any program location you choose.
2. Replace an instruction with another.
3. Delete an instruction and close up the hole.
4. Create a space for an additional instruction without destroying previously programmed instructions.
5. Single-step forward or backward through program memory without disturbing its contents.

These features allow you to inspect, correct, and modify a program without having to reenter correct instructions.

The four keys that may be pressed while in the learn mode without being interpreted as a program instruction are **SST**, **BST**, **Ins**, and **Del**. Briefly, **SST** and **BST** allow you to step forward and backward through program memory and examine its contents one location at a time. From the keyboard, **SST** may be used to execute a program one step at a time allowing you to observe the results of each operation. The **2nd Ins** instruction causes the current instruction and all following instructions to be advanced one location in program memory while inserting a null instruction at the current location. If an instruction is stored in the last program location it is lost as a result of pressing this key. Pressing **2nd Del** causes the instruction at the current program location to be deleted and shifts all following instructions back one location, and fills the last location with a zero.

Two additional keys useful in program editing are **RST** (Caution: **RST** performs several functions. See *Basic Program Control Functions* in Section V.) and **GTO**. Pressing **RST** from the keyboard places the program pointer at 000. Pressing **GTO** followed by a three-digit absolute program address or a label, repositions the program pointer to that location in program memory. (Leading zeros may be suppressed in short form addressing.) Pressing **GTO** followed by a label address causes the program pointer to be positioned at the first location following the label in the program. Entering the learn mode following any of the above sequences allows you to examine the contents of program memory at the desired location.

Note that if these keys are pressed while your calculator is in the learn mode they are interpreted as program instructions.

If you want to change a program sequence, locate the sequence using one of the methods described above and simply cover up the old instructions by entering the new ones or add and delete instructions as needed.



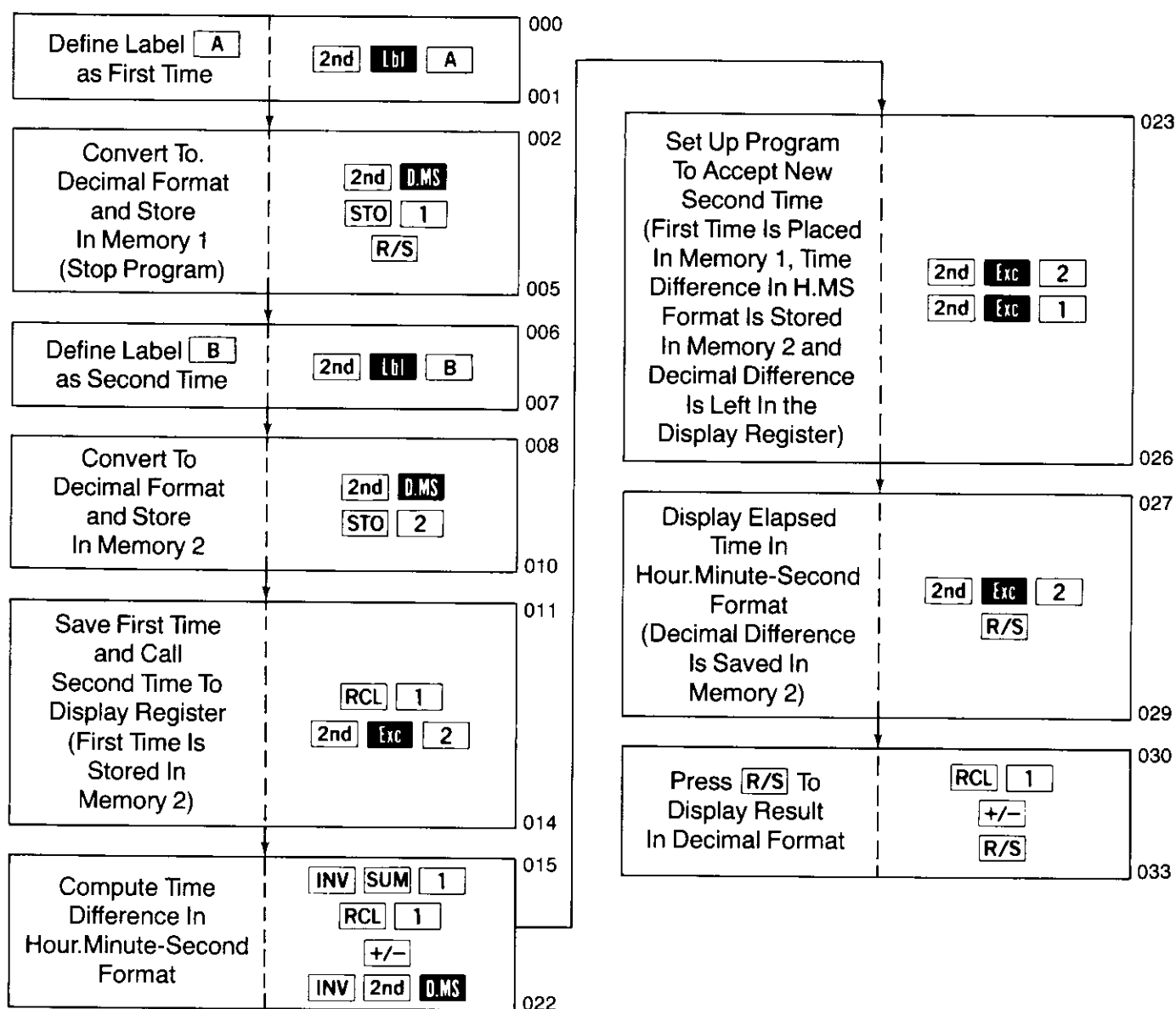
Programming Considerations

IV

Improving the Elapsed Time Program

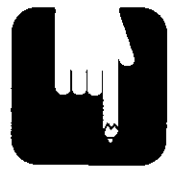
Let's modify the last program so that the second time may be changed without reentering the first time. Make the modification after the original program has been entered rather than keying in the entire program again.

We need to do three things. First, use a label to enter the second time so that this segment of the program may be accessed directly. Second, provide a means of saving the first time so that it may be retrieved after computation. And third, set up the program to accept a new second time after computing the elapsed time.



There is a mistake in the key sequence given above. See if you can find it before reading further.

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Programming Considerations

Make the necessary changes according to the procedure outlined below:

Press	Display	Comments
GTO 6		Set program pointer to location 006
LRN	006 88	Enter learn mode
2nd Ins	006 00	Insert label B
2nd Ins	006 00	
2nd Lbl	007 00	
B	008 88	
SST	009 22	Advance program pointer one step
2nd Ins	009 00	Insert instructions 009-014
2nd Ins	009 00	
STO 2	010 00	
2nd Ins	011 00	
2nd Ins	011 00	
RCL 1	012 00	
2nd Ins	013 00	
2nd Ins	013 00	
2nd Exc 2	014 00	
SST SST SST	018 43	Advance program pointer eight steps
SST SST SST	021 22	
SST SST	023 91	
2nd Ins	023 00	Insert Instructions 023-028
2nd Ins	023 00	
2nd Exc 2	024 00	
2nd Ins	025 00	
2nd Ins	025 00	
2nd Exc 1	026 00	
2nd Ins	027 00	
2nd Ins	027 00	
2nd Exc 2	028 00	
LRN		Exit learn mode



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Programming Considerations

You may use this procedure to verify that you have modified the program correctly.

Press	Display	Corresponding Keystrokes
RST LRN	000 76	2nd Lbl
SST	001 11	A
SST	002 88	2nd D.MS
SST	003 42	STO
SST	004 01	1
SST	005 91	R/S
SST	006 76	2nd Lbl
SST	007 12	B
SST	008 88	2nd D.MS
SST	009 42	STO
SST	010 02	2
SST	011 43	RCL
SST	012 01	1
SST	013 48	2nd Exc
SST	014 02	2
SST	015 22	INV
SST	016 44	SUM
SST	017 01	1
SST	018 43	RCL
SST	019 01	1
SST	020 94	+/-
SST	021 22	INV
SST	022 88	2nd D.MS
SST	023 48	2nd Exc
SST	024 02	2
SST	025 48	2nd Exc
SST	026 01	1
SST	027 48	2nd Exc
SST	028 02	2
SST	029 91	R/S
SST	030 43	RCL
SST	031 01	1
SST	032 94	+/-
SST	033 91	R/S

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Programming Considerations

Run this program using 1:30 for the first time and 2:13:57 and 2:14:24 for the second times

Enter	Press	Display	Comments
1.3	<input type="button" value="A"/>	1.5	t_1 (HH.MMSS) \rightarrow t_1 (HH.hh)
2.1357	<input type="button" value="B"/>	0.4357	t_2 (HH.MMSS) \rightarrow Δt (HH.MMSS)
	<input type="button" value="R/S"/>	-1.5	?

The example is discontinued here because this last answer is obviously wrong. The output should be the elapsed time in decimal hours; however, it is the negative value of the first time represented in decimal hours. Upon inspecting the flow diagram and the accompanying keystrokes, you can see that the desired output has not been lost. The exchange sequences of steps 023-28 have merely transferred this information to data register 2. Therefore, the problem may be eliminated by changing step 031. This correction can be made by simply replacing the instruction.

Press	Display
<input type="button" value="GTO"/> <input type="button" value="3"/> <input type="button" value="1"/>	
<input type="button" value="LRN"/>	031 01
<input type="button" value="2"/>	032 94
<input type="button" value="LRN"/>	

Now, run the program again.

Enter	Press	Display	Comments
1.3	<input type="button" value="A"/>	1.5	t_1 (HH.MMSS) \rightarrow t_1 (HH.hh)
2.1357	<input type="button" value="B"/>	0.4357	t_2 (HH.MMSS) \rightarrow Δt (HH.MMSS)
	<input type="button" value="R/S"/>	0.7325	\rightarrow Δt (HH.hh)
2.1424	<input type="button" value="B"/>	0.4424	t_2 (HH.MMSS) \rightarrow Δt (HH.MMSS)
	<input type="button" value="R/S"/>	0.74	\rightarrow Δt (HH.hh)



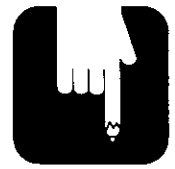
Programming Considerations

Editing with Merged Code

Let's suppose for a moment that the output in the above example had been left in data register 12 instead of 2. If this were the case you would need to store 12 in program location 031. Here, you should be extra careful to ensure that this code is properly merged. (See *Displaying the Program* a few pages back.) One method of entering this code is described below.

Press	Display
CLR GTO 30	0
LRN	030 43
RCL	031 01
1 2	032 94
LRN	0

This procedure requires that the **RCL** instruction be reentered so as to instruct the calculator to automatically merge the data register address and store it in a single program location. Observe that short form addressing may be used for program addresses.



Typical Programming Applications

PROGRAMMING IS PERSONAL

Before proceeding, it is important to understand that programming is very definitely a personal thing. This is to say that two people programming the same problem do not necessarily arrive at the same program instructions, although they may get exactly the same result. This is because we are all individuals, and often approach a problem in different ways. Organization processes can differ as a result of different educational and career backgrounds. An engineer with a great deal of mathematical training would probably need to choose an approach requiring the use of complex mathematical equations, whereas a liberal arts major with less mathematical training may solve his problems using basic arithmetic functions in a different approach. One person may be satisfied to use a set of instructions taking a great deal of program memory space, while another person may prefer to look for ways to condense his program to use the minimum amount. Each of us will want to choose a familiar approach.

Your style should grow as you get into the process of programming. You should even find this learning period adventurous and best of all — fun! Don't be afraid to make mistakes through exploration — your calculator won't mind. Tying up a large-scale computer can cost a lot of money, so beginning programmers are often kept away. Your calculator charges you essentially nothing for its time — so take advantage of this fabulous opportunity and experiment with alternate routes, functions, patterns and anything else you can think of!

INVESTMENT CALCULATION PROGRAM

What advantages do programmable calculators offer? The programmable calculator is designed to obtain solutions faster and with less chance of making errors through repetitive entries. Now, to program a problem that demonstrates how it saves time.

At one time or another everyone has had a savings account where they received interest on the money in the account. If 5% interest per year is received on an account worth \$1000, at the end of one year \$50 in interest is added making the account worth \$1050. The \$1000 in the account today is called the "present value" of the account because it has received no interest. But at the end of one year you would expect it to be worth \$1050 which is its "future value." Compounding interest means that once money is placed in an account it is left alone for two or more periods and at the end of each period, interest is added to what was in the account at the beginning of that period. Thus interest is also earned on interest such that the original \$1000 is worth:

$$\$1000 + \$1000 (.05) = \$1050 \text{ at the end of the first year}$$

$$\$1050 + \$1050 (.05) = \$1102.50 \text{ at the end of the second year}$$



Programming Considerations

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Nearly everyone is familiar with but may not be aware of the expression for this concept, which can be stated:

“The future value of money equals its present value times one plus the interest rate multiplied by itself the number of compounding periods.”

Mathematically:

$$FV = PV \times (1 + i)^n$$

Before writing the program, you should logically lay out what is to be done. First the interest rate should be entered into the equation as a decimal. Let the calculator do this by dividing the interest rate by 100 after it is entered. Also, savings institutions use various periods in compounding interest (quarterly, daily, etc.). Flexibility may be added to the program by providing a means to tell the calculator how the compounding is done. Incorporating these changes into the future value equation it may be rewritten as:

$$FV = PV \times \left[1 + \left(\frac{i}{100} \div c \right) \right]^{cn}$$

The variables used above are:

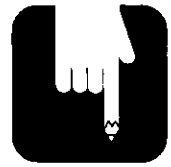
- FV= future value of investment
- PV= present value of investment
- i= annual interest rate
- c= number of compounding periods per year
- n= number of years of investment

Now you should decide whether to enter the variables into the display as each is called for or place them in memory to be recalled as needed. In this example they are placed in memory. This allows the variables to be entered individually making it easier to evaluate different possibilities. Note that when a program is to be rerun using previously entered data, care must be taken to preserve the original data. This is the modification that was required by the elapsed time program example.

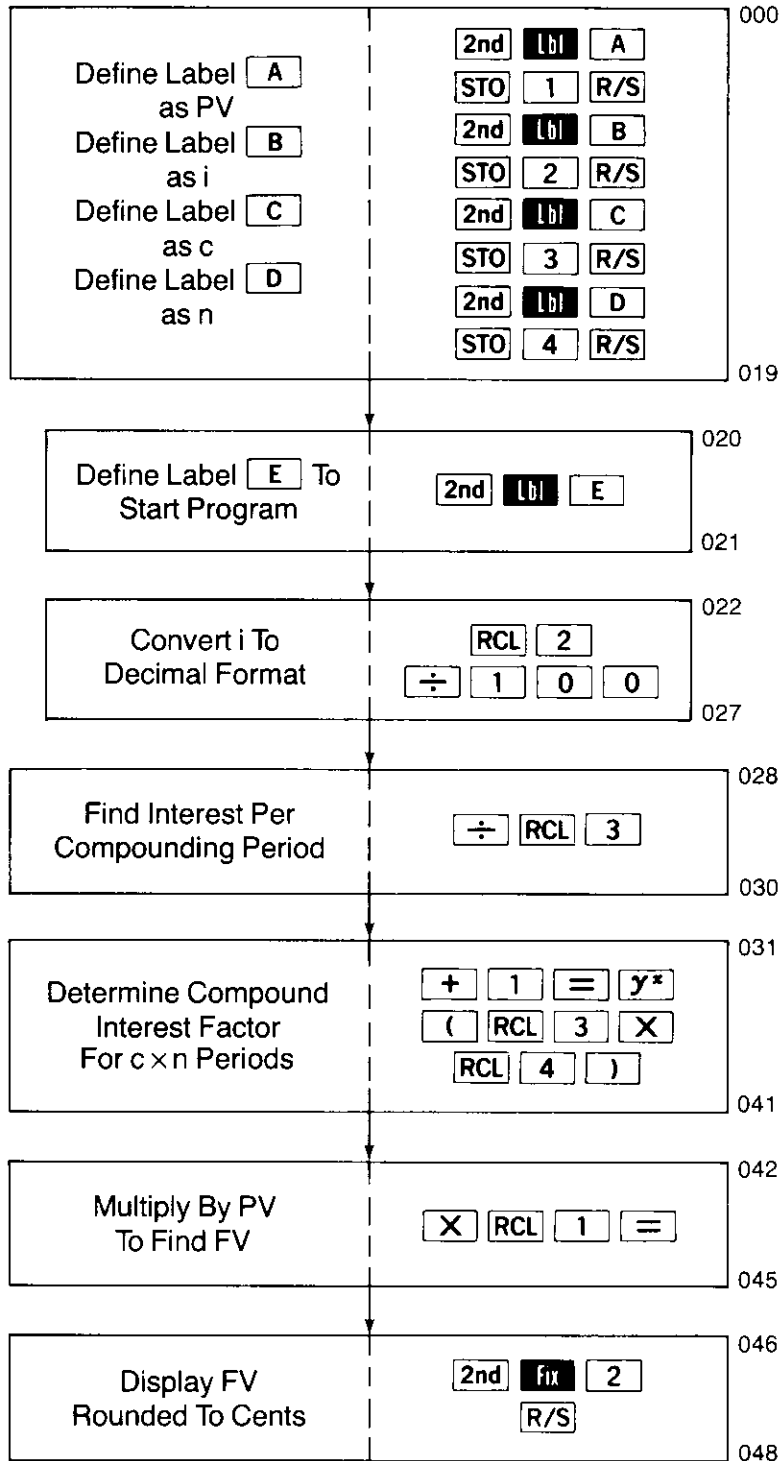
The approach has been decided, the equation structured to reflect the variables desired, and it has been determined how to handle the variables. Now diagram the approach and write the program.

NOTE: In Europe it is usual to quote annual effective rates for compound interest. These are not simple multiples of the compounding period rate of interest, but are themselves governed by the compound interest equation. For the sake of simplicity, only the U.S. method is used here.

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Programming Considerations



Investment Calculation Program



Programming Considerations

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USER INSTRUCTIONS				
Step	Procedure	Enter	Press	Display
1	Clear Program Memory and Reset Program Pointer		2nd CP	
2	Enter Learn Mode		LRN	000 00
3	Enter Investment Calculation Program			
4	Exit Learn Mode		LRN	0
5	Enter Present Value	PV	A	PV
6	Enter Annual Interest	i	B	i
7	Enter Number of Compounding Periods Per Year	c	C	c
8	Enter Number of Years	n	D	n
9	Compute Future Value		E	FV
	Variables May Be Entered In Any Order — There Is No Need to Reenter Variables That Do Not Change For New Problems			

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Programming Considerations

Location and Key Code	Key Sequence	Location and Key Code	Key Sequence
000 76	2nd Lbl	025 01	1
001 11	A	026 00	0
002 42	STO	027 00	0
003 01	1	028 55	÷
004 91	R/S	029 43	RCL
005 76	2nd Lbl	030 03	3
006 12	B	031 85	+
007 42	STO	032 01	1
008 02	2	033 95	=
009 91	R/S	034 45	y^x
010 76	2nd Lbl	035 53	(
011 13	C	036 43	RCL
012 42	STO	037 03	3
013 03	3	038 65	X
014 91	R/S	039 43	RCL
015 76	2nd Lbl	040 04	4
016 14	D	041 54)
017 42	STO	042 65	X
018 04	4	043 43	RCL
019 91	R/S	044 01	1
020 76	2nd Lbl	045 95	=
021 15	E	046 58	2nd fix
022 43	RCL	047 02	2
023 02	2	048 91	R/S
024 55	÷		

Investment Calculation Program



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Programming Considerations

Find the future value of a \$3,000 investment 5 years from now if the annual return rate is 8% compounded daily and compounded monthly.

Enter	Press	Display	Comments
3000	<input type="button" value="A"/>	3000.	PV
8	<input type="button" value="B"/>	8.	i
365	<input type="button" value="C"/>	365.	c
5	<input type="button" value="D"/>	5.	n
	<input type="button" value="E"/> *	4475.28	FV
12	<input type="button" value="C"/>	12.00	c
	<input type="button" value="E"/>	4469.54	FV

*All results from this point on are displayed with the decimal fixed at two places. Also, the TI Programmable 58C will retain the fix-decimal at two places until you change it, even if turned off.

PRICING CONTROL PROGRAM

Thus far we have used the calculator data registers primarily for storing and recalling variables. However, the calculator can add to, subtract from, multiply and divide the variables previously stored in data registers without recalling them. Using the memory in this fashion is often referred to as memory arithmetic. The value of memory arithmetic is demonstrated by the sample program below. Also note that an extremely useful program can be developed using only simple arithmetic, further emphasizing the fact that programmable calculators are ideal and easy to use in solving any type of program — not just ones involving complex mathematics.

Assume the normal purchase order received in a business is comprised of like items selling at various prices. In order to invoice the customer, multiply the quantity for each line item by its unit price to find the line item price. Then sum each line item price to determine the total order price. Additionally, to keep a record of the average unit price of each order, you must total the line item quantities and divide the sum into the total order price. This process is not difficult, but it is time consuming.

Line Item	Quantity	Unit Price	Line Item Price
1	100	\$0.25	\$ 25.00
2	200	0.15	30.00
3	50	0.35	17.50
4	150	0.40	60.00
5	300	0.10	30.00
Total Order	800		\$162.50
Order Avg. Unit Price		\$0.203125	

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Programming Considerations

A glance at the order immediately tells one to multiply, add, and divide. The key is how to organize the problem and what to instruct the calculator to do.

If you need a program that can handle an unlimited number of line items, choose another approach. First, decide how to enter your variables. In the example below the variables are entered through the display while the program is running rather than storing them in data registers to be recalled at a later point in the program. If you use memory arithmetic to calculate the cumulative totals, each set of data is used only once and does not need to be permanently stored in data registers. To save time lost by displaying intermediate data, the cumulative order quantity is stored in R_1 (data register 1 is denoted by R_1 , data register 2 by R_2 , etc.), the cumulative order price is stored in R_2 , and the current average unit price is stored in R_3 . The sample program is designed to display the line item price of a given line item after you enter the appropriate quantity and unit price; however, you may recall any of the other results whenever you need to see them.

One last note is that since the initial operations on R_1 and R_2 are to be sum instructions, the program should be equipped with an initialization routine which zeros these data registers.

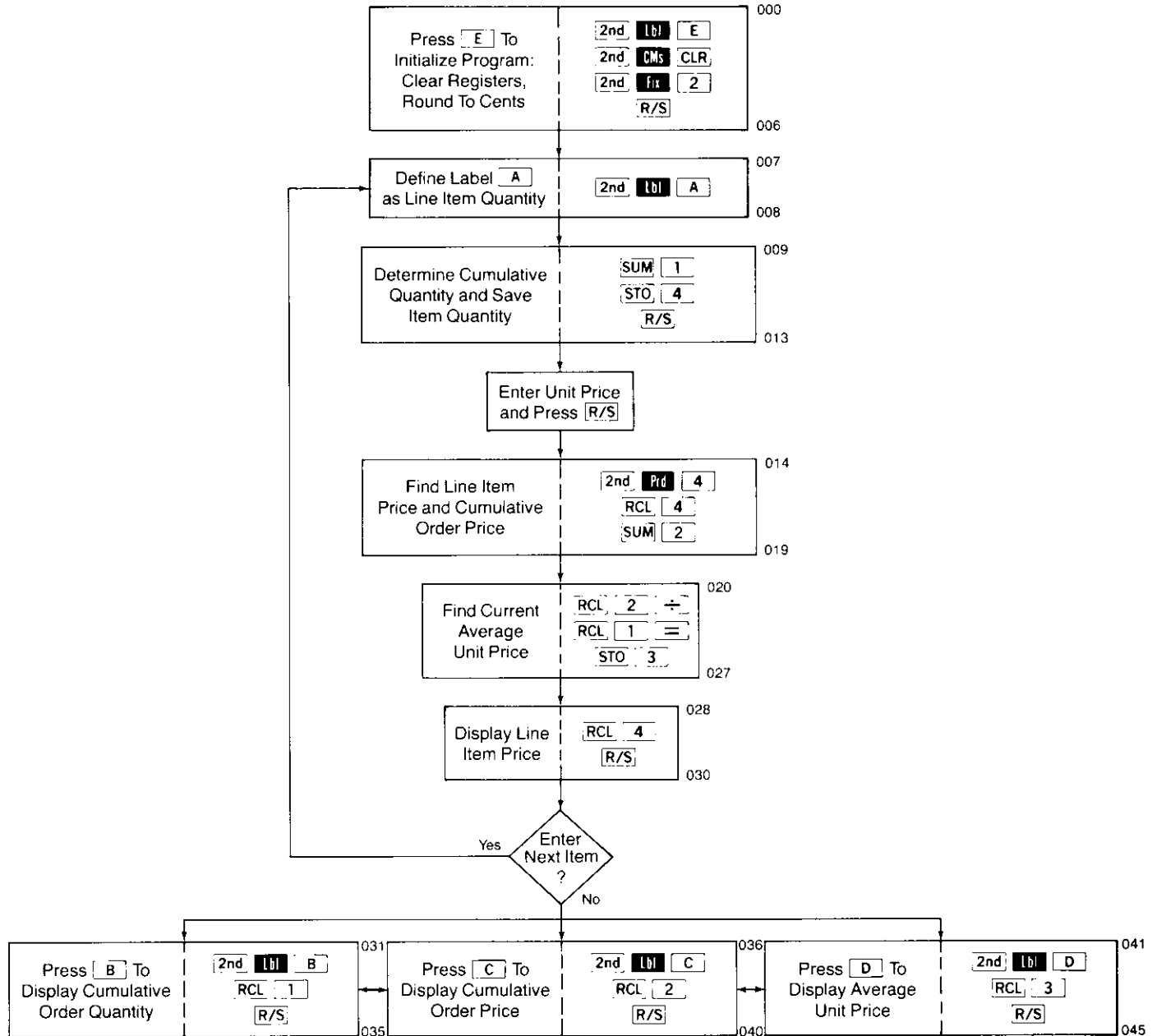
With this example, the importance of organizing the approach should be apparent. The first approach would have limited the capability of the program by fixing the number of line items that could be handled for any one order; the second approach allows an order to have an unlimited number of line items.



Programming Considerations

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Now flowchart the problem and determine the keystrokes needed in the program.



Pricing Control Program

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Programming Considerations

USER INSTRUCTIONS				
Step	Procedure	Enter	Press	Display
1	Clear Program Memory and Reset Program Pointer		2nd CP	
2	Enter Learn Mode		LRN	000 00
3	Enter Pricing Control Program			
4	Exit Learn Mode		LRN	0
5	Initialize Program		E	00.00
6	Enter Line Item Quantity	Quantity	A	Quantity
7	Enter Unit Price	Unit Price	R/S	Line Item Price
	Repeat Steps 6 and 7 for Each Line Item			
	After Each Line Item Entry the Following Variables May Be Displayed:			
	Cumulative Quantity		B	Order Quantity
	Cumulative Cost		C	Order Price
	Average Unit Price		D	Average Price



Programming Considerations

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Location and Key Code	Key Sequence	Location and Key Code	Key Sequence
000 76	2nd Lbl	024 01	1
001 15	E	025 95	=
002 47	2nd CMS	026 42	STO
003 25	CLR	027 03	3
004 58	2nd Fix	028 43	RCL
005 02	2	029 04	4
006 91	R/S	030 91	R/S
007 76	2nd Lbl	031 76	2nd Lbl
008 11	A	032 12	B
009 44	SUM	033 43	RCL
010 01	1	034 01	1
011 42	STO	035 91	R/S
012 04	4	036 76	2nd Lbl
013 91	R/S	037 13	C
014 49	2nd Prd	038 43	RCL
015 04	4	039 02	2
016 43	RCL	040 91	R/S
017 04	4	041 76	2nd Lbl
018 44	SUM	042 14	D
019 02	2	043 43	RCL
020 43	RCL	044 03	3
021 02	2	045 91	R/S
022 55	÷		
023 43	RCL		

Pricing Control Program

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Programming Considerations

Now let's run the program using the data given earlier.

Enter	Press	Display	Comments
	E	0.00	Initialize
100	A	100.00	Quantity A
.25	R/S	25.00	Unit Price A Line Item Price
200	A	200.00	Quantity B
.15	R/S	30.00	Unit Price B Line Item Price
50	A	50.00	Quantity C
.35	R/S	17.50	Unit Price C Line Item Price
150	A	150.00	Quantity D
.4	R/S	60.00	Unit Price D Line Item Price
300	A	300.00	Quantity E
.1	R/S	30.00	Unit Price E Line Item Price
	B	800.00	Total Order Quantity
	C	162.50	Total Order Price
	D	0.20	Avg. Unit Price (Rounded)
	INV 2nd fix	0.203125	Avg. Unit Price (Exact)

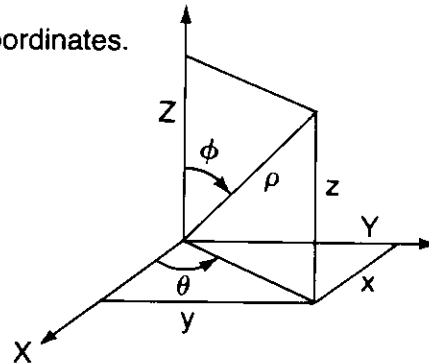


Programming Considerations

SPHERICAL COORDINATES PROGRAM

Write a program to convert from spherical to rectangular coordinates.

$$\begin{aligned}x &= \rho \sin \phi \cos \theta \\y &= \rho \sin \phi \sin \theta \\z &= \rho \cos \phi\end{aligned}$$



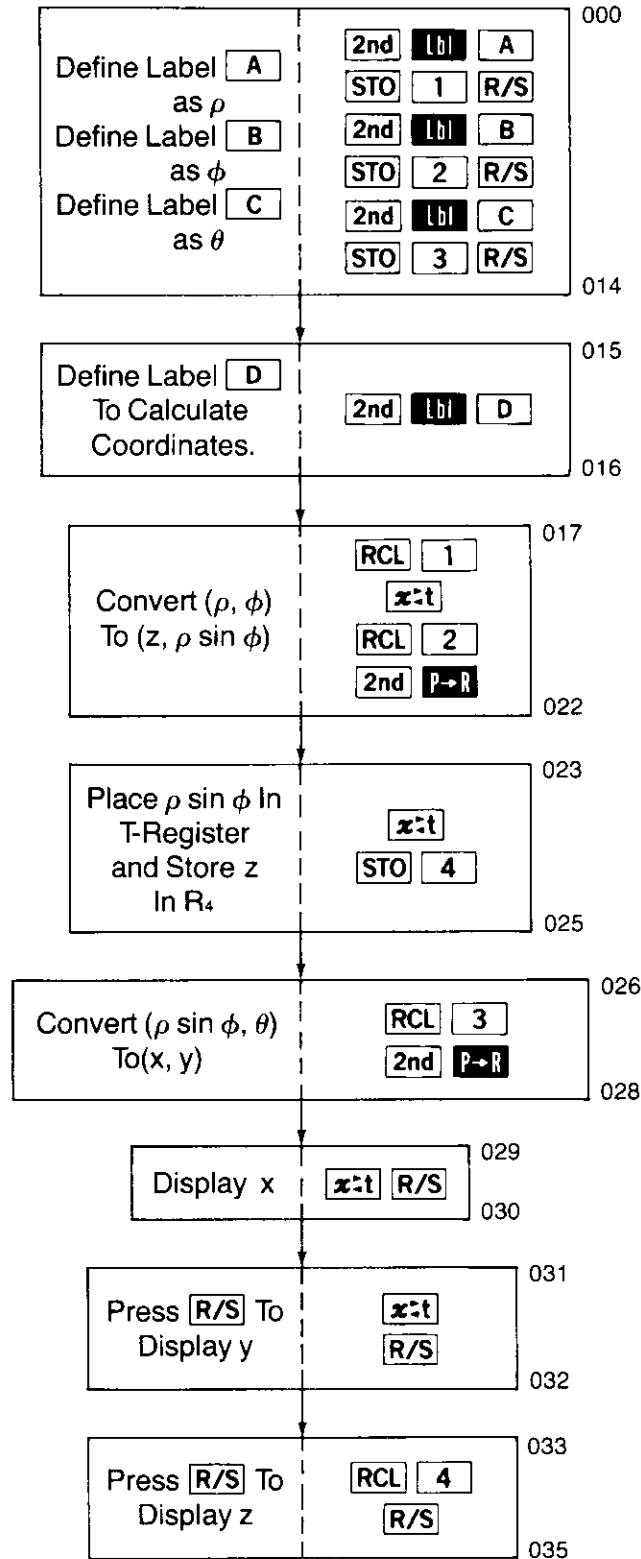
Your calculator has a built-in function, $\boxed{2nd} \boxed{P \rightarrow R}$ that is preprogrammed to convert from polar to rectangular coordinates. (See *Conversions* in Section V.) This function could be very useful here.

The easiest way to enter the spherical coordinates is to simply store ρ , ϕ , and θ in data registers R_1 , R_2 , and R_3 respectively. Instructing the calculator to place ρ in the T-register and ϕ in the display register, allows z to be found by converting to rectangular coordinates using $\boxed{2nd} \boxed{P \rightarrow R}$. This conversion places $\rho \sin \phi$ in the display register and $\rho \cos \theta (=z)$ in the T-register. Storing Z in R_4 for safekeeping and placing $\rho \sin \phi$ in the T-register, it is possible to use this conversion again to find x and y after recalling θ to the display register. The program should be designed so as to display x , y , and z in the given order by using the $\boxed{R/S}$ key.

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Programming Considerations



Spherical Coordinates Program



USER INSTRUCTIONS				
Step	Procedure	Enter	Press	Display
1	Clear Program Memory and Reset Program Pointer		2nd CP	
2	Enter Learn Mode		LRN	000 00
3	Enter Program			
4	Exit Learn Mode		LRN	
5	Enter ρ	ρ	A	ρ
6	Enter ϕ	ϕ	B	ϕ
7	Enter θ	θ	C	θ
8A	Compute Coordinates and Display x		D	x
8B	Display y		R/S	y
8C	Display z		R/S	z

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Programming Considerations

Location and Key Code	Key Sequence	Location and Key Code	Key Sequence
000 76	2nd Lbl	019 32	x\rightarrowt
001 11	A	020 43	RCL
002 42	STO	021 02	2
003 01	1	022 37	2nd P\rightarrowR
004 91	R/S	023 32	x\rightarrowt
005 76	2nd Lbl	024 42	STO
006 12	B	025 04	4
007 42	STO	026 43	RCL
008 02	2	027 03	3
009 91	R/S	028 37	2nd P\rightarrowR
010 76	2nd Lbl	029 32	x\rightarrowt
011 13	C	030 91	R/S
012 42	STO	031 32	x\rightarrowt
013 03	3	032 91	R/S
014 91	R/S	033 43	RCL
015 76	2nd Lbl	034 04	4
016 14	D	035 91	R/S
017 43	RCL		
018 01	1		

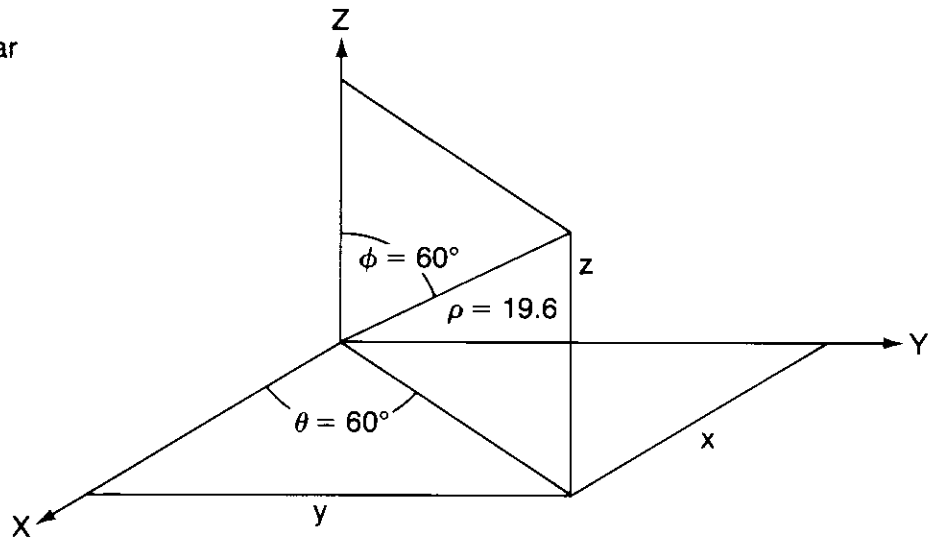
Spherical Coordinates Program



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Programming Considerations

Example: Convert $\rho = 19.6$,
 $\phi = 60^\circ$, $\theta = 60^\circ$ to rectangular
coordinates.



Enter	Press	Display	Comments
	2nd Deg		Place calculator in degree mode.
19.6	A	19.6	ρ
60	B	60	ϕ
60	C	60	θ
	D	8.487048957	x
	R/S	14.7	y
	R/S	9.8	z



ADVANCED PROGRAMMING

More About Labels

As you remember, the user-defined keys (A-E, A'-E') are designed for use as labels. Once a program segment is labeled with one of these keys, pressing it from the keyboard sends the program pointer to that part of the program and the program starts immediately.

In addition to the user-defined keys, you can use almost any first or second function on the calculator as a label. For instance, **2nd** **Sin**, **x²**, **=**, **CLR**, **2nd** **Pgm**, **EE**, **2nd** **Fix** and others can be labels. These are called *Common Labels*. Only the following keys *cannot* be used as labels.

2nd **SST**
Ins **LRN** **BST**
Del **Ind** **numbers** **0** - **9**

The only difference between the common labels and the user-defined labels is that pressing a common label from the keyboard cannot start program execution. Even though you have a program segment labeled x^2 , for example, pressing **x²** from the keyboard simply squares the displayed value. The keyboard sequence **GTO** **x²** **R/S** does cause the program to start running at label x^2 . Nonetheless, you now have over 60 more labels to work with.

Common labels can be used anywhere in a program as can the user-defined labels. However, you must not split obvious instruction clusters like **STO** **12** or **2nd** **Fix** **6** or **INV** **2nd** **Sin**. Throughout the remainder of this section we'll primarily discuss user-defined keys as labels because of their versatility.

Transfer Instructions

There are several important instructions that further increase the programming capabilities of your calculator. They allow you extra flexibility of control over the order in which your program instructions are executed. These new program controls are called *Transfer Instructions* or just simply *transfers*. They can divert the normal "top" flow of a program by jumping to some other location. Basically there are two types of transfers, termed *unconditional* and *conditional*.

Unconditional transfer instructions immediately branch to wherever the program asks, unconditionally. Unconditional transfers are independent of all calculations. A conditional transfer instruction on the other hand tests some value and transfers to a location other than the one next in line if that value fulfills the conditions of the test.



Unconditional Transfers

RST , **GTO** and **SBR** are called unconditional transfer instructions. **RST** automatically positions the program pointer at location 000. **GTO** and **SBR** unconditionally place the pointer at the location *you* specify. Note also that **RST** performs additional functions that you should be aware of. (See *Basic Program Control Functions* on page V-43.)

THE GO TO INSTRUCTION — **GTO**

Back in *Editing Programs* you learned how to use the Go To instruction from the keyboard. It's just the same when running a program, **GTO** followed by an absolute address or a label causes the program pointer to go immediately to that location. Processing continues at the new location.

Short form addressing can be used with absolute addresses (program memory addresses). In the learn mode, for example, pressing **GTO** 9 is the same as **GTO** 009 *if and only if the next keystroke is not a number*. Key in the following little program that counts.

Press	Display	Comments
CLR 2nd CP	0.	Prepare for program
GTO 9 LRN	009 00	Go To location 009 and enter learn mode
+	010 00	Key in program
1	011 00	
=	012 00	
2nd Pause	013 00	
GTO	014 00	
9	014 00	Location number did not advance, waiting for rest of address
LRN	0.	Exit learn mode
LRN	016 00	Program pointer advanced when first LRN signaled the end of the incoming address

To run this program, exit the learn mode and press **GTO** 9 **R/S** .

In program memory, absolute addresses are stored in two program locations. For example, the sequence **GTO** 136 occupies 3 program locations. The first location contains the **GTO** instruction while the address is stored in the next two. The hundreds digit of the address goes into the first of these locations and the last two digits are merged to occupy the next. The resulting key code sequence is 61 01 36 in program memory. This compact way of doing things is called "merging" and is completely automatic within the calculator.

IV



Programming Considerations

Try the following exercise on your calculator.

Press	Display	Comments
2nd CP CLR	0.	Clear program memory and display
GTO 136	0.	Sends the program pointer to location 136
LRN	136 00	
R/S	137 00	Store R/S in location 136
LRN RST LRN	000 00	Return to 000
GTO	001 00	Store GTO in 000
1	001 00	
3	001 00	
6	003 00	Memory waits for all 3 digits before storing address
BST	002 36	
BST	001 01	Address stored as explained
BST	000 61	
LRN	0.	
R/S	0.	Execute program
LRN	137 00	Transfer is instantly made to location 136 where the R/S stored there is executed, leaving the program pointer at location 137.

The same thing would work for a label. Pressing **GTO** **x²**, for example, from the keyboard sends the program pointer to label x^2 and awaits further instructions. If you ask the calculator to find a label that doesn't exist, the display flashes its current value.

You can see here how the Go To instruction works when used from the keyboard or in a program. The other transfers operate much the same way. As soon as they are pressed from the keyboard or encountered in a program, they transfer to the requested program location.



SUBROUTINES

As you begin writing more and more programs, you'll often find sequences of calculations that are performed repeatedly. These are called *Subroutines*. Subroutines give you the capability to define a "subprocess" or sequence of keystrokes that have a unique purpose. These you can label and reference at any time from anywhere in your program almost as easily as if a key on the keyboard was devoted to it. Once a subroutine has completed its purpose, the program pointer repositions itself to the first program location following the point where you began using it. When you use a subroutine — it is often said that you "call" it — you are telling the machine to run a whole sequence of steps with a single subroutine instruction.

It's a good programming practice to write your programs so that they can be used as subroutines. Now, they can be used by other programs without having to be modified. You may do this by simply using **INV** **SBR** to halt program execution instead of **R/S**. The remaining programs in this section are written using this technique.

THE SUBROUTINE INSTRUCTION — **SBR**

The subroutine instruction is a Go To that has been modified in two ways — from the keyboard, it can start program execution and in a program, it remembers where it transferred from. From the keyboard, pressing **SBR** 136 sends the program pointer instantly to location 136 and program execution automatically starts at that point. It is exactly the same as pressing **GTO** 136 **R/S**. The same thing happens when you press **SBR** **x²**, the program starts running at label **x²**, wherever it may be.

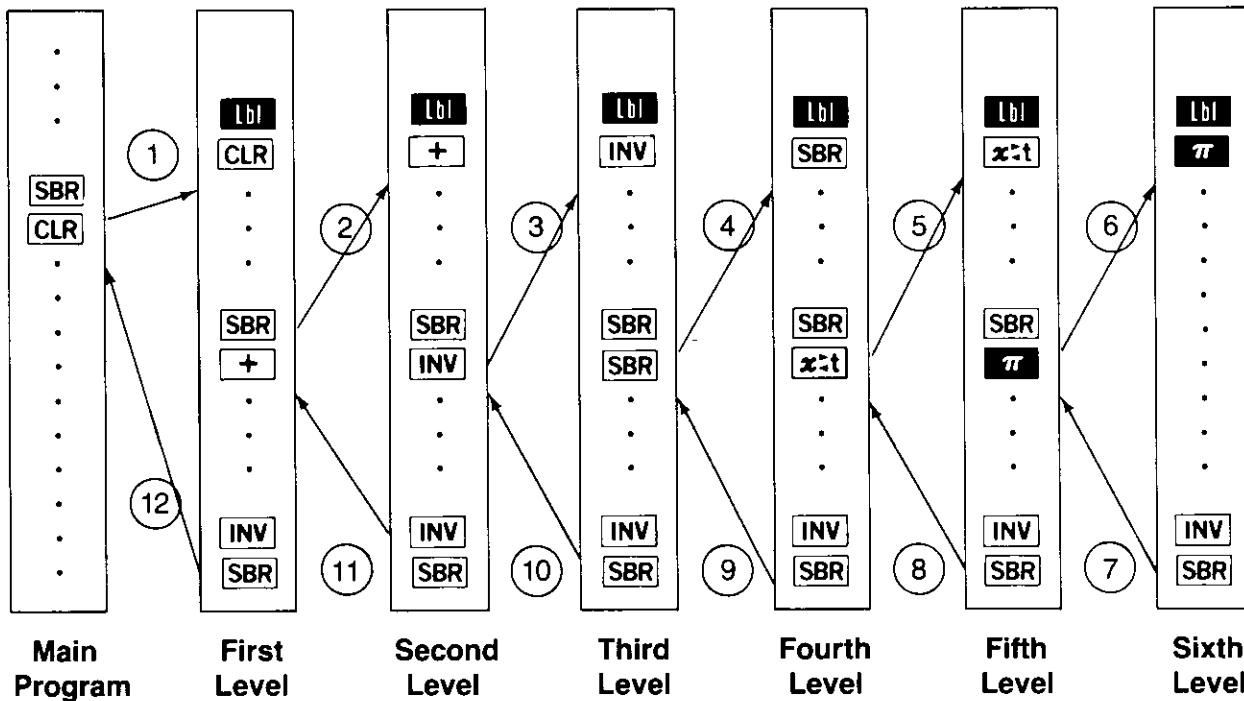
If **SBR** 136 had been keyed into locations 000-002 as **GTO** 136 was in the previous example, it would have been executed the same way. But, when executed, program location 003 is stored in the *Subroutine Return Register*. Now, if there is a calculation sequence beginning at 136 that you have ended with **INV** **SBR**, processing would look at the subroutine return register, find 003, and bounce back to location 003 where processing continues. To get processing to go back where it came from, simply end the subroutine with **INV** **SBR**. What actually has happened is that you have transferred to a subroutine at 136 and return is automatic when the **INV** **SBR** instruction is encountered.

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Programming Considerations

Actually, as many as six return addresses can be stored in the subroutine return register at any one time. This means that a subroutine can contain and use or “call” a subroutine that can also call a subroutine, etc., — up to six times. This tremendous capability is shown graphically.



If the sequence of steps shown above was written as part of a program, processing would flow as numbered above. Note that **INV SBR** ends each subroutine, instructing the calculator to go to the subroutine return register and retrieve the address that was stored last and transfer there. Processing usually ends up back in the *main program* — the one that started calling subroutines. By the way, **INV SBR** is merged in program memory to occupy only one location as key code 92. This code doesn't match the row/column key designations.

When a program part is labeled with a user-defined key, that part can be executed from the keyboard simply by pressing the applicable label as we have seen. The same thing happens when one of these keys is encountered in a program — the program pointer goes to that label and processing continues. These user-defined keys have an automatic **SBR** instruction built in. So, if you label a program part with a user-defined key and end it with **INV SBR**, that part is processed just as though you had called it with the **SBR** instruction.



Programming Considerations

ACCESSING OR CALLING SUBROUTINES

To clarify the definition, a subroutine is a segment of a program designed for a specific purpose — to be written once, but used repeatedly. All subroutines must end with **INV** **SBR** to instruct processing to return to the sequence that called it.

There are three methods of calling subroutines.

- Absolute address, **SBR** **136**
- Common label, **SBR** **x²**
- User-defined label, **A**

Labeling subroutines adds clarity and simplicity to the program instructions. A label descriptive of the purpose of the subroutine can even be used. You should choose your labels well and record the meaning of each. Labeled subroutines can be placed anywhere in program memory because, when called, a label can be found regardless of where it is. Also, a subroutine that is labeled is not affected by insert and delete instructions that are performed ahead of the subroutine in program memory.

To have a program evaluate $x^2 + 3x$ for incoming x values, simply key in the following.

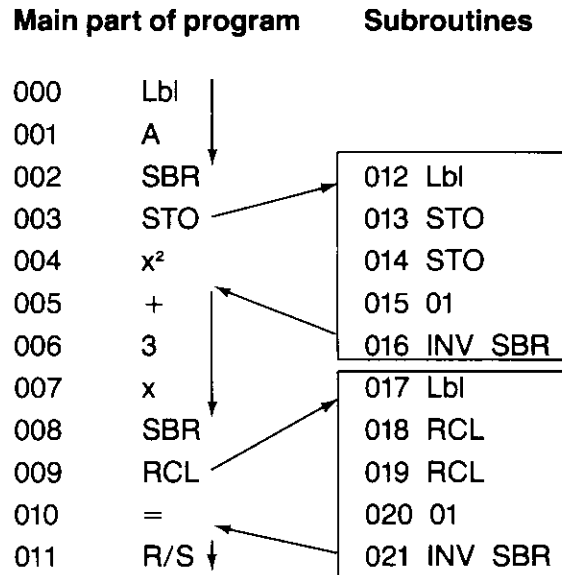
STO
1
x²
+
3
X
RCL
1
=
R/S

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Programming Considerations

For demonstration, let's let subroutines do our storing and recalling. The program looks like this.



Enter any x value and press **A**. The sequence of processing is charted by the arrows. Note that a user-defined label is used to start the program because that's the easiest way to do it. The subroutine names were chosen to identify their respective segments, but other labels could have been used just as well.

THINGS TO WATCH OUT FOR IN SUBROUTINES

Two instructions that should be used very carefully in subroutines are Reset **RST** and Equals **=**. Also you need to be sure that the subroutine return register is cleared before the start of a new problem.

The reset instruction, among its other functions, automatically clears the subroutine return register. If you do need to transfer to location 000 (the primary function of **RST**) in a subroutine, use **GTO 000** or a label if there is one at 000.

The equals instruction completes *all* pending operations. If used in a subroutine, the pending operations not only of the subroutine, but those of the main program are completed as well.



Programming Considerations

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Consider the following program segment to evaluate $4 + (1 + 2) \times 3$.

```
4
+
SBR x²
X
3
=
R/S
2nd Lbl x²
1
+
2
=
INV SBR
```

The equals here in subroutine x^2 not only completes $1 + 2$, but also the $4 +$ before returning to the $\times 3$. The resulting answer is now 21 where it should be 13.

This program can be easily modified to correctly handle the problem by using parentheses to evaluate the subroutine.

```
4
+
SBR x²
X
3
=
R/S
2nd Lbl x²
(
1
+
2
)
INV SBR
```

This sequence yields the correct answer, 13.

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Programming Considerations

Beginning each subroutine with $($ and placing $)$ right before the INV SBR are a good habit to develop. It takes an extra keystroke as opposed to using $=$, but can save you much misery down the road, the primary advantage being that parentheses affect no pending operations other than those contained within that parenthesis set.

Avoiding the equals $=$ instruction in such cases should impose no hardship as parentheses are designed to selectively complete expressions like this. However, there are some things you need to know to use the current display register value in the subroutine.

Whenever a subroutine requires repeated access to the display register contents at the time of the call, you should store the variable in a data register prior to performing calculations and recall it whenever it is needed. If the contents of the display register are needed only to begin computation, the CE key may be used as a trick to pull this value inside the parentheses. This trick works the same in a program as it does from the keyboard.

Press: 2.18 \times $($ CE $+$ 6 $)$ $=$

Display: 17.8324

In the above sequence the CE key pulls 2.18 inside the parentheses and enables the calculator to evaluate $2.18 \times (2.18 + 6) = 17.8324$.

Occasionally you may design a program so that completion of a program occurs inside a subroutine. In other words, the answer to your problem is found without returning control to the calling routine. In such situations return of control remains pending as the subroutine return register has not been cleared. Unless you turn the calculator off, use RST , or clear the return register using the 2nd CP instruction, difficulties may arise when you run a new problem, as erroneous transfers to the previous return addresses may result. To prevent such left-over return addresses from ruining future solutions, you should use the RST instruction to clear the subroutine return register. You may do this manually, but it is preferable, whenever possible, to include RST at a proper point in the program.



LIBRARY PROGRAMS AS SUBROUTINES

You may often find it quite useful to extend the power of a program you write through effective use of library programs. The same instructions used to access these programs from the keyboard can be built right into your program. The library programs simply become subroutines of your program in program memory. Thousands of instructions worth of subroutines are stored in each of the library modules. Each program of a library is a subroutine. Most do not use $\boxed{=}$, $\boxed{R/S}$ or \boxed{RST} , are evaluated with parentheses and end in \boxed{INV} \boxed{SBR} .

From the keyboard, pressing $\boxed{2nd}$ \boxed{Pgm} \boxed{mm} relocates the program pointer to the library program numbered mm . Upon completion of a library program segment, the program pointer remains in that program.

In a program, the function of \boxed{Pgm} is similar to that of the \boxed{SBR} instruction. The only difference is that $\boxed{2nd}$ \boxed{Pgm} \boxed{mm} tells the calculator to look for the subroutine in library program mm rather than in program memory of the calculator itself. Once the library routine is completed, the program pointer returns to the point of call in program memory and normal processing continues. The two-digit program number is merged and stored in a single program location.

If a segment of a library routine is identified by a user-defined key such as \boxed{A} , the program sequence required to execute that routine is $\boxed{2nd}$ \boxed{Pgm} \boxed{mm} \boxed{A} . If a label such as \boxed{tan} is used, the sequence becomes $\boxed{2nd}$ \boxed{Pgm} \boxed{mm} \boxed{SBR} $\boxed{2nd}$ \boxed{tan} . Note that following $\boxed{2nd}$ \boxed{Pgm} \boxed{mm} with anything other than \boxed{SBR} or a user-defined key is not a valid key sequence and can produce unwanted results.

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Programming Considerations

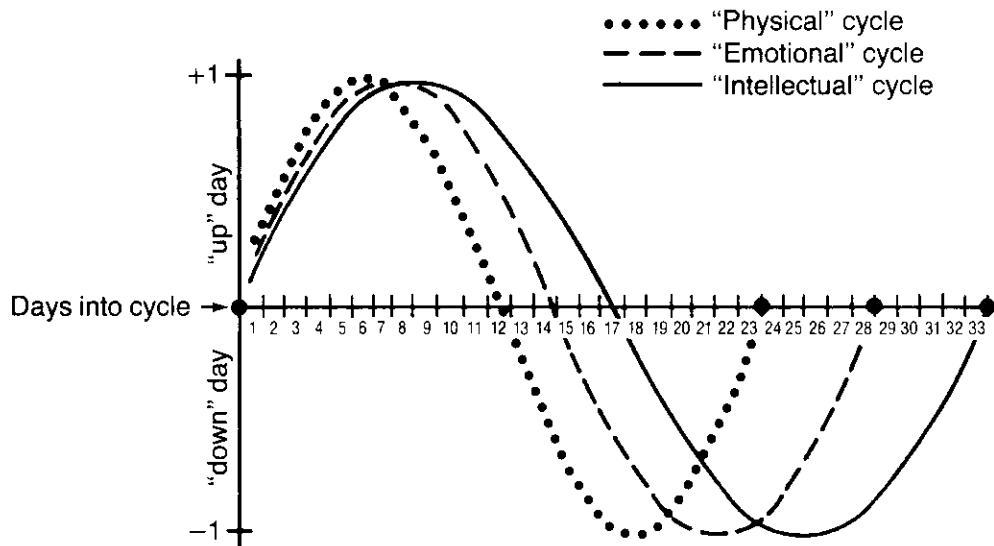
BIORHYTHM PROGRAM

Let's examine an illustrative example of subroutines in action in an interesting program situation.

The theory of biorhythms states that there are three cycles to your life that started on the day you were born:

1. The Physical cycle — 23 days long
2. The Emotional cycle — 28 days long
3. The Intellectual cycle — 33 days long.

The first half of each cycle is said to contain your "up days" while the lower half represents "down days."



The amplitudes of these biorhythm cycles on a given day may be expressed as a value between -1 and 1 using the following equation.

$$\text{Amplitude} = \sin \left(360 \times \frac{\text{Number of Days Since Birth}}{\text{Number of Days in Cycle}} \right)$$

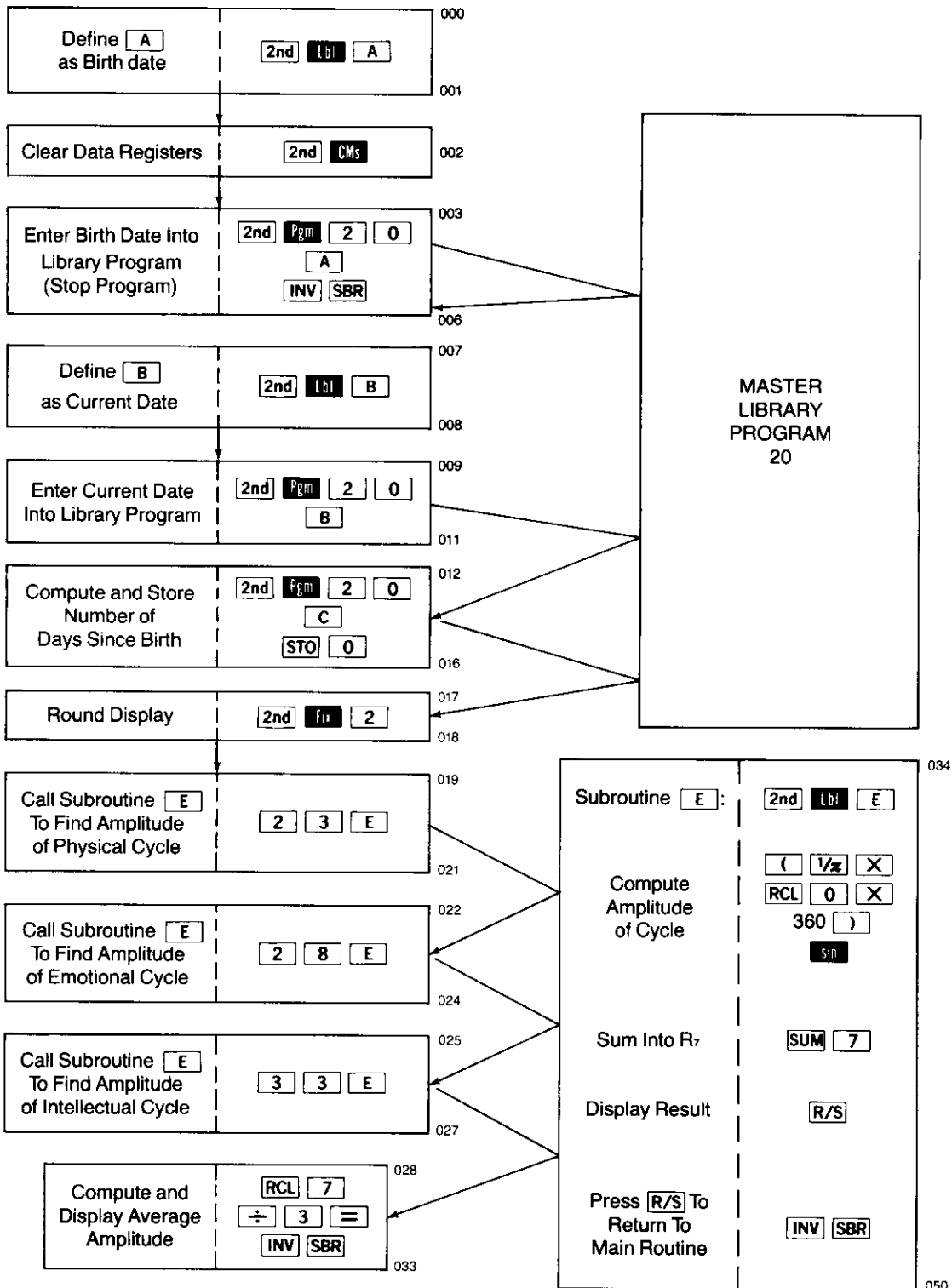
Now let's write a program designed to determine the amplitudes of a person's biorhythmic cycles. Since each cycle uses the same equation, a subroutine may be used to simplify your program. Also you can use program 20 of the Master Library as a subroutine to compute the number of days since birth.

In the sample program below, the amplitude of each cycle is computed using the subroutine labeled **E** since the only difference between calculations is the number of days in the cycles. We can use **R/S** to stop the program and display the amplitudes of the physical, emotional, and intellectual cycles in that order. **INV** **SBR** is not used here because it would return program control to the main program rather than stop execution (see *The Subroutine Instruction* — **SBR** a few pages back). The final result of the program is the average of these three values. All results are rounded to two decimal places for display.



Programming Considerations

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Biorhythm Program

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Programming Considerations

Location and Key Code	Key Sequence	Location and Key Code	Key Sequence
000 76	2nd Lbl	027 15	E
001 11	A	028 43	RCL
002 47	2nd CMs	029 07	7
003 36	2nd Pgm	030 55	÷
004 20	2 0	031 03	3
005 11	A	032 95	=
006 92	INV SBR	033 92	INV SBR
007 76	2nd Lbl	034 76	2nd Lbl
008 12	B	035 15	E
009 36	2nd Pgm	036 53	(
010 20	2 0	037 35	1/x
011 12	B	038 65	X
012 36	2nd Pgm	039 43	RCL
013 20	2 0	040 00	0
014 13	C	041 65	X
015 42	STO	042 03	3
016 00	0	043 06	6
017 58	2nd Fix	044 00	0
018 02	2	045 54)
019 02	2	046 38	2nd Sin
020 03	3	047 44	SUM
021 15	E	048 07	7
022 02	2	049 91	R/S
023 08	8	050 92	INV SBR
024 15	E		
025 03	3		
026 03	3		

Biorhythm Program



Programming Considerations

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USER INSTRUCTIONS				
Step	Procedure	Enter	Press	Display
1	Clear Program Memory and Reset Program Pointer		2nd CP	
2	Enter Learn Mode		LRN	000 00
3	Enter Biorhythm Program			
4	Exit Learn Mode		LRN	
5	Enter Birth Date	MMDD.YYYY	A	0.
6	Enter Current Date and Compute Amplitude of Physical Cycle	MMDD.YYYY	B	Amplitude of Physical Cycle
7	Compute Amplitude of Emotional Cycle		R/S	Amplitude of Emotional Cycle
8	Compute Amplitude of Intellectual Cycle		R/S	Amplitude of Intellectual Cycle
9	Compute Average Amplitude		R/S	Average Amplitude

Example: Fred was born on May 2, 1944. Calculate his biorhythm for March 1, 1977. (Assume the Biorhythm program is still in program memory.)

Press	Display	Comments
502.1944 A	0.	Enter birth date
301.1977 B	0.82	Amplitude of physical cycle
R/S	1.00	Amplitude of emotional cycle
R/S	0.76	Amplitude of intellectual cycle
R/S	0.86	Average amplitude

Fred seems to be in pretty good shape for whatever he attempts to do. Use this program to determine where you are in your biorhythmic cycles.

When using library programs as subroutines in your own program, be extra careful as to which data registers you use and which ones are used by the library program. If you both attempt to use the same data registers for different purposes, program results can be erroneous.



Conditional Transfers (Decision Makers)

Other features that are very useful in problem solving, are instructions that are capable of making decisions in your programs. A family of what are called *conditional transfer instructions* make this decision-making process possible. Each time one of them is encountered in a program, it makes some test and decides whether to transfer or not — strictly dependent upon the outcome of the test.

There are three types of conditional transfer instructions, differentiated by *what* they test.

1. Compare display register contents to T-register **x=t** , **x≠t**
2. Test contents of data registers 0-9 **Dsz**
3. Test status of program flags **flg**

A transfer address follows each of these instructions. When the answer to the test is “yes” (test positive), transfer is made to that address. If the answer to test is “no” (test negative), the transfer is skipped. For instance, if the test **2nd** **x=t** **A** is positive, transfer is made to **A** just as if **GTO** **A** had been encountered. If x is not exactly equal the T-register value, no transfer takes place.

DISPLAY REGISTER VS T-REGISTER

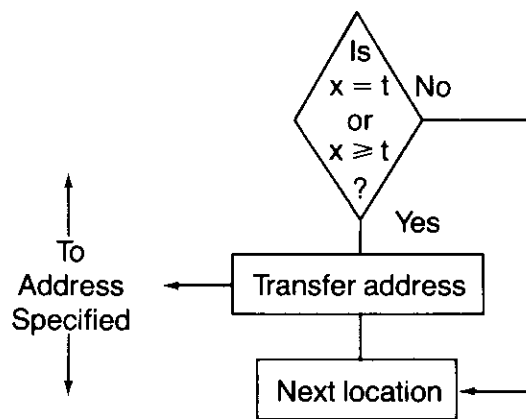
What is this *T-register*? Well, T stands for “TEST” and the register itself is a data memory type of register where numbers can be stored and recalled and compared against the displayed number. The key that gets numbers into and out of the T-register is the “x exchange t” **x:t** key. This key simply swaps whatever is in the display register, call it x, with t, the contents of the T-register. Initially, 0 is in the T-register. Key 5 into the machine and press **x:t**. Zero is now in the display and your 5 is in the T-register. Press **x:t** again and the 5 returns to the display while the zero goes back into the T-register. That’s all this key does.



Programming Considerations

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Several instructions are available to compare the current display register value with the contents of the T-register. These "test" instructions are "x equal to t" $x=t$ and "x greater than or equal to t" $x \geq t$. A program memory address, either absolute or label, must follow each of these instructions whenever they are used. When a test is made, for instance, "Does $x = t$?" and the answer is "yes," a transfer is made to the address following the test instruction. If not, the address is ignored and processing continues as though no test had even been made. Graphically, here's what happens.



These instructions are designed for use within a program to direct the flow of processing, but they can be used from the keyboard as well. Try these few keystrokes.

Press	Display	Comments
5 $x=t$	0.	Put 5 into the T-register
6 2^{nd} $x \geq t$ 123	6.	Place 6 in the display and tell the calculator to go to program location 123 if $x \geq t$
LRN	123 00	Sure enough transfer was made because 6 is greater than 5
LRN 4 2^{nd} $x \geq t$ 111	4.	Back to keyboard control and test for $x = 4$
LRN	123 00	Still location 123, no transfer was made because 4 is not greater than 5
LRN 5 2^{nd} $x \geq t$ 111	5.	Back to keyboard control and test for $x = 5$
LRN	111 00	Now we've transferred because the display equals the T-register value 5.

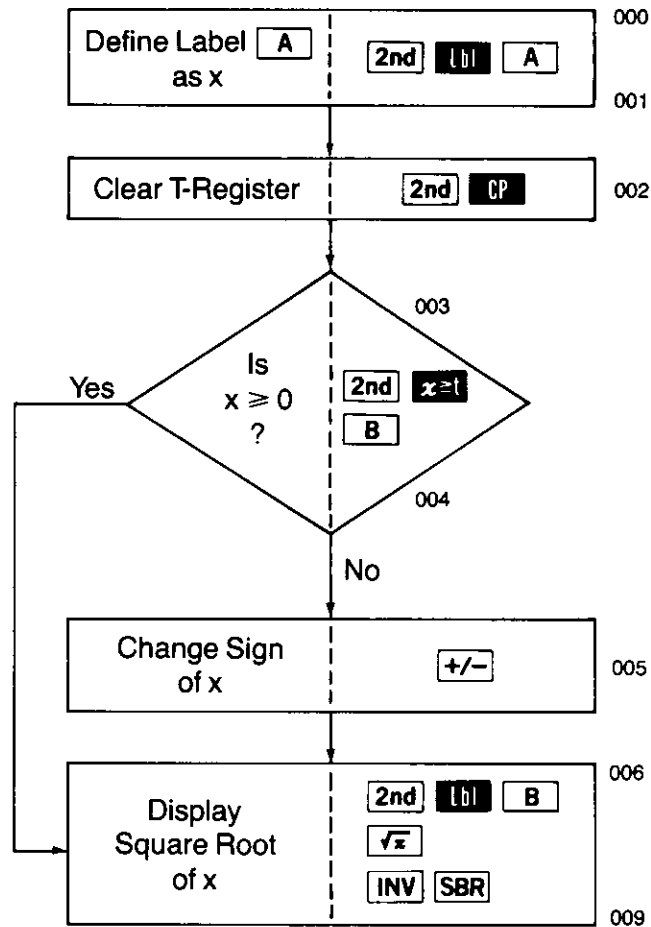
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Programming Considerations

SQUARE ROOT EXAMPLE

Problem: Find the square root of any number x , entered into the display. If the number is negative, change its sign, then take the square root.





Programming Considerations

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Location and Key Code	Key Sequence
000 76	2nd b
001 11	A
002 29	2nd CP
003 77	2nd x≥t
004 12	B
005 94	+/-
006 76	2nd |b|
007 12	B
008 34	√x
009 92	INV SBR

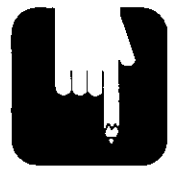
Now you can exercise the program. Enter 4, for example, and press **A**. 2 is the result. Enter -4 and press **A** and you get the same thing, 2.

These test instructions can also be used with **INV** to reverse the conditions of the transfer as shown below.

Instruction Sequence	Question Asked (Test Made)
2nd x=t	Is the display register value exactly equal to the T-register value?
INV 2nd x=t	Is the display register value unequal to the T-register value?
2nd x≥t	Is the display register value greater than or equal to the T-register value?
INV 2nd x≥t	Is the display register value less than the T-register value?

When the answer is "yes" to any of the above questions, the flow of processing transfers to the address that immediately follows the instruction. If the answer is "no," processing simply ignores the accompanying address and goes to the next location of program memory.

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Programming Considerations

FLAG OPERATION

What is a program flag and how can it be used in a program? A flag is an internal switch that is either "ON" or "OFF." (Figuratively speaking, a program flag is either raised or lowered.) A flag can be turned on (or set) at some point in a program and tested at a later time. This raising, lowering and testing of flags is independent of the display register and data memory.

Now, when would you want to use a flag? Flags have numerous uses, three are listed below.

- Controlling program options manually from the keyboard before running a program
- Program conditions set a flag for later testing
- Keeping track of execution history — which path through the program has led to the present point?

Actually, there are 10 individual flags, numbered 0-9, that you can use. Consequently, with each flag instruction you must specify to which flag you're referring.

The instructions that control flags are defined below.

- To set flag y, press **2nd** **St flg y**
- To reset flag y, press **INV** **2nd** **St flg y**
- To test flag y and transfer if it is set, press **2nd** **If flg y**, then complete the instruction with a transfer address just like the test instructions, mentioned earlier.
- To test flag y and transfer if it is not set, press **INV** **2nd** **If flg y**, followed by a transfer address.



Programming Considerations

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These instructions operate from the keyboard as well as in a program. Key in the following and observe the effect of flags.

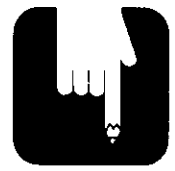
Press	Display	Comments
2nd CP	0.	Clear program memory and display. This instruction also resets or turns off all program flags and clears the T-register.
2nd St flg 4	0.	Set flag number 4
2nd If flg 4 136	0.	Test flag 4, if set, go to location 136
LRN	136 00	Transferred to 136 because flag is set
LRN 2nd If flg 5 111	0.	Test flag 5, if set, go to location 111
LRN	136 00	Did not transfer because flag is not set
LRN INV 2nd St flg 4	0.	Reset flag 4
2nd If flg 4 222	0.	Test flag 4, if set, go to location 222
LRN	136 00	Flag is not set, so no transfer is made
LRN INV 2nd If flg 4 222	0.	Test "If flag is not set — transfer to 222"
LRN	222 00	Flag not set, so transfer to 222 is performed.

The Flag test instruction behaves similar to the T-register tests. The difference is that these instructions test flags and the T-register tests compare the display to the T-register. Remember that the transfer address following this instruction can be an absolute address as was used in the exercise above or can be a label of either type (user-defined or common).

Setting a flag that has already been set, resetting a flag that has already been reset, and the testing of a flag have no affect on the status of the flag nor do they affect calculations. All flags can be reset at once with **RST** or **2nd** **CP** .

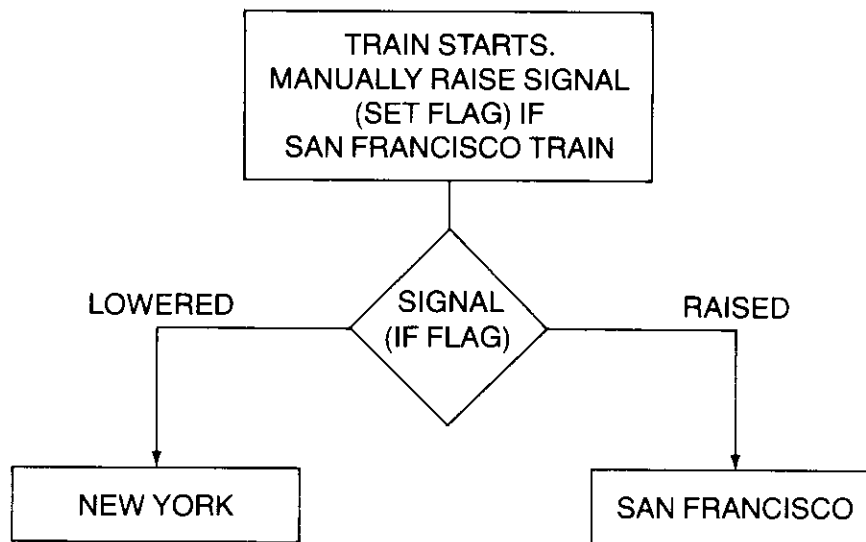
Also, note that you cannot directly see if a flag is set (on) or reset (off) in the display (as you can with the T-register or any other data memory). You can only "see" it by testing it.

IV



Programming Considerations

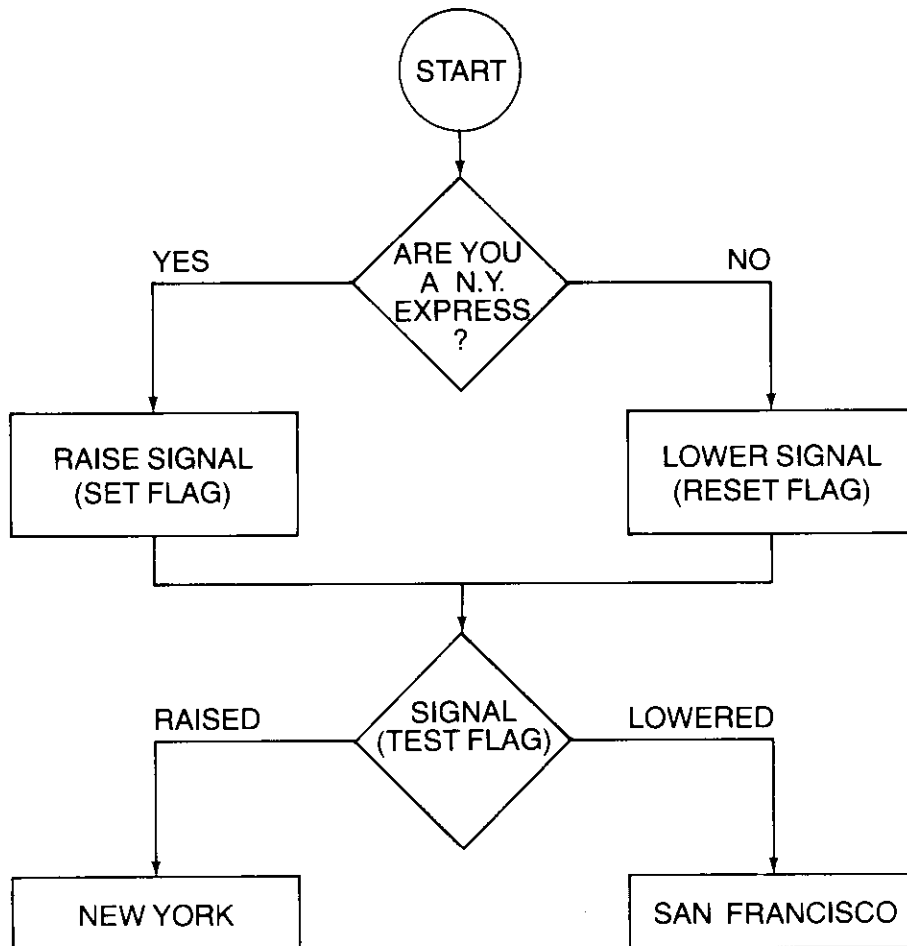
The following situation illustrates the first of the three uses mentioned for flags, how they can be used manually from the keyboard. Suppose you are a train dispatcher in a switch tower. A train is going down the track. It encounters a signal at a junction. If the signal is raised, the train is switched to the San Francisco track. If the signal is lowered, the train is transferred to the New York track. As a dispatcher, you must raise or lower the signal which, in turn, controls which track the train takes. Likewise, you can manually set and reset flags to determine which part of a program is to be executed.



Manual (Keyboard) Flag Operation

When working with a program, you can set flags manually from the keyboard to control program operation. For instance, you may have a cost control program in the calculator and a series of credits and debits to be digested by your program. Since debits are to be handled differently than credits, set a flag for the debits and the program should be designed to check the flag and process the incoming entries accordingly.

Now, let's modify the train example to show how the trains themselves could raise and lower flags. This situation demonstrates the principle of program conditions setting flags. Let's say that the New York and San Francisco expresses are to be specially routed to their destinations.



Automatic (Program) Flag Operation

The routing system asks each train: "Are you a New York express?" If the answer is "yes," a flag is raised. If the answer is "no," the flag is lowered. This flag is checked later for routing — if it is raised, the train is shunted to New York; if the flag is lowered, it is sent to San Francisco. Similarly, in a program, the most recently calculated value can be asked "Are you negative?" or "Are you greater than 1000?" or many other questions. If the answer is "yes," set a flag and test it later when you need to choose processing options.

The third use of flags gives the program a means of remembering how it reached a given point. This is necessary in situations where what you wish to do depends on which path your program has taken. You recall that the program pointer only knows where it is and has no recollection of how it got there. Such recollective ability is sometimes needed, however, and the program flags provide a convenient way to do this. Just place `2nd St flg y` in one path and `INV 2nd St flg y` in the other path. It is not wise to leave this other path blank as future runs of the program could cause errors if the flag is not reset. Then you can easily determine which path has been followed with `2nd If flg y`. For instance, a flag can tell you which of two possible interest rates was applied in a program or if a number's sign has to be changed before it can be operated on or lots of other choices.

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Programming Considerations

SPECIAL FUNCTIONS OF FLAGS

Some flags are internally programmed to perform special functions as follows.

- Flag 7** **2nd** **Op** **18** instructs the calculator to set flag 7 if no error condition exists. Flag 7 is set by the sequence **2nd** **Op** **19** if an error condition does exist. (See *SPECIAL CONTROL OPERATIONS* on page V-27.) For the TI Programmable 58C only, **2nd** **Op** **40** instructs the calculator to set flag 7 if the PC-100A or PC-100C printer is attached.
- Flag 8** Setting flag 8 causes the calculator to stop a program if an error occurs while a program is running.
- Flag 9** If you are using your calculator with the optional printer, you may control the trace mode of the printer with flag 9. If flag 9 is set, the printer is placed in the trace mode and calculated results are printed after each new function or operation. If flag 9 is reset, then results are printed only by a print instruction. Flag 9 may be used normally if you are not using the optional printer.

METRIC CONVERSION PROGRAM

Create a program that converts meters to feet and kilometers to miles. Now obviously there are quite a few ways to approach this problem. The method used below converts the entered data to feet and then tests to see whether the input data was in kilometers or meters. If the test indicates the entered value was in kilometers, convert to miles; if not, display the answer in feet. R_1 is used to store the intermediate result while the test is being made. The conversion factors are:

$$1 \text{ km.} = 1,000 \text{ meters}$$

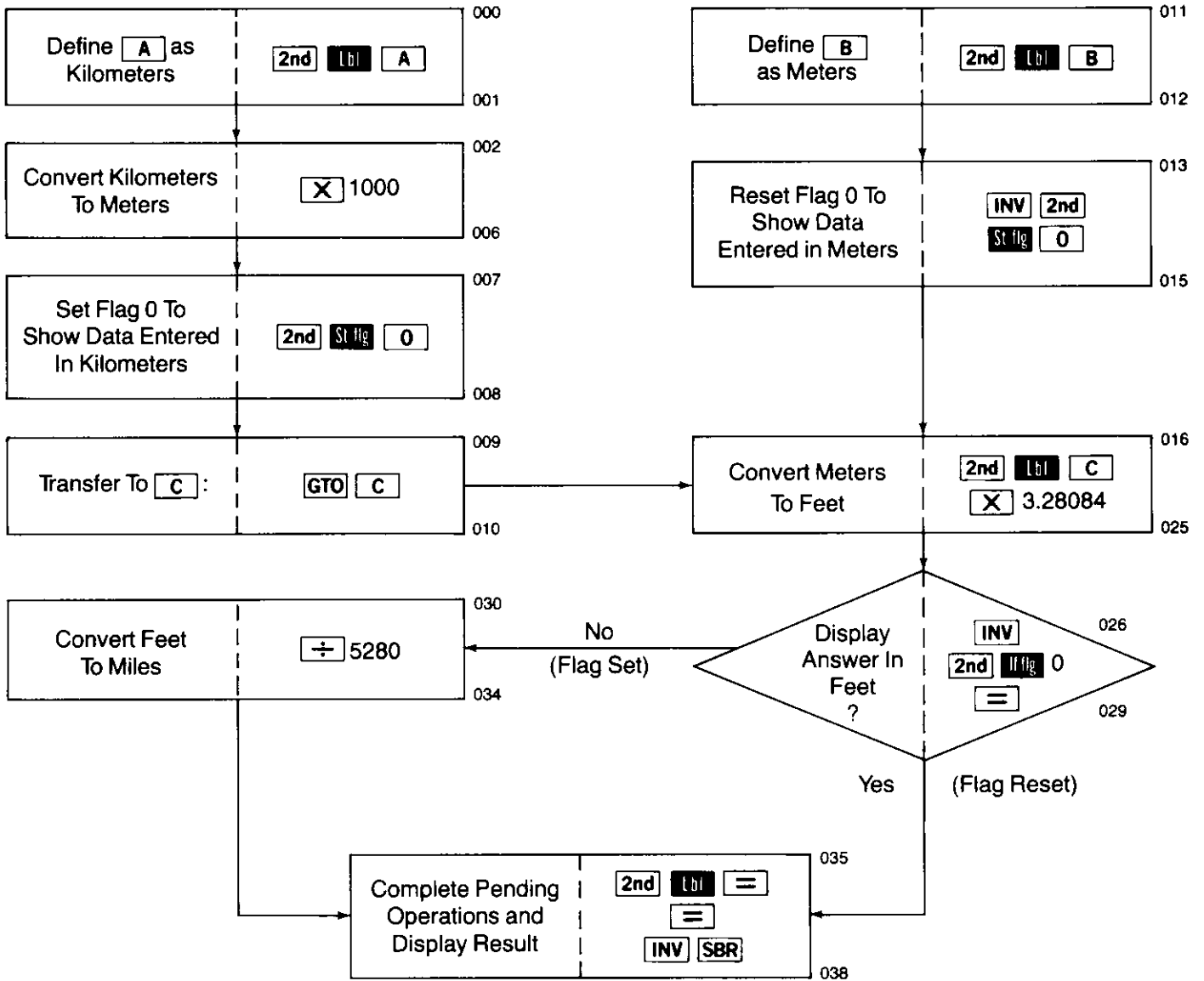
$$1 \text{ meter} = 3.28084 \text{ ft.}$$

$$1 \text{ mile} = 5,280 \text{ ft.}$$



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Programming Considerations



Metric Conversion Program

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Programming Considerations

USER INSTRUCTIONS				
Step	Procedure	Enter	Press	Display
1	Clear Program Memory and Reset Program Pointer		2nd CP	
2	Enter Learn Mode		LRN	000 00
3	Enter Metric Conversion Program			
4	Exit Learn Mode		LRN	
5	Enter Kilometers	Kilometers	A	Miles
	OR Enter Meters and Compute Result	Meters	B	Feet

Location and Key Code	Key Sequence	Location and Key Code	Key Sequence
000 76	2nd Lbl	020 93	.
001 11	A	021 02	2
002 65	X	022 08	8
003 01	1	023 00	0
004 00	0	024 08	8
005 00	0	025 04	4
006 00	0	026 22	INV
007 86	2nd St flg	027 87	2nd If flg
008 00	0	028 00	0
009 61	GTO	029 95	=
010 13	C	030 55	÷
011 76	2nd Lbl	031 05	5
012 12	B	032 02	2
013 22	INV	033 08	8
014 86	2nd St flg	034 00	0
015 00	0	035 76	2nd Lbl
016 76	2nd Lbl	036 95	=
017 13	C	037 95	=
018 65	X	038 92	INV SBR
019 03	3		

Metric Conversion Program



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Programming Considerations

Example: Key in the above program and then convert 50 meters to feet and 90 kilometers to miles.

Enter	Press	Display	Comments
50	B	164.042	Meters → Feet
90	A	55.92340909	Kilometers → Miles

DATA REGISTER TRANSFERS — **DSZ**

This powerful instruction uses the contents of data registers 0-9 to decide whether or not to transfer. **DSZ** is used primarily for conditional looping so further discussion is postponed until that section.

Creating Loops

Often in your problem solving, you may require certain processes to be repeated several times in succession to achieve your required result. In this situation you can set up a “looping process.” *Looping* is a programming technique where you instruct your calculator to perform a sequence of instructions over and over again until it has done the job you have asked it to do. To create a loop, you simply provide the program with an instruction that resets the program pointer to an earlier location.

UNCONDITIONAL LOOPING

There are two methods of unconditional looping.

RST loops back to program location 000

GTO loops back to wherever you tell it.

Let's create a program to count by fours. The simple sequence

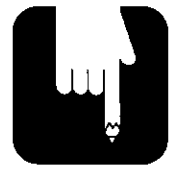
+ 4 **=** **2nd** **Pause** **RST**

should do it if placed at the very start of program memory. After keying this sequence into program memory, exit the learn mode, reset to location 000, enter a starting number and press **R/S** and watch it count. If you were to place the sequence in program memory starting at location 020, you could replace **RST** with **GTO 020** and accomplish the same thing. Just remember that initially you have to begin execution at location 020.

Be careful with **RST** because it also resets all flags and clears the subroutine return register.

To exit from a loop, place a transfer inside the unconditional loop to transfer out under the conditions you specify. In the counting by fours example above, let's again count by fours beginning at 0 and stopping at 20.

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Programming Considerations

Location and Key Code	Key Sequence	Comments
000 02	2	
001 00	0	
002 32	x=t	Store 20 in T-register
003 25	CLR	Clear display
004 76	2nd Lib	
005 85	+	Label this segment as +
006 85	+	
007 04	4	
008 95	=	
009 66	2nd Pause	Display each count
010 67	2nd x=t	Test calculated value against T-register
011 00	1	
012 15	5	Skip to location 015 if x = 20
013 61	GTO	Otherwise go back to label +
014 85	+	
015 91	R/S	Stop when x = t

Once the program is stored in program memory, just press **RST** **R/S** to execute it. Notice that the conditional test in location 010 tests each number that comes through and does nothing until the count reaches 20 then it transfers to 015 and stops. The looping is actually handled by **GTO**.



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Programming Considerations

CONDITIONAL LOOPING

The counting example can also be totally controlled by a conditional transfer instruction as was done by **GTO** in the previous example. Again let's count from 0 to 20.

Location and Key Code	Key Sequence	Comments
000 02	2	
001 00	0	
002 32	x=t	
003 25	CLR	
004 76	2nd Lbl	Label program part as A
005 11	A	
006 85	+	
007 04	4	
008 95	=	
009 66	2nd Pause	
010 22	INV	
011 77	2nd x≠t	Reverse test and transfer to A if last calculated value less than 20
012 11	A	
013 91	R/S	Stop when counting reaches 20

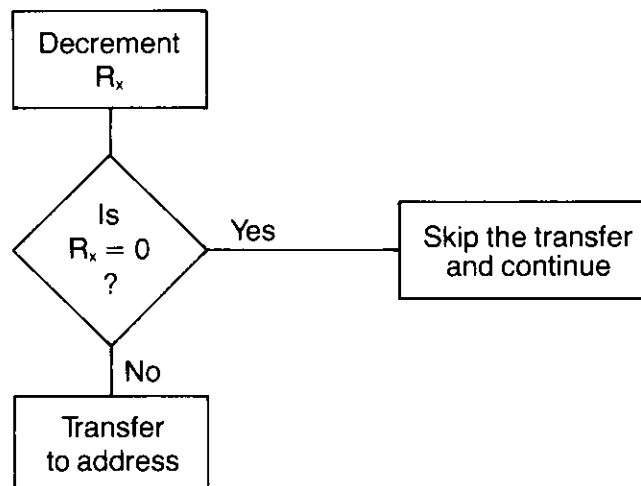
Here, **INV** **2nd** **x≠t** controls the looping.



LOOPING WITH THE DSZ CONDITIONAL TRANSFER

Whenever you know how many times a sequence should repeat itself, you can use the “Decrement and Skip on Zero” **DSZ** instruction to handle the looping. The sequence used here is **2nd** **DSZ** X followed by a transfer address. X is the number of one of the 10 data registers 0-9 that can be used with this instruction.

This versatile transfer decreases the magnitude of the contents of data register X by 1 (if the data register contents are less than 1 they are decremented to 0), then tests the contents of register X. (For this discussion, let R_x represent the *contents* of data register X.) If R_x is zero, the transfer address is skipped. Otherwise the address causes the processing sequence to transfer. DSZ decrements register X and skips the transfer on zero. Graphically, this instruction sequence works like this.



Like the other transfer instructions, DSZ can be used from the keyboard as well as in the program. Key in the following and see how.

Press	Display	Comments
2nd CP	0.	Clear program memory
2 STO 6	2.	Store 2 in data register 06
2nd DSZ 6 136		Decrements R_6 by 1, then asks, "Is $R_6 = 0$?" If no, transfer
LRN	136 00	Transfer made to 136
LRN RCL 06	1.	R_6 was 2 and is now 1 because of DSZ
2nd DSZ 6 111	1.	Decrement and test again
LRN	136 00	No transfer because $R_6 = 0$ now
LRN RCL 06	0.	R_6 actually is 0

DSZ is actually an effective counter that loops until it counts down to zero and then proceeds to another instruction.

To see how this can be beneficial in a program, let's look at our "counting by" example one more time. We can see that the process of counting by fours to 20 takes 5 passes through the (+4=) loop.



Programming Considerations

Location and Key Code	Key Sequence	Comments
000 47	2nd CMs	Clear all data memories
001 05	5	
002 48	2nd Exc	Store 5 in register 00 and clear display
003 00	0	
004 76	2nd Lbl	Label this part A
005 11	A	
006 85	+	
007 04	4	
008 95	=	
009 66	2nd Pause	Display each count
010 97	2nd DSZ	Decrement register 00 and test to see if R_0 is less than 1
011 00	0	
012 11	A	If R_0 is greater than 0, transfer to A
013 91	R/S	Stops when R_0 is zero

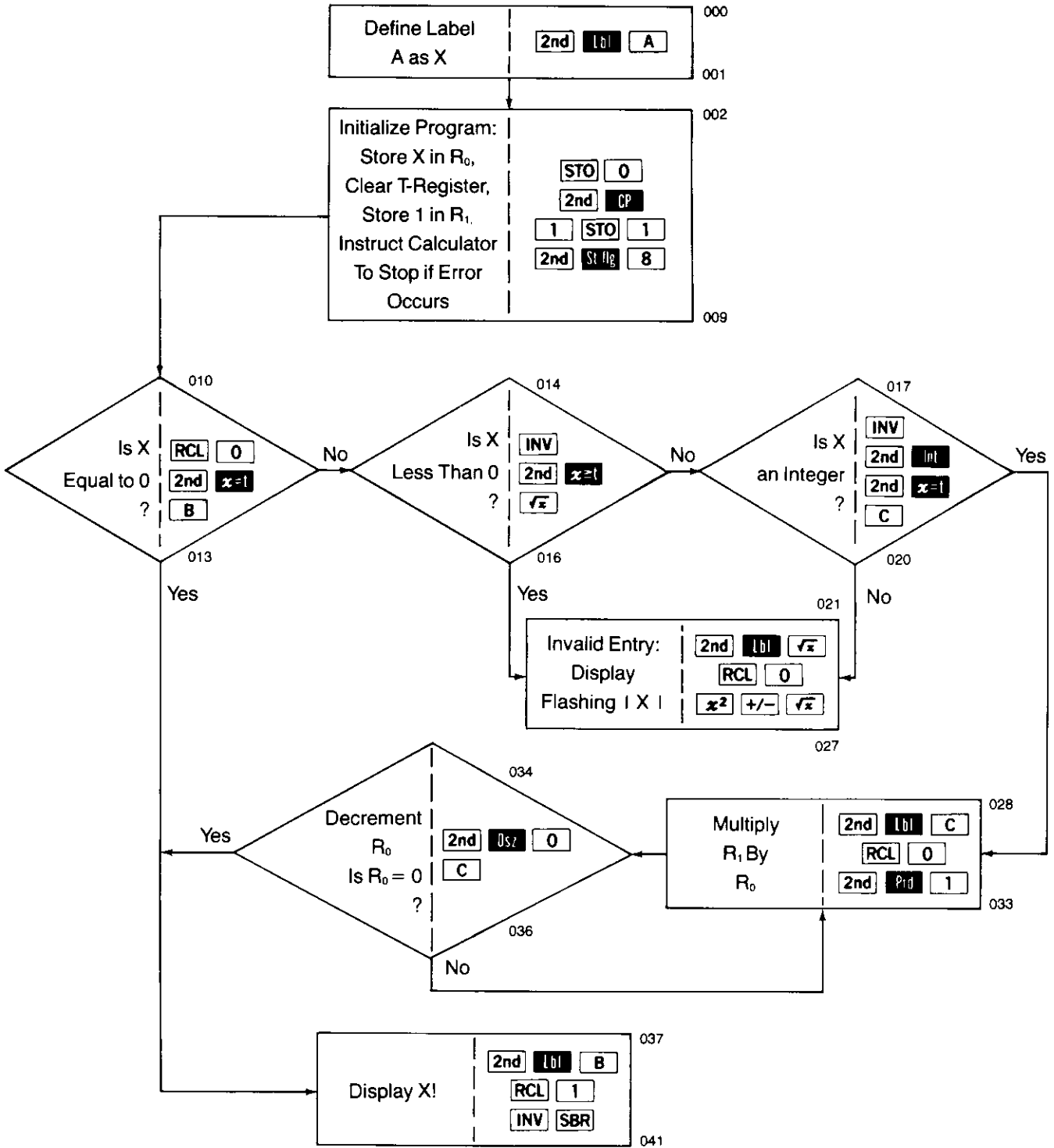
DSZ can *increment* R_x (add 1 to R_x) from the negative side of zero as well. A -5 could have been used just as well in the above example. Also, **INV** **2nd** **DSZ** still decrements or increments the same as before, but the transfer is skipped on nonzero now instead of zero.

For more details, see *Decrement and Skip on Zero* on page V-63.

This instruction is also valuable when computing a series from 1 to N. You may use DSZ to compute the series by establishing a loop to evaluate the expression for different values of the variable and instructing the calculator to recall the contents of the data register being decremented each time the variable is needed. (Note that the series is actually computed from N to 1 because DSZ decrements.)

X! PROGRAM

Now to exercise the principles of DSZ looping, let's design a program to compute factorials, $X!$, where $X! = x \cdot (x - 1) \cdot (x - 2) \cdot \dots \cdot 2 \cdot 1$. By definition of this function, X must be a positive integer and $0! = 1$.



X! Program



Location and Key Code	Key Sequence	Location and Key Code	Key Sequence
000 76	2nd Lbl	021 76	2nd Lbl
001 11	A	022 34	\sqrt{x}
002 42	STO	023 43	RCL
003 00	0	024 00	0
004 29	2nd CP	025 33	x^2
005 01	1	026 94	+/-
006 42	STO	027 34	\sqrt{x}
007 01	1	028 76	2nd Lbl
008 86	2nd St flg	029 13	C
009 08	8	030 43	RCL
010 43	RCL	031 00	0
011 00	0	032 49	2nd Prd
012 67	2nd $x=t$	033 01	1
013 12	B	034 97	2nd Dsz
014 22	INV	035 00	0
015 77	2nd $x=t$	036 13	C
016 34	\sqrt{x}	037 76	2nd Lbl
017 22	INV	038 12	B
018 59	2nd Int	039 43	RCL
019 67	2nd $x=t$	040 01	1
020 13	C	041 92	INV SBR

X! Program

In the sample program, 1 is stored in R₁ so as to allow multiplication by memory arithmetic. As a complete programming exercise, the first three conditional transfers are included to trap out invalid entries. Note that if an invalid entry is made, the error condition created at location 027 halts the program since flag 8 is set earlier in the program. The actual loop occurs between locations 028-036.

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Programming Considerations

Use of this program is very straightforward. Simply enter an x value less than 70 and press **A**. (70! overflows the calculation limits of the calculator.)

Example: Compute 6!; -2!; 0!; 7.3!; 39!

Enter	Press	Display	Comments
6	A	720	6!
2	+/- A	"2"	Invalid entry
	CLR	0	Clear error
0	A	1	0!
7.3	A	"7.3"	Invalid entry
	CLR	0	Clear error
39	A	2.0397882 46	39!

NOTE: Quote marks in the display column indicate a flashing display.

More on Applications

BOND COST PROGRAM

Many investors find buying bonds to be a secure and profitable means of putting their money to work. Others would be interested in buying bonds if they can analyze the potential earnings of their investments. Design a program that may be used to calculate the present value (cost) of a bond with periodic coupons using the formula where the cost of a bond is the sum of the discounted values of the coupons and the maturity value.

$$PV = I \sum_{j=1}^N (1 + YLD)^{-j} + MV (1 + YLD)^{-N}$$

where:

MV = maturity value

N = number of periods to maturity (j = 1, 2, . . . N)

I = coupon value

YLD = bond yield to maturity (interest per period)

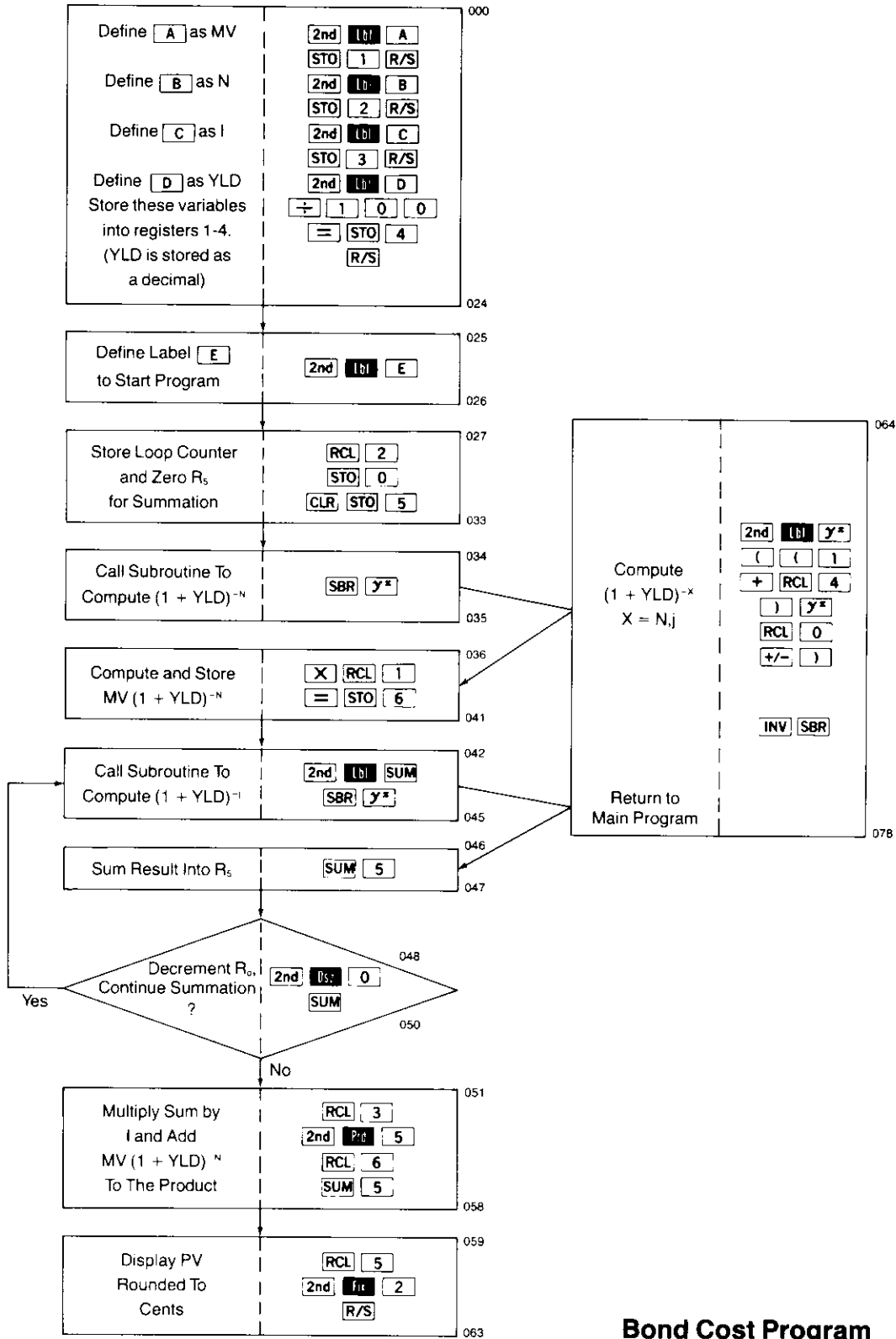
PV = present value or cost of bond

You may write this program using a loop to complete the summation. Since you know the number of loops needed in advance, using the DSZ instruction is the most efficient means of programming the loop, especially since the contents of the data register being decremented may be used to supply the value for j. Also, you may save program space by using a subroutine to evaluate $(1 + YLD)^{-x}$, $x = j, N$.



Programming Considerations

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Bond Cost Program

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Programming Considerations

USER INSTRUCTIONS				
Step	Procedure	Enter	Press	Display
1	Clear Program Memory and Reset Program Pointer		2nd CP	
2	Enter Learn Mode		LRN	000 00
3	Enter Bond Cost Program			
4	Exit Learn Mode		LRN	0
5	Enter Maturity Value	MV	A	MV
6	Enter Number of Periods	N	B	N
7	Enter Coupon Value	I	C	I
8	Enter Periodic Bond Yield to Maturity	YLD	D	YLD/100
9	Compute Present Value		E	PV
	Variables That Do Not Change Need Not Be Reentered For New Problems			



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Programming Considerations

Location and Key Code	Key Sequence	Location and Key Code	Key Sequence	Location and Key Code	Key Sequence
000 76	2nd Lbl	027 43	RCL	054 05	5
001 11	A	028 02	2	055 43	RCL
002 42	STO	029 42	STO	056 06	6
003 01	1	030 00	0	057 44	SUM
004 91	R/S	031 20	CLR	058 05	5
005 76	2nd Lbl	032 42	STO	059 43	RCL
006 12	B	033 05	5	060 05	5
007 42	STO	034 71	SBR	061 58	2nd Fix
008 02	2	035 45	y*	062 02	2
009 91	R/S	036 65	X	063 91	R/S
010 76	2nd Lbl	037 43	RCL	064 76	2nd Lbl
011 13	C	038 01	1	065 45	y*
012 42	STO	039 95	=	066 53	(
013 03	3	040 42	STO	067 53	(
014 91	R/S	041 06	6	068 01	1
015 76	2nd Lbl	042 76	2nd Lbl	069 85	+
016 14	D	043 44	SUM	070 43	RCL
017 55	÷	044 71	SBR	071 04	4
018 01	1	045 45	y*	072 54)
019 00	0	046 44	SUM	073 45	y*
020 00	0	047 05	5	074 43	RCL
021 95	=	048 97	2nd DSZ	075 00	0
022 42	STO	049 00	0	076 94	+/-
023 04	4	050 44	SUM	077 54)
024 91	R/S	051 43	RCL	078 92	INV SBR
025 76	2nd Lbl	052 03	3		
026 15	E	053 49	2nd Prd		

Bond Cost Program

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Programming Considerations

Example: Find the present cost of a bond maturing in 12 years at \$20,000 with an annual coupon value of \$1,400 and a desired yield of 8%.

Enter	Press	Display	Comments
20000	<input type="button" value="A"/>	20000	MV
12	<input type="button" value="B"/>	12	N
1400	<input type="button" value="C"/>	1400	I
8	<input type="button" value="D"/>	.08	YLD
	<input type="button" value="E"/>	18492.78	→ PV

A purchase price of \$18,492.78 yields 8% annually under these conditions. The total profit of such an investment is $12 \times \$1,400.00 + (\$20,000.00 - \$18,492.78) = \$18,307.22$.

QUADRATIC EQUATION PROGRAM

A particularly illustrative example of some of the techniques we've been reviewing is the following program designed to handle quadratic equation solutions. It may come in handy also if you find yourself faced with quadratics in problem-solving situations.

Write a program that may be used to calculate the real or complex roots of the equation.

$$ax^2 + bx + c = 0 \quad (a \neq 0)$$

The roots x_1 and x_2 are found by:

$$x_1 = \frac{-b + \sqrt{b^2 - 4ac}}{2a}$$

$$x_2 = \frac{-b - \sqrt{b^2 - 4ac}}{2a}$$

In the event that the value of $b^2 - 4ac$ is positive or equal to zero, the roots are real and are computed according to the above equations. However, if $b^2 - 4ac$ is negative, x_1 and x_2 are complex roots and must be divided into their real and imaginary parts as demonstrated below.

$$x_1 = R + (j \cdot I) \quad \text{and} \quad x_2 = R - (j \cdot I)$$

where:

$$\begin{aligned} R &= -b/2a \\ i &= \sqrt{-1} \\ I &= \sqrt{4ac - b^2}/2a \end{aligned}$$

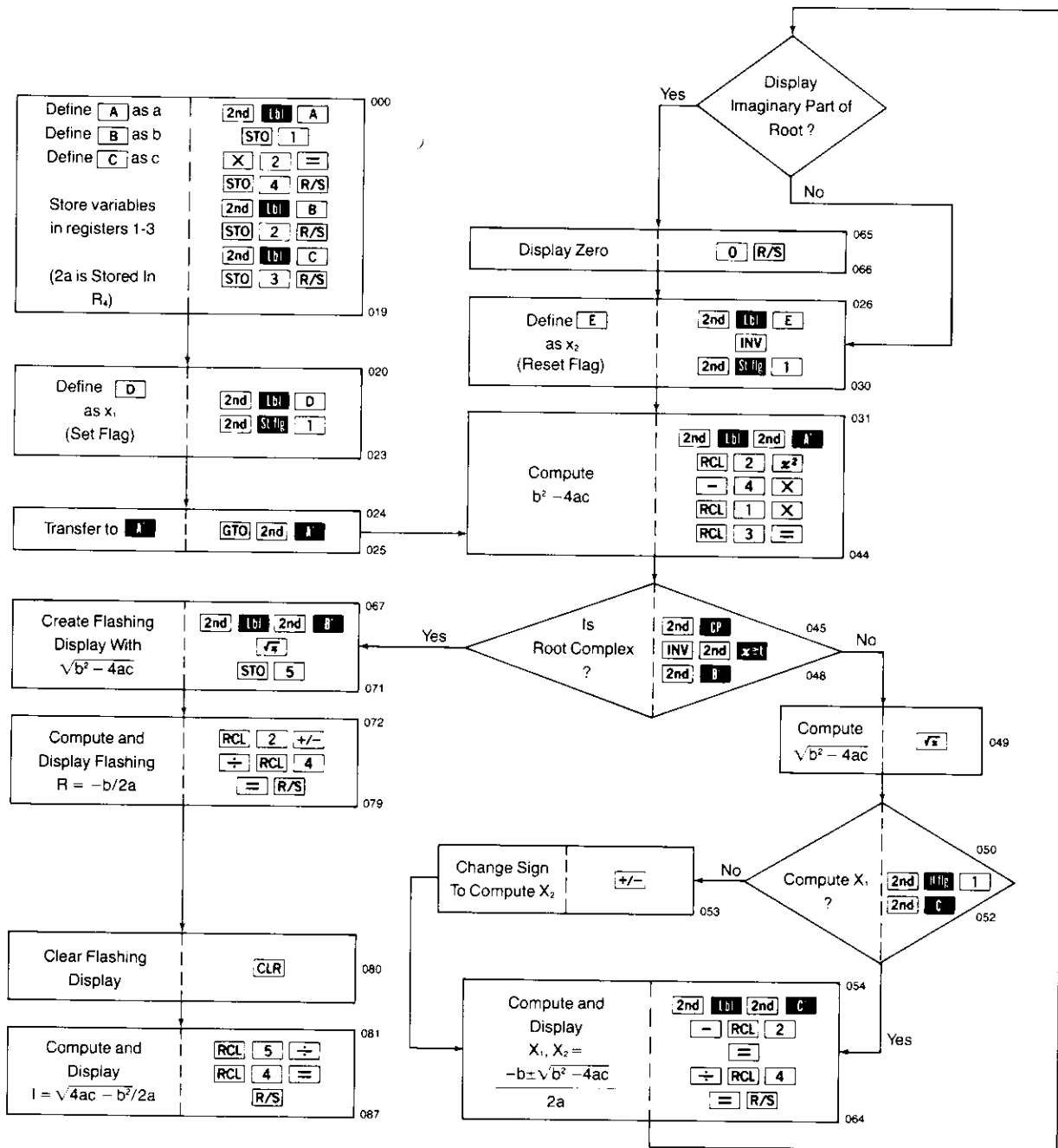
Since x_1 and x_2 are calculated using the same basic equations you may save program space by combining the routines and using a flag to indicate which root is being calculated. A separate routine is required to break up complex roots to their real and imaginary parts. You can determine whether the root is complex or real by testing to see if $b^2 - 4ac$ is negative. Note that when the roots are complex you don't need to compute x_2 as the values of R and I are the same for both roots.



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You should also provide a means of displaying whether a root is real or complex. Since $b^2 - 4ac$ is negative when a root is complex you may create a flashing display by taking the square root of this value before computing the real part of the root. (Note that $\sqrt{4ac - b^2}$ is the actual expression evaluated rather than $\sqrt{b^2 - 4ac}$ when $b^2 - 4ac$ is negative. You may store this result and use it later in determining the imaginary part of the root.) In the sample program below, the imaginary part of the root is determined by pressing **R/S** after computing the real part of the root. As a safeguard, zero is displayed if the root has no imaginary part. This program is not suited for use as a subroutine since **≡** and **R/S** have been used.



Quadratic Equation Program

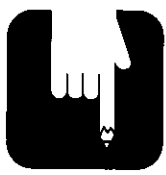
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Programming Considerations

USER INSTRUCTIONS				
Step	Procedure	Enter	Press	Display
1	Clear Program Memory and Reset Program Pointer		2nd CP	
2	Enter Learn Mode		LRN	000 00
3	Enter Quadratic Equation Program			
4	Exit Learn Mode		LRN	0
5	Enter a ($a \neq 0$)	a	A	a
6	Enter b	b	B	b
7	Enter c	c	C	c
8	Compute x_1 If Display Flashes Real Part — Root Is Complex — Compute Imaginary Part		D R/S	x_1 (Real) x_1 (Imaginary)
9	Compute x_2 If Display Flashes Real Part — Root Is Complex — Compute Imaginary Part		E R/S	x_2 (Real) x_2 (Imaginary)

NOTE: If roots are real, there is no need to compute the imaginary part which is zero, if computed. If the roots are complex, the imaginary parts of x_1 and x_2 are equal. So, the roots are $x_1 = R + (i \cdot I)$ and $x_2 = R - (i \cdot I)$.



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Location and Key Code	Key Sequence	Location and Key Code	Key Sequence	Location and Key Code	Key Sequence
000 76	2nd Lbl	030 01	1	059 95	=
001 11	A	031 76	2nd Lbl	060 55	÷
002 42	STO	032 16	2nd A'	061 43	RCL
003 01	1	033 43	RCL	062 04	4
004 65	X	034 02	2	063 95	=
005 02	2	035 33	x²	064 91	R/S
006 95	=	036 75	-	065 00	0
007 42	STO	037 04	4	066 91	R/S
008 04	4	038 65	X	067 76	2nd Lbl
009 91	R/S	039 43	RCL	068 17	2nd B'
010 76	2nd Lbl	040 01	1	069 34	√x
011 12	B	041 65	X	070 42	STO
012 42	STO	042 43	RCL	071 05	5
013 02	2	043 03	3	072 43	RCL
014 91	R/S	044 95	=	073 02	2
015 76	2nd Lbl	045 29	2nd CP	074 94	+/-
016 13	C	046 22	INV	075 55	÷
017 42	STO	047 77	2nd x>1	076 43	RCL
018 03	3	048 17	2nd B'	077 04	4
019 91	R/S	049 34	√x	078 95	=
020 76	2nd Lbl	050 87	2nd If flg	079 91	R/S
021 14	D	051 01	1	080 25	CLR
022 86	2nd St flg	052 18	2nd C'	081 43	RCL
023 01	1	053 94	+/-	082 05	5
024 61	GTO	054 76	2nd Lbl	083 55	÷
025 16	2nd A'	055 18	2nd C'	084 43	RCL
026 76	2nd Lbl	056 75	-	085 04	4
027 15	E	057 43	RCL	086 95	=
028 22	INV	058 02	2	087 91	R/S
029 86	2nd St flg				

Quadratic Equation Program

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Example: Find the roots of the equation:

$$1.5x^2 + 3.7x + 2.25 = 0$$

Enter	Press	Display	Comments
1.5	A	3.	$a \rightarrow 2a$
3.7	B	3.7	b
2.25	C	2.25	c
	D	- 1.088036702	Compute x_1 (Stable Display Indicates Root Is Real)
	E	- 1.378629965	Compute x_2

Find the roots of the equation:

$$x^2 + 2x + 17 = 0.$$

Enter	Press	Display	Comments
1	A	2.	$a \rightarrow 2a$
2	B	2.	b
17	C	17.	c
	D	"-1."	Compute Root (Flashing Display Indicates Roots are Complex — R Is Displayed)
	R/S	4.	Compute I



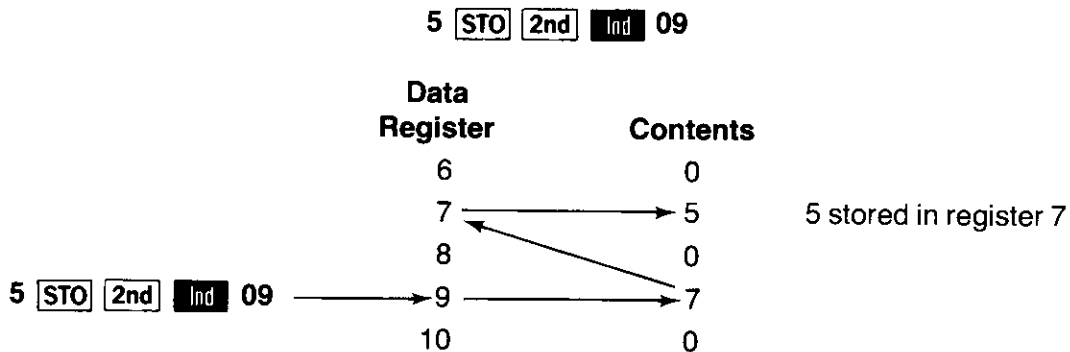
ADDITIONAL TECHNIQUES

Programming Indirect Instructions

A whole new set of capabilities can be added to data memory operations, transfer sequences and special control and library program addressing through use of the indirect instruction, **2nd Ind**. The basic concept is simple. You go to some data register not to find the information you need, but for *where* to find the information. It's just like telling someone to "Go ask Sam where Fred is" instead of telling the person to "Go and find Fred". You can see that if Sam knows where Fred is, Fred's whereabouts is immediately known to the person asking. But, for someone to just go and find Fred may take hours. In programming, it is sometimes much easier to obtain information indirectly like this. As a matter of fact, for some situations, Fred can never be found directly, so indirect methods are the only means available. Instructions are used indirectly by placing **2nd Ind** and a data register number after the instruction. In this data register is found the information needed to complete the instruction.

DATA REGISTERS ACCESSED INDIRECTLY

All data register instructions (store, recall, exchange, sum, product) can use indirect addressing. Consider the sequence



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Let's write a program segment to clear a series of data registers. For simplicity, clear register 1 through X where you can vary X.

Location and Key Code	Key Sequence	Comments
000 76	2nd Lbl	To enter X and press A
001 11	A	
002 42	STO	Store X in data register 00
003 00	0	
004 76	2nd Lbl	
005 12	B	
006 25	CLR	
007 72	STO 2nd Ind	Zero is to be stored where register 00 says to
008 00	0	
009 97	2nd Dsz	DSZ loop on register 00
010 00	0	
011 12	B	Go to B if register 00 not zero
012 92	INV SBR	Halts program when register 00 reaches zero

First time through the loop, X is in register 00 so the **CLR** **STO** **2nd** **Ind** **00** stores a 0 in register X. DSZ then decrements register 00 to (X - 1). Now the indirect store sequence stores its 0 in register (X - 1), etc. The registers have been zeroed in reverse order which really should make little difference. Can you write a program to clear them in numerical order?

Note here the special key code 72 for **STO** **2nd** **Ind**. Several of the indirect instructions are merged like this to save program space. For a complete list, see *Instruction Codes (Key Codes)* on page V-48.



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INDIRECT TRANSFER STATEMENTS

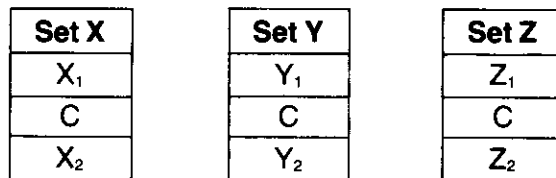
The usefulness of indirect addressing may be extended to program transfers. Recall that there are two ways to specify a transfer address: by using the absolute location or a label in program memory. Indirect program addressing permits another, more flexible, method. You specify the data register in which the desired absolute address is to be found. A label address cannot be stored in a data register.

Indirect transfer sequences are begun by placing **2nd** **Ind** after either an unconditional transfer statement (**GTO** , **SBR**) or a conditional transfer instruction (**2nd** **x=t** , **2nd** **DSZ** , etc.). The sequence must then be completed with the address of the data register containing the absolute address of the program location you wish to transfer to. Try this sequence from the keyboard.

Key Sequence	Display	Comments
35 STO 18	35.	Store 35 in data register 18
GTO 2nd Ind 18 LRN	035 00	Program pointer sent to location 035

The DSZ instruction may also indirectly specify the register being decremented. That is, sequences such as **2nd** **DSZ** **2nd** **Ind** 12 **2nd** **Ind** 14 are possible when using this instruction. Both the data register used by DSZ and its transfer address can be obtained indirectly.

Here is a graphical representation to demonstrate this method of transfer and how it may be used. Assume there are three separate sets of instructions that are to be included in the same program as shown below.

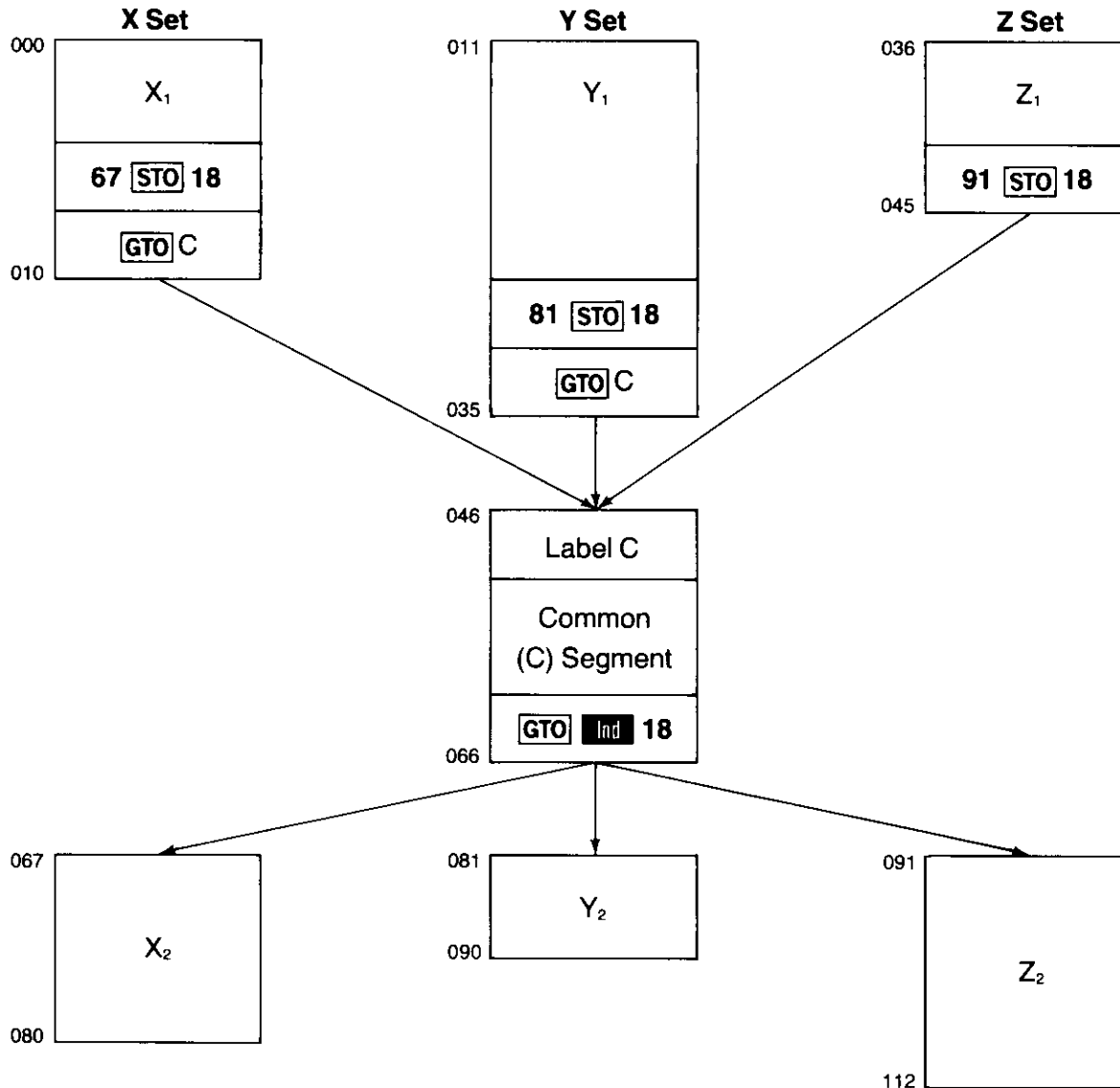


The center portion (C) of each set of instructions is the same, so it would be logical to write the common portion only once. It is an easy matter to use **GTO** instructions at the ends of the segments X₁ and Y₁ to get to C (Z₁ flows directly to C), but how does the program appropriately transfer from C to X₂, Y₂, and Z₂? This problem may be solved using indirect addressing. Simply store the address of the third section before transferring to C and then end C with a **GTO** **2nd** **Ind** instruction. In the diagram, program locations are arbitrarily added to the beginning and end of each segment for illustrative purposes.

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OTHER FEATURES

You may also use **2nd** **Ind** to indirectly set and reset program flags and to control the fix-decimal format option of the calculator.

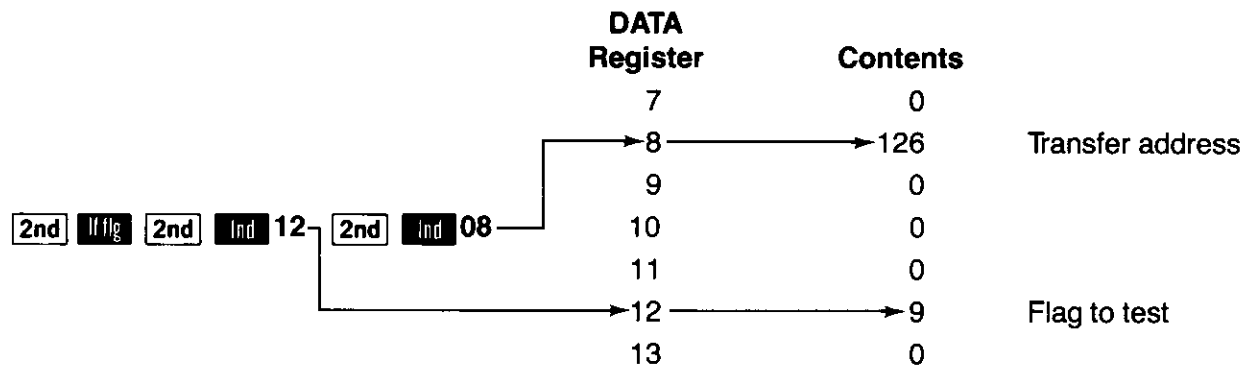
Again, indirect flag control is accomplished by placing the number of the flag in a data register. For example, storing 6 in R₁₂ and completing the sequence **2nd** **St I/g** **2nd** **Ind** **12** effectively sets flag 6 while **2nd** **If I/g** **2nd** **Ind** **12** **A** branches to label **A** depending upon the status of flag 6.



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Programming Considerations

Since **2nd If flg** is a branching instruction, the branch may also be performed indirectly. Sequences such as **2nd If flg 2nd Ind 12 2nd Ind 08** are therefore made possible.



An equivalent statement is **2nd If flg 9 126**. Key this example into your calculator to see it work.

Press	Display	Comments
126 STO 08	126.	Store 126 in register 08
9 STO 12	9.	Store 9 in register 12
2nd St flg 9	9.	Set flag 9
2nd If flg 2nd Ind 12		
2nd Ind 8 LRN	126 00	Transfer is made to location 126

Similarly, fix-decimal can be controlled indirectly as the following example shows.

Press	Display	Comments
2 STO 12	2.	Store 2 in register 12
2nd Fix 2nd Ind 12	2.00	Calculator placed in fix 2 format

For more on indirect addressing, see *INDIRECT ADDRESSING* on page V-68.



Program Optimization

Of the many reasons to optimize a program, two are especially significant. One is to make the program easier to use, and the second is to condense the program to fit in the partition established for program memory.

PROGRAMMING TECHNIQUES TO SIMPLIFY USAGE

Whether or not a program is easy to use depends upon your own particular needs and preferences. As a general rule, however, a well written program may be easily executed by just a few keystrokes (even by a person other than the programmer).

Many programs require that the entire problem be restarted if a wrong entry or keystroke is made. This can be quite annoying and time consuming, especially when working with long and involved programs. Simplifying error recovery procedures is one way to make a program easier to use. Usually, you may accomplish this by storing and saving the original data. Also, beginning routines that perform memory arithmetic with a `STO` instruction is a good practice as the routine may be rerun without having to clear any data registers.

PROGRAMMING TECHNIQUES FOR MINIMIZING STEPS

Condensing a program to a smaller number of steps is a time-consuming exercise. If a program fits within the program memory partition and operates properly, any time spent to condense the program, in most cases, is unnecessary except for the personal satisfaction of doing it.

When attempting to reduce the number of program steps, you should look for sequences that appear more than once. Then, if these sequences are long enough and needed often enough so that replacing them with subroutines reduces the amount of program space needed, do so.

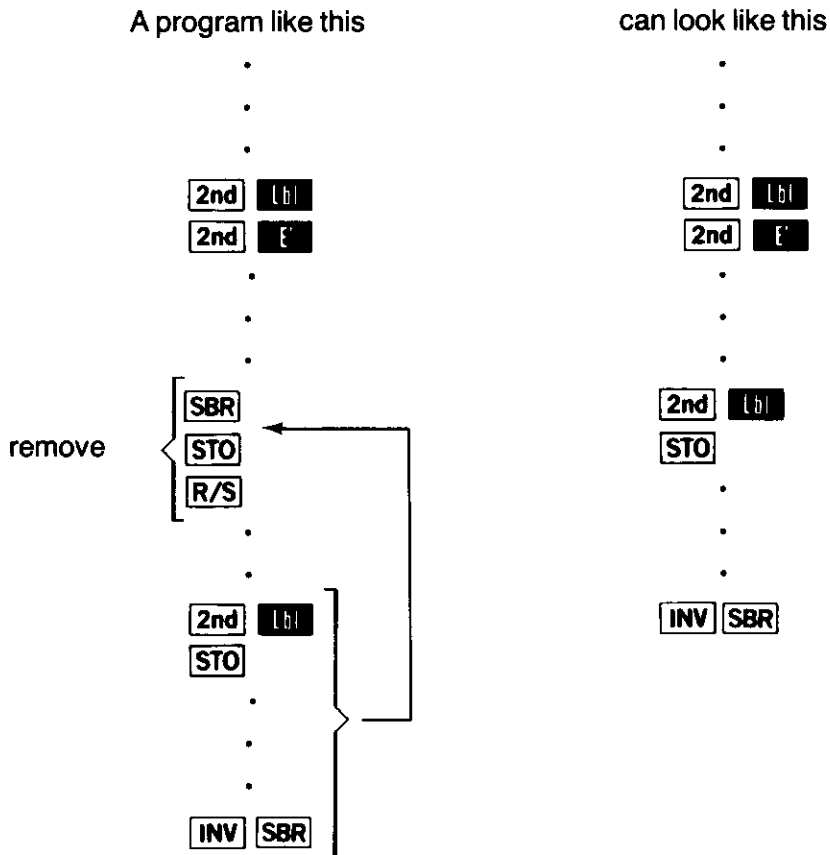
A program requiring numerous subroutines may still exceed the bounds of program memory. Optimization of subroutines thus becomes important.

There are many methods of combining separate program parts to save space. For instance, if a subroutine call occurs as the last operation of another routine, you may place the subroutine in line with the first.



Programming Considerations

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Not only is a savings of several steps realized, but one level of the subroutine return register has been freed. **INV SBR** now acts like a **R/S**, because the subroutine return register is clear.

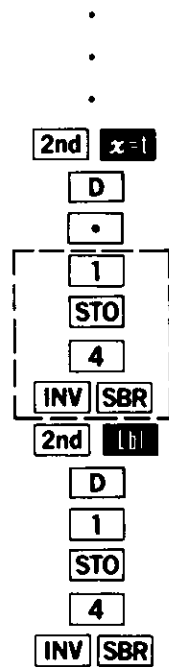
IV



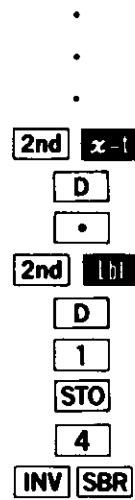
Programming Considerations

As another illustration, consider the two sequences shown below:

Workable Segment



Efficient Segment



The purpose here is to store a .1 or a 1 depending upon the results of the test. Both of these routines perform the same function; however, the second is four steps shorter than the first as the extraneous instructions enclosed in the box have been eliminated.



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Programming Considerations

In addition to the various techniques of combining separate routines there are also numerous programming tricks that you may find valuable. In the next example the programmer desires to use only the rounded two-digit value of the number displayed in his calculations. Simply placing the calculator in fix-decimal does not work as most calculations continue to use the full unrounded value.

Workable Segment

·
·
·
X
1
0
0
=
2nd Int
÷
1
0
0
=
·
·
·

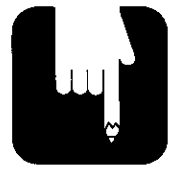
Efficient Segment

·
·
·
2nd fix
2
EE
INV
EE
2nd fix
9
·
·
·

The purpose and method of the routine on the left are fairly straightforward. The reasoning behind the second sequence is more efficient but also more obscure. Since the **EE** instruction operates only on the displayed digits, this instruction discards the unwanted digits after placing the display in fix-decimal. The routine then normalizes the display and continues using only the rounded value.

The following routines demonstrate three methods of performing the same operation: adding 10,000 to the display register.

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Programming Considerations

.	.	.
.	.	.
.	.	.
[+]	[+]	[+]
[1]	[1]	[4]
[0]	[EE]	[INV]
[0]	[4]	[2nd] [log]
[0]	[=]	[=]
[0]	.	.
[=]	.	.
.	.	.
.	.	.

Both the second and the third routine require the same number of program locations. The second method, however, is advantageous only when you wish to leave the display in scientific notation.

As you become more acquainted with the capabilities of your calculator, you will undoubtedly discover short cuts that fit your needs. Be sure to record these sequences for future use as they will lessen the programming task. Until then, you may use the many step-saving features already built into your calculator in optimizing programs. These features include functions such as the memory operations **[SUM]** and **[2nd] [Prd]**, indirect instructions and the many special control operations.

If you still have trouble fitting some programs into the allotted space you may be forced to break your program into segments and compute intermediate results before reprogramming the calculator to determine the final solution. Sometimes, however, if you are attempting to program in too straightforward a manner, there is another alternative as illustrated in this next example.

SERVICE CHARGE PROGRAM

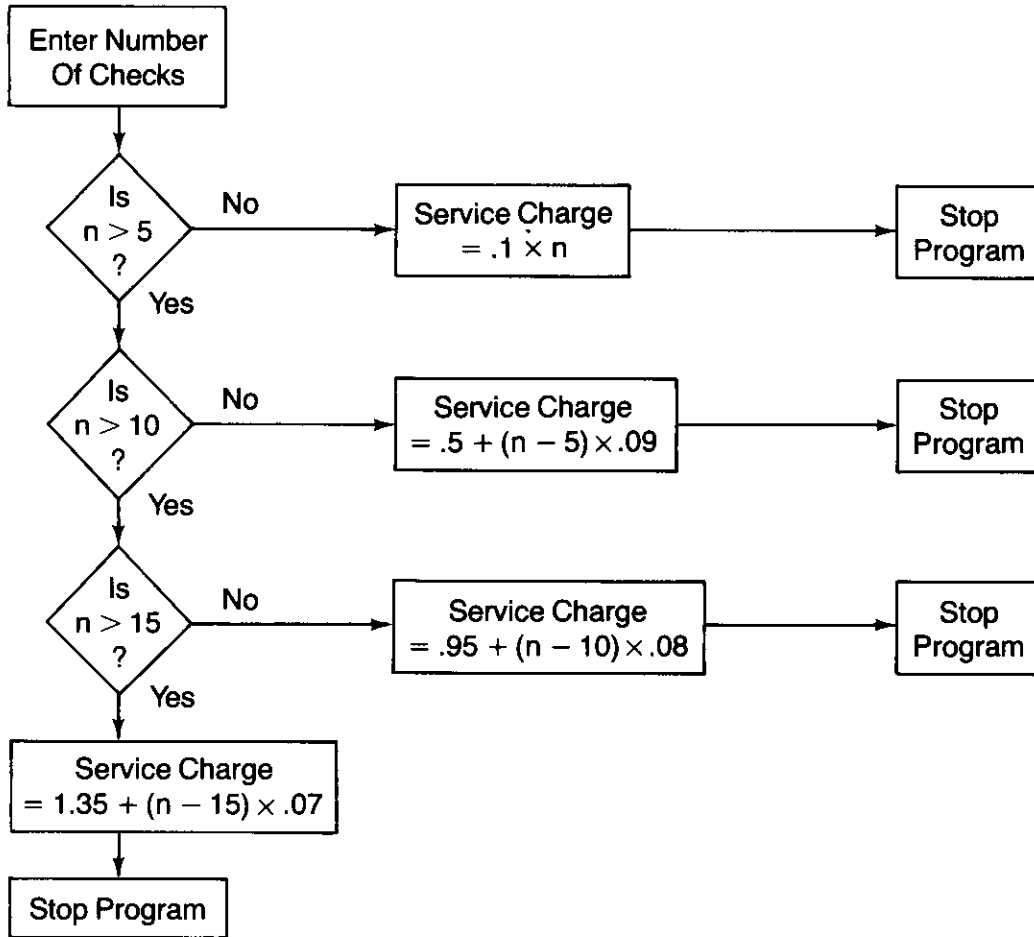
As manager of a prominent local bank, you need a fast and easy method of determining the monthly service charge for the many customers who have accounts with your bank.

The service charge for each account is calculated as follows:

- \$0.10 per check for the first five checks (1-5),
- \$0.09 per check for the next five (6-10),
- \$0.08 per check for the next five (11-15),
- \$0.07 per check for each check over 15.



A straightforward approach of solving this problem is demonstrated by the following flow diagram.



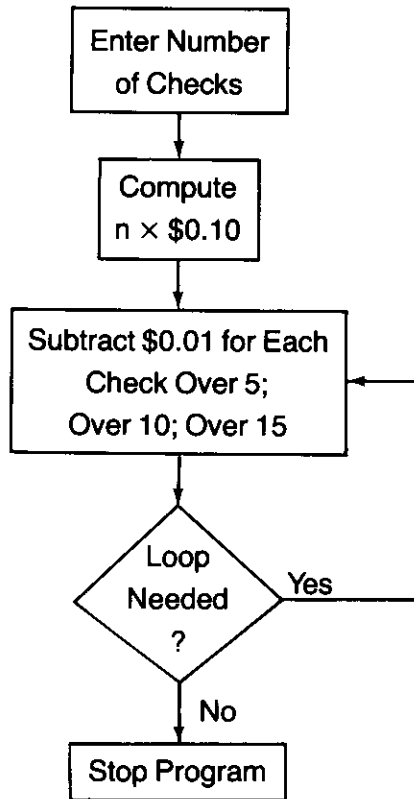
Service Charge Program (Basic Approach)

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Programming Considerations

Attempting to write a program following this approach would probably require at least eighty or ninety program locations. Although such a routine could easily fit within program memory, if it were to be used as a subroutine, it may have to be streamlined significantly to allow room for the other program parts. Perhaps another solution would require fewer steps. Consider the following approach.



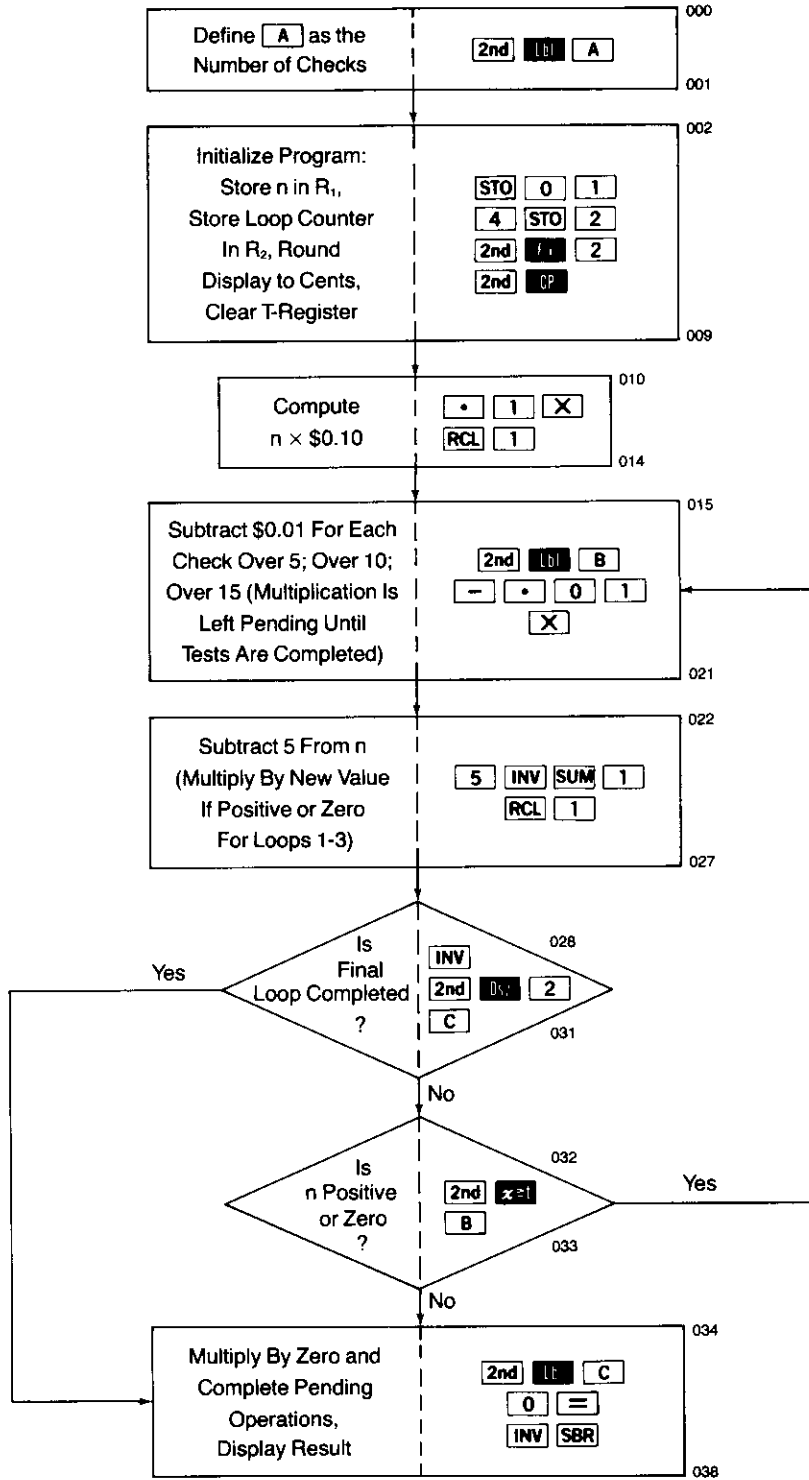
Service Charge Program (Advanced)

At a first glance it would appear that a program following this line of thinking could be easily stored in the program memory of your calculator; however, the reasoning behind some of the sequences used is not readily apparent. Examine the logic here for a moment.



Programming Considerations

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Service Charge Program

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Programming Considerations

The program is fairly straightforward until location 022 where the multiplication in step 021 is left pending while an adjustment is made to n and tests are completed. The loop is used to reduce the charge on each check over 5 to \$0.09; over 10 to \$0.08; over 15 to \$0.07. The [2nd] [057] instruction asks which loop is in progress. For loops 1-3, the value of n is tested; if it is negative, zero is placed in the display to complete the pending multiplication and the program is terminated upon computing the total service charge.

If the fourth loop is reached, the pending multiplication is always completed with zero, as the charge on each check over 20 would otherwise be reduced to \$0.06. The program then determines the total service charge and halts the program. This last loop is not necessary for computation; however, its elimination would require the use of additional program instructions and the idea is to minimize the size of the routine.

Only two approaches have been made to this service charge problem. Realizing that there are many ways to program the solution to a problem, these two extremes show just how different programming techniques can be. Naturally, there are trade-offs. In this instance the second method requires less than half the program space needed for the first method; however, the first example demands less time for the program to run. Regardless of the approach you take to programming, bear in mind that the correct method is the one that works best for you.



Programming Considerations

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Location and Key Code	Key Sequence	Location and Key Code	Key Sequence
000 76	2nd Lb	020 01	1
001 11	A	021 65	X
002 42	STO	022 05	5
003 01	0 1	023 22	INV
004 04	4	024 44	SUM
005 42	STO	025 01	1
006 02	2	026 43	RCL
007 58	2nd fix	027 01	1
008 02	2	028 22	INV
009 29	2nd CP	029 97	2nd 0sz
010 93	.	030 02	2
011 01	1	031 13	C
012 65	X	032 77	2nd ≠t
013 43	RCL	033 12	B
014 01	1	034 76	2nd Lbl
015 76	2nd Lbl	035 13	C
016 12	B	036 00	0
017 75	-	037 95	=
018 93	.	038 92	INV SBR
019 00	0		

Service Charge Program

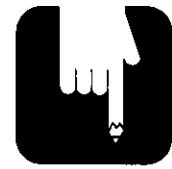
To run the program, simply key in some number of checks and press **A**. For instance, 1 check costs \$0.10, 6 checks cost \$0.59 and 63 checks cost \$4.71.

Programming Techniques for Speed

There are occasions where some time can be saved by reducing the execution time of long running programs that are to be used many times. Under these conditions, different key sequences may result in faster and more efficient program operation.

When a program is running, the most time-consuming operations are program transfers. Certainly, minimizing the number of transfer statements leads to a faster running program. Therefore, although the use of subroutines is emphasized in earlier discussions, when program space allows, you may replace subroutines with in-line instructions to significantly increase speed.

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Programming Considerations

Remember that a program step may be absolutely addressed with a 3-digit address or with a program label. If an absolute address is used, the program pointer is immediately positioned at the new location. However, if a label is used, the calculator must search for its location. The label search is always begun at location 000 and progresses through program memory until the desired location is found. Then, program execution is continued from that point.

Naturally, when a program is initially entered into the calculator, it is difficult to know ahead of time what the absolute addresses will be. Also, editing a program often causes these addresses to change and significantly increases the difficulty of the task. The best procedure then is to write the original program using labels and convert to absolute addressing only after the program is completely debugged. Again, inserting addresses and deleting labels cause the addresses to change. However, this problem may be overcome using the **2nd Nop** instruction.

2nd Nop simply performs no operation when encountered in a program. Since this command does not interfere with execution (except when used as a label), it may be used as a space-holder when program space allows. This technique is illustrated below.

	.		.
	.		.
	.		.
027	SBR	027	SBR
028	Inx	028	0
029	2nd Nop	029	7 5
	.		.
	.		.
	.		.
	.		.
073	2nd Lbl	073	2nd Nop
074	Inx	074	2nd Nop
	.		.
	.		.
	.		.
	.		.
099	GTO	099	GTO
100	Inx	100	0
101	2nd Nop	101	7 5

Label Addressing Converted to Absolute Addressing



Programming Considerations

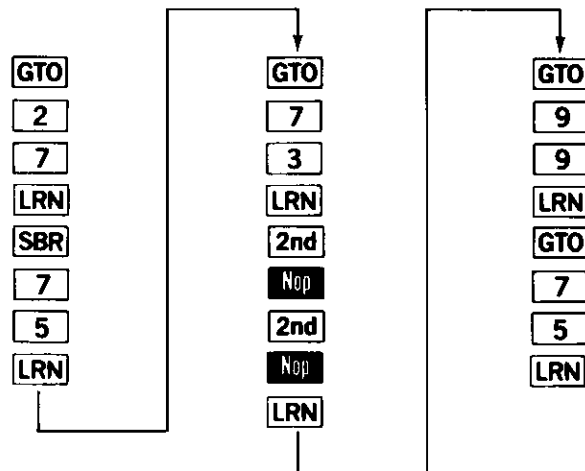
IV

Note that location 075 is used as the absolute address since transferring to a label address positions the program pointer at the first location following the label.

Remember that the absolute address 075 is stored in two program locations rather than three. The first digit, 0, is stored in the first location following the transfer instruction using its standard key code. Then, the second and third digits are merged into the two-digit code "75" and stored in the next program location.

The transfer instruction itself must also be reentered so as to instruct the calculator to automatically merge the address.

Use this key sequence for converting the previous example to absolute addressing.



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Programming Considerations

Codebreaker (Game Program)

This final programming example is not intended for the beginner. The techniques used are designed to make the most efficient use of the array of programming tools available to you. The game is fun to play and there is much to be learned from the program structure itself.

“Codebreaker” is a calculator game where the calculator generates a four-digit secret number and you try to guess it. Zeros are not allowed and no digit may be the same. Even with these restrictions there are 3024 possible codes, making slim your chances of guessing the number on your first guess. Your guess is automatically scored by the calculator. The score is displayed in the form “N”. “R” where N is the number of digits in your trial number that appear in the secret number and are positioned correctly, R is the number of digits in your guess which although correct, are improperly placed. For example, if the number generated by the calculator is 8261 and you guess 6285, you receive a score of 1.2. This indicates that one number you guessed is in the right place (the 2) and that two of your other numbers (8 and 6) are present in the secret number, but not in the right place. A score of 4.0 indicates that your guess is correct.

Test your skill by developing a program of your own for this game. Then, study the example given below. Optimize your program to use a minimum number of instructions.

The flow of processing in this example is easy to follow; however, the complexity of the code requires that the flow diagram and its explanation be presented simultaneously.

For the program to derive its secret number, it must have a starting point. A “seed” number is entered at for the calculator to work with.



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Programming Considerations

Flow Diagram	Comments	Location and Key Code	Key Sequence
<pre> graph TD A[Define A as Seed Number] --> B[Clear Memory and Store Seed in R09] B --> C[Increment Indirect Register Pointer and Loop Counter] C --> D[Restore Loop Counter] D --> E[Generate Random Digit] E --> C </pre> <p>The flowchart consists of five rectangular boxes connected by arrows. The first box is 'Define A as Seed Number'. An arrow points down to the second box, 'Clear Memory and Store Seed in R09'. Another arrow points down to the third box, 'Increment Indirect Register Pointer and Loop Counter'. From the bottom of the third box, an arrow loops back to the top of the fourth box, 'Restore Loop Counter'. An arrow points down from the fourth box to the fifth box, 'Generate Random Digit'. From the bottom of the fifth box, an arrow points down to a label 'c'. From the left side of the fifth box, an arrow points left to a label 'a'. From the left side of the fourth box, an arrow points left to a label 'b'.</p>	<p>This routine is used to establish the code number.</p>	<p>000 76 001 11</p>	<p>2nd Lbl A</p>
	<p>Store seed in data register 09.</p>	<p>002 47 003 42 004 09</p>	<p>2nd CMs STO 0 9</p>
	<p>The generated digits are indirectly stored according to the contents of R_6. Op code 25 is used to increment R_6 by 1.</p>	<p>005 76 006 44 007 69 008 25</p>	<p>2nd Lbl SUM 2nd Op 2 5</p>
	<p>A loop is used to test new digits against zero and previously generated digits. To reduce running time, a minimum number of loops is used.</p>	<p>009 76 010 42 011 43 012 05 013 42 014 06</p>	<p>2nd Lbl STO RCL 5 STO 6</p>
	<p>Subroutine D.MS of program 15 is used to generate a random number x where $0 \leq X < 1$. The number is then multiplied by 10 to place it in the proper range and its integer value is placed in the test register. Using routine C of program 15 to generate the number would require additional program space to establish the range of the output. Also, routine C uses data registers R_1-R_6 where subroutine D.MS does not.</p>	<p>015 36 016 15 017 71 018 88 019 65 020 01 021 00 022 95 023 59 024 32</p>	<p>2nd Pgm 1 5 SBR 2nd D.MS X 1 0 = 2nd Int x:t</p>

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Programming Considerations

Flow Diagram	Comments	Location and Key Code	Key Sequence
	<p>Since the data registers are initially cleared, the first loop tests the generated digit against zero. The remaining loops test against previously generated digits. If the digit is rejected, a new digit is generated without incrementing R_6. R_6 serves both as an indirect register pointer and a loop counter. The DSZ instruction also serves a dual purpose in that it controls the looping process and the indirect pointer.</p>	<p>025 76 026 67 027 73 028 06 029 67 030 42</p>	<p>2^{nd} Lbl 2^{nd} $x=t$ RCL 2^{nd} Ind 6 2^{nd} $x=t$ STO</p>
	<p>If the digit is accepted, it is indirectly stored using R_6 as a pointer.</p>	<p>031 97 032 06 033 67</p>	<p>2^{nd} DSZ 6 2^{nd} $x=t$</p>
	<p>Once four digits have been accepted, the code is complete. The test is made against 3 rather than 4 for a savings of 1 program step. The alternative is</p>	<p>034 32 035 72 036 05</p>	<p>$x=t$ STO 2^{nd} Ind 5</p>
	<p>4 INV 2^{nd} $x=t$.</p>	<p>037 43 038 05 039 32 040 03 041 77 042 44</p>	<p>RCL 5 $x=t$ 3 2^{nd} $x=t$ SUM</p>
	<p>Stop Program and Display Zero</p>	<p>043 00 044 91</p>	<p>0 R/S</p>
	<p>Define B as Guess</p>	<p>045 76 046 12</p>	<p>2^{nd} Lbl B</p>
	<p>Store Guess and Establish Major Loop Counter</p>	<p>047 42 048 12 049 04 050 42 051 05</p>	<p>STO 1 2 4 STO 5</p>



Flow Diagram	Comments	Location and Key Code	Key Sequence
<pre> graph TD Start(()) --> Extract[Extract Digit for Testing] Extract --> Counter[Establish Minor Loop Counter] Counter --> Match{Do Digits Match?} Match -- No --> Test[Test Against Next Code Digit?] Match -- Yes --> RCL[Transfer to Label RCL] Test -- No --> Counter Test -- Yes --> DSZ[Transfer To Label DSZ] RCL --> Test DSZ --> Test </pre>	<p>This instruction sequence picks off the last digit in the guess and stores it in the T-register so that it may be compared against the code number. This digit is also removed from the guess so that the third digit becomes the last digit for the second loop and so on. The equation used is:</p> $\text{Digit} = 10 \times \text{INV Int} \frac{\text{Guess}}{10}$ <p>The EE trick is again used for dividing and multiplying by 10.</p> <p>The minor loop is used to test the above digit against each digit in the code number.</p> <p>Here the digit selected from the player's guess is compared with the digits appearing in the code number. If a match is found, processing is transferred to the scoring section.</p> <p>This instruction makes sure that each digit guessed is compared to each digit of the secret number (unless a match is found in an earlier comparison). Again, R₆ and DSZ serve dual functions.</p>	<p>052 76 053 52 054 43 055 12 056 52 057 01 058 94 059 42 060 12 061 22 062 59 063 22 064 44 065 12 066 52 067 00 068 00 069 32 070 04 071 42 072 06 073 76 074 97 075 73 076 06 077 67 078 43 079 97 080 06 081 97</p>	<p>2nd Lbl EE RCL 1 2 EE 1 +/- STO 1 2 INV 2nd Int INV SUM 1 2 EE 0 0 x=t 4 STO 6 2nd Lbl 2nd DSZ RCL 2nd Ind 6 2nd x=t RCL 2nd DSZ 6 2nd DSZ</p>

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Programming Considerations

Flow Diagram	Comments	Location and Key Code	Key Sequence
	<p>If no match occurs, the scoring segment is bypassed.</p>	<p>082 61 083 25</p>	<p>[GTO] [CLR]</p>
	<p>The guessed digit is in the right position when the loop counters are at the same level.</p>	<p>084 76 085 43 086 43 087 06 088 32 089 43 090 05 091 67 092 24</p>	<p>[2nd] [LbI] [RCL] [RCL] [6] [x<=t] [RCL] [5] [2nd] [x=1] [CE]</p>
<p>If the guessed digit is in the wrong place score .1 point. If it is correctly positioned, score 1 point, Notice how easily the two routines are combined.</p>	<p>093 93 094 76 095 24 096 01 097 44 098 13</p>	<p>[.] [2nd] [LbI] [CE] [1] [SUM] [1] [3]</p>	
<p>Using [CLR] in place of [INV] [EE] saves 2 steps as it also places 0 in the display register for use below.</p>	<p>099 76 100 25 101 25</p>	<p>[2nd] [LbI] [CLR] [CLR]</p>	
<p>If a major loop has been performed for each digit of the guess the program is terminated and the score is displayed.</p>	<p>102 97 103 05</p>	<p>[2nd] [DsZ] [5]</p>	
<p>In addition to calling the score to the display, the [EE] instruction also zeros R₁₃ (See location 101) to allow summation when the next guess is entered. Placing the calculator in fix 1 allows R to be displayed even when this value is zero.</p>	<p>104 52 105 48 106 13 107 58 108 01 109 91</p>	<p>[EE] [2nd] [EE] [1] [3] [2nd] [EE] [1] [R/S]</p>	



IV

Programming Considerations

The program designed here requires the entry of a decimal "seed" number (between 0 and 199017) and pressing . Once the secret number is derived, a zero appears in the display. Begin guessing by entering your guess and pressing . The validity of your guess is displayed as previously explained. Let's play a game.

Enter	Press	Display	Comments
.258	<input type="button" value="A"/>	0.	Enter "seed" and wait until secret number determined.
1234	<input type="button" value="B"/>	0.1	First guess
5678	<input type="button" value="B"/>	2.1	Second guess
9238	<input type="button" value="B"/>	1.0	Third guess
5694	<input type="button" value="B"/>	1.0	Fourth guess
5198	<input type="button" value="B"/>	2.1	Fifth guess
5718	<input type="button" value="B"/>	4.0	Sixth guess is correct

A proficient player seldom needs more than six guesses.

V



THE DETAILS

AN IN-DEPTH ANALYSIS OF FEATURES AND FUNCTIONS

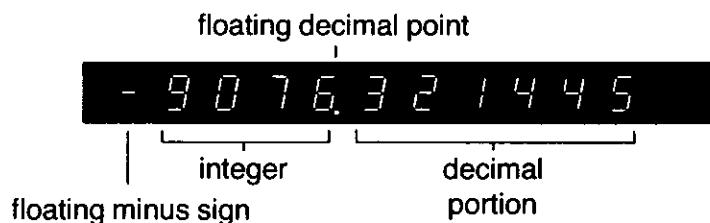
Now for an in-depth analysis of each facet of your calculator. This section is specifically designed as a detailed reference to be used once you have a basic understanding of the calculator's functions. If you do not have a good understanding of the calculator, return to the earlier sections of this manual to obtain this information.

Throughout this section, all discussions about keyboard operations and functions apply both to manual (number by number) calculations as well as to program calculations using those operations.

BASIC OPERATIONS

Standard Display

In addition to power-on indication, the display provides numerical information complete with negative sign and decimal point and flashes on and off for an overflow, underflow or error condition. An entry can contain as many as 10 digits. All digits entered after the tenth are ignored.



Any negative number is displayed with a minus sign immediately to the left of the number.



See *Appendix C* for the accuracy of all displayed results.



The Details

AN IN-DEPTH ANALYSIS OF FEATURES AND FUNCTIONS

Data Entry Keys

The keys have been selectively positioned on the keyboard to provide for efficient calculator operation. Although many of the operations are obvious, some are not. The following instructions and examples can help you develop skill and confidence in using your calculator.

0 THROUGH **9** DIGITS — Enters the numbers 0 through 9.

. — **DECIMAL POINT** — Enters the decimal point. The decimal point can be entered wherever needed. If no decimal point is entered, it is assumed to be to the right of the number, and appears when any operation or function key is pressed. A zero precedes the decimal point for numbers less than 1 unless all ten available display digits are used. Trailing zeros on the decimal portion of a number are not normally displayed. Only the first decimal point entered is accepted, all others are ignored. Pressing the decimal point immediately after an exponent entry allows you to alter the mantissa again, like changing its sign.

2nd **π** — **PI** — Enters the value of pi **π** to 13 significant digits (3.141592653590) for calculations; display indicates the rounded value. **CE** does not remove π , however, it can be written over by another number.

+/- — **CHANGE SIGN** — Instructs the calculator to change the sign of the displayed number. When pressed after **EE**, **2nd** **Eng** or exponent entry, changes the sign of the exponent.

The procedure for entering a positive number is simply to press the keys in the left to right sequence exactly as the number is written. Each digit entry causes the displayed numbers to shift left as the new digit is entered. Only the first decimal point entered in any single number entry is accepted.

Example: $7.892 - \pi + (-2) = 2.750407346$

Press	Display
7.892 -	7.892
2nd π	3.141592654
+	4.750407346
2 +/-	-2
=	2.750407346



 AN IN-DEPTH ANALYSIS OF FEATURES AND FUNCTIONS

Clearing Operations

CE — **CLEAR ENTRY** — Clears entries made with the digit, decimal point and change-sign keys only when pressed before a function key. This key does not clear calculated results, numbers recalled from memory or π . **CE** also stops the flashing of the display when needed. Use of this key does not affect pending operations.

CLR — **GENERAL CLEAR** — Clears calculations in progress and the display. It resets scientific notation to standard format and stops a flashing display. This key does not affect the contents of the data or program memories, the T-register, angular mode, engineering or fix-decimal display formats or the partition.

The calculator effectively clears itself after most calculations. When the **☰** key is pressed to complete a calculation, the answer is displayed and the calculator is ready for the start of a new problem without pressing any of the clear keys. The contents of the data memories are not automatically cleared.

2nd CP — **CLEAR PROGRAM** — Clears all locations of program memory (and protection), clears the subroutine return register, resets all flags, clears the T-register and resets the program pointer to 000 when pressed from the keyboard. When encountered within a program it only zeros the T-register.

2nd CMs — **CLEAR DATA MEMORY** — Instructs the calculator to clear all data memory registers as defined by the current partition.

Dual Function Keys (**2nd** and **INV**)

Most of your calculator's keys have dual functions. The first function is printed on the key and the second function is written above it. To execute a function shown on a key, simply press the desired key. To use the second function of a key, press the **2nd** key, then press the key immediately below the desired second function. For example, to find the natural logarithm of a number, press **lnx**. To find the common logarithm of a number, press **2nd lnx**. In order to distinguish the second function key, this manual shows it as **2nd log**. First function operations, therefore, are indicated by **☐**. Second functions are indicated by **2nd ☐**. When **2nd** is pressed twice in succession, or if a key that does not have a second function is pressed after **2nd**, the calculator returns to first function operation.



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The inverse key **INV** adds additional computing capabilities without increasing the number of keys on the keyboard just like the **2nd** key. When **INV** precedes another key, the purpose of that key is reversed. The inverse can be used with the following keys to obtain the indicated function. Pressing **CE** cancels an inverse key press.

Function	Inverse Function
EE	removes EE
ENG	removes ENG
Fix	removes Fix
log	10^x
ln x	e^x
y^x	$\sqrt[x]{y}$
Int	fractional part
sin	\sin^{-1}
cos	\cos^{-1}
tan	\tan^{-1}
Prod	divide into memory
SUM	subtract from memory
D.MS	decimal to D.MS
P→R	R→P.
$\Sigma+$	$\Sigma-$
x	standard deviation
list	list data registers
SBR	return
$x = t$	$x \neq t$
$x \geq t$	$x < t$
if flg	if no flag
st flg	reset flag
Dsz	skip on nonzero
Write	read

Programming uses of the **INV** key are discussed in the programming sections where used.

An inverse instruction can be canceled by pressing **INV** a second time if no other key has been pressed. For those keys that do not have an inverse, i.e., **DEL**, **LRN**, etc., a preceding inverse key is ignored. When used in conjunction with the second function key, the inverse key can be pressed before or after the second function key is pressed, i.e., **INV** **2nd** **log** equals **2nd** **INV** **log**. This is true for the keyboard only. The inverse key must always come first in a program to obtain the desired result. For examples of **INV** uses with a specific key, see the section relating to that key.



AN IN-DEPTH ANALYSIS OF FEATURES AND FUNCTIONS

Display Formats

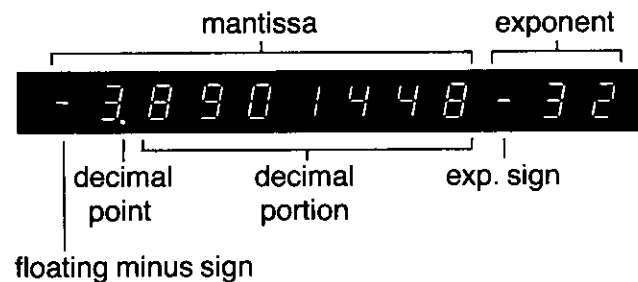
In addition to the versatile 10-digit standard display, there are several other display capabilities that increase the operating range and flexibility of your calculator.

Even though a maximum of 10 digits can be entered or displayed, the internal display register always retains results to 13 digits. The results are then rounded for display only. These extra digits guard the displayed value to insure its accuracy and are not intended to be extended precision. Using these guard digits should be done with extreme care. See *Appendix C* for a detailed discussion of accuracy.

SCIENTIFIC NOTATION

EE — **ENTER EXPONENT** — Instructs the calculator that the subsequent number entry is an exponent of 10. After the **EE** key is pressed, all further results are displayed in scientific notation format until **CLR** is pressed or until the calculator is turned off. Also, **INV** **EE** or **INV** **2nd** **Eng** can remove this format, but only if the displayed number is in the range $\pm 5 \times 10^{-11}$ to $\pm 1 \times 10^{10}$. When **EE** is pressed *after a result* (intermediate or final), internal (guard) digits 11, 12, and 13 are discarded and only the value in the display is used for further calculations.

Any number can be entered as the product of a value (mantissa) and 10 raised to some power (exponent). Just enter the mantissa (up to 8 digits), press **EE**, then enter the exponent (any 2 digits).



This capability allows you to work with numbers as small as $\pm 1 \times 10^{-99}$ or as large as $\pm 9.9999999 \times 10^{99}$. Numbers smaller in magnitude than .0000000001 or larger than 9999999999 must be entered in scientific notation. When the results of calculations exceed these limits, the calculator automatically shifts into scientific notation. The entry procedure is to key in the mantissa up to 8 digits (including its sign), then press **EE** and enter the exponent of 10 and its sign.

For example, the number 320,000,000,000 can be written as 3.2×10^{11} and can be entered into the calculator as:

Press	Display
CLR	0
3.2	3.2
EE	3.2 00
11	3.2 11



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More than 2 digits can be entered after pressing \boxed{EE} , but only the last two entered are retained as the exponent. This feature can be used to correct an erroneous exponent entry without having to clear the entry.

In scientific notation, a positive exponent indicates how many places the decimal point of the mantissa should be shifted to the right. If the exponent is negative, the decimal should be moved to the left.

Regardless of how a mantissa is entered for scientific notation, the calculator *normalizes* the number, displaying a single digit to the left of the decimal point, when any function or operation key is pressed.

Example: Enter 6025×10^{20}

Press	Display
\boxed{CLR}	0
6025	6025
\boxed{EE}	6025 00
20	6025 20
$\boxed{+}$	6.025 23

In scientific notation, the mantissa is limited to 8 digits to allow display space for the exponent. A mantissa resulting from a calculation is also displayed to 8 digits, but internally is carried to 13 digits. This 13-digit value is the one used for all ensuing calculations. See *Appendix C* for more on these extra digits.

Note: You cannot enter scientific notation format, even though \boxed{EE} is pressed, if there are more than 8 mantissa digits entered. If \boxed{EE} is pressed with more than 8 digits in the display, the display goes into scientific notation format when an operation or function key is pressed.

The change sign key can be used to attach a negative sign to the mantissa and to the power-of-ten exponent. Simply press $\boxed{+/-}$ after entry of the mantissa to change its sign or after the exponent to change its sign. To change the sign of the mantissa or to enter numbers in its decimal portion after the \boxed{EE} key has been pressed, press $\boxed{\cdot}$, then enter the mantissa's sign change or additional numbers to the decimal portion.

Example: Enter -4.962×10^{-12} then complete the decimal portion of the mantissa to read -4.96236×10^{-12} .

Press	Display	Comments
\boxed{CLR}	0	
4.962 $\boxed{+/-}$	-4.962	Enter mantissa and sign
\boxed{EE}	-4.962 00	
12 $\boxed{+/-}$	-4.962 -12	Enter exponent and sign
$\boxed{+/-}$	-4.962 12	Change exponent sign
$\boxed{\cdot}$ $\boxed{+/-}$	4.962 12	Change mantissa sign
36 $\boxed{+/-}$	-4.96236 12	Complete the mantissa



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Data in scientific notation form can be intermixed with data in standard form. The calculator converts the entered data for proper calculation. After the **EE** key is pressed, the calculator displays all the results in scientific notation format until **CLR**, **INV** **EE** or **INV** **2nd** **Eng** is pressed, or until the calculator is turned off. **CE** clears an entry in scientific notation, but the format remains.

Example: $1.816 \times 10^3 - 581.432191 = 1.2345678 \times 10^3 = 1234.567809$

Press	Display
CLR	0
1.816 EE	1.816 00
3 -	1.816 03
581.432191 =	1.2345678 03
INV EE	1234.567809

When **INV** **EE** is pressed to remove scientific notation and the number is outside of the range $\pm 1 \times 10^{10}$ to $\pm 5 \times 10^{-11}$, the calculator returns to standard format only when or if a calculated result comes into the displayable range.

Example: $(7 \times 10^{11} + 5 \times 10^{10}) \div 25 \div 25 = 1200000000$

Press	Display
7 EE	7 00
11 +	7. 11
5 EE	5 00
10 = INV EE	7.5 11
÷	7.5 11
25 = ÷	3. 10
25 =	1200000000.

If *calculations* exceed 9999999999 or go below .0000000001, the display automatically goes into scientific notation. When this occurs without the **EE** having been pressed during that calculation sequence, the display will automatically revert back to standard display format whenever numerically possible.

To convert a *calculated result* to a scientific notation, there are two approaches. The first is to press **X** **1** **EE** **=** which multiplies the number in the display register by 1×10^0 and converts the display to scientific notation. The complete 13-digit number is still present. The second method is to press **EE** **=**. You should be careful in using the second method. It has the effect of instructing the calculator to use the **ROUNDED** quantity being displayed for subsequent calculations discarding the guard digits.

You should avoid using the display commands which use **=** in the middle of a computation. The reason is that the **=** key completes all pending calculations. To avoid this, use these conversion methods only after computations are complete, or else multiply by **X** **1** **EE**, followed by another operation.



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ENGINEERING NOTATION

This modified form of scientific notation is accessed by pressing **2nd** **Eng**. The displayed value in this format consists of a mantissa and an exponent that are adjusted so that the exponent is a multiple of three (10^{12} , 10^{-6} , etc.) and the mantissa has 1, 2, or 3 digits to the left of the decimal point. This allows the calculator to display results in units that are readily usable such as 10^{-12} for picofarads, 10^{-3} for millimeters, 10^6 for megohms or 10^{-9} for nanoseconds.

Example: What is the diameter of a fibre in micrometers (1 micrometer = 10^{-6} meters) whose circumference is 3×10^{-3} meters?

$C = \pi d$	$d = C/\pi$
Press	Display
CLR 2nd Eng	0. 00
3 EE	3 00
3 +/- ÷	3. -03
2nd π =	954.92966 -06

Pressing **INV** **2nd** **Eng** removes this display format. Clearing operations or **INV** **EE** does not affect this format.

FIX-DECIMAL CONTROL

In standard display format, scientific notation or engineering notation, you can selectively choose the number of digits to display following the decimal point. Pressing **2nd** **Fix**, then entering the desired number of decimal places (0 to 8), instructs the calculator to round all displayed results to the selected number of decimal places. This rounding only affects the display, not the display register. So all further calculations use the full unrounded value.

Pressing **2nd** **Fix** 9 or **INV** **2nd** **Fix** returns the calculator to the standard display. Data entries can still be made with 10 digits (8 in scientific notation) with all subsequent calculations using the 13-digit unrounded results except the DMS-DD conversion that uses the displayed value only. Only the display is altered to the requested number of decimal places unless you press **EE** **INV** **EE** to discard the nondisplayed unit.

The *Constant Memory* feature of the TI Programmable 58C retains the fix-decimal setting. Therefore, a fix-decimal selection remains in effect until changed or until battery power is lost for an extended period.



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Be sure you have removed the display from Engineering Notation format in the previous example.

Example: $2/3 = .666666667$

Press	Display
2 \div	2.
3 $=$	.666666667
2nd Fix 5	0.66667
2nd Fix 2	0.67
2nd Fix 0	1.
INV 2nd Fix	.666666667

Remember that the display register value is *rounded* to the desired format.

Example: $1 \times 10^{-3} \div 2 = .0005$

Press	Display
1 EE	1 00
3 +/- \div	1.-03
2 $=$	5.-04
2nd Fix 2	5.00-04
INV EE	0.00
2nd Fix 3	0.001
2nd Fix 4	0.0005
2nd Fix 5	0.00050

Note that the zero that occurs about the middle of the example is not really a zero in the display register. The value just does not round into the fix-2 display format. Always be aware that the display register is not affected by the fix-decimal option.

FLASHING DISPLAY

The display flashes off and on whenever the limits of the calculator are violated or when an improper mathematical operation is requested. Press **CE** to stop the flashing without disturbing any calculations in progress. Calculations can continue from this point if the number in the display is still usable. **CLR** also stops a flashing display, but discards the display value and any calculations in progress. See *Appendix B* for a complete list of error and overflow/underflow conditions and the results they produce.



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ARITHMETIC CALCULATIONS

This calculator's method of entering numbers and operations allows straightforward entry of most problems just as they are mathematically stated. The calculator remembers each operation and, if necessary, stores it until the standard rules of algebra say that it can be applied.

Basic Functions — $\boxed{+}$ $\boxed{-}$ $\boxed{\times}$ $\boxed{\div}$ $\boxed{=}$

To perform simple addition, subtraction, multiplication or division, this calculator with its algebraic operating system allows you to key in the problem just as it is written.

Example: $1.6 \times 10^{-19} \times 6.025 \times 10^{23} = 9.64 \times 10^4$

Press	Display
$\boxed{\text{CLR}}$	0
1.6 $\boxed{\text{EE}}$	1.6 00
19 $\boxed{+/-}$ $\boxed{\times}$	1.6-19
6.025 $\boxed{\text{EE}}$	6.025 00
23 $\boxed{=}$	9.64 04

Notice that the $\boxed{=}$ key completes the arithmetic operation(s) and displays the final answer.

Pressing $\boxed{\text{CLR}}$ at the beginning of a new sequence clears any calculations in progress and always ensures that no pending operations remain from prior calculations.

This is not required if the previous problem used $\boxed{=}$ to obtain the result. Following $\boxed{=}$ with a numeric entry accomplishes the same as pressing $\boxed{\text{CLR}}$, except that $\boxed{=}$ does not remove scientific notation or stop a flashing display.

Pressing any two of the operations keys — $\boxed{+}$ $\boxed{-}$ $\boxed{\times}$ $\boxed{\div}$ $\boxed{y^x}$ — in succession causes a flashing display. Also, following any of these with $\boxed{=}$ or $\boxed{)}$, or preceding with $\boxed{(}$ causes a flashing display. See *Appendix B* for more on error conditions.

After a result is obtained in one calculation it may be directly used as the first number in a second calculation. There is no need to reenter the number from the keyboard.

Example: $1.84 + 0.39 = 2.23$ then $(1.84 + 0.39)/365 = .006109589$

Press	Display	Comments
1.84 $\boxed{+}$	1.84	
.39 $\boxed{=}$	2.23	1.84 + 0.39
$\boxed{\div}$	2.23	
365 $\boxed{=}$	0.006109589	2.23 ÷ 365



AN IN-DEPTH ANALYSIS OF FEATURES AND FUNCTIONS

Algebraic Operating System Entry Method

Algebraic hierarchy is an essential feature of the Algebraic Operating System method of entering numbers. To efficiently combine operations, the standard rules of algebraic hierarchy have been specifically programmed into the calculator.

These algebraic rules assign priorities to the various mathematical operations. Without a fixed list of priorities, expressions such as $5 \times 4 + 3 \times 2$ could have several meanings:

$$\begin{aligned}5 \times (4 + 3) \times 2 &= 70 \\ \text{or } (5 \times 4) + (3 \times 2) &= 26 \\ \text{or } ((5 \times 4) + 3) \times 2 &= 46 \\ \text{or } 5 \times (4 + (3 \times 2)) &= 50\end{aligned}$$

Algebraic hierarchy rules state that multiplication is to be performed before addition. So algebraically, the correct answer is $(5 \times 4) + (3 \times 2) = 26$. The complete list of priorities for interpreting expressions is:

1. Math Functions
 2. Exponentiation (y^x) and Roots ($\sqrt[x]{y}$)
 3. Multiplication, Division
 4. Addition, Subtraction
 5. Equals
-
1. Math functions (trigonometric, logarithmic, square, square root, e^x , 10^x , integer, absolute value, reciprocal and conversions) immediately replace the displayed value with its functional value.
 2. Exponentiation (y^x) and roots ($\sqrt[x]{y}$) are performed next.
 3. Multiplication and division are performed after completing math functions, exponentiation, root extraction and other multiplication and division.
 4. Addition and subtraction are performed only after completing all operations through multiplication and division as well as other addition and subtraction.
 5. Equals completes all uncompleted operations in the above order.



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An operation completes another operation of the same (or lower) priority level. Your calculator knows these rules and applies them to each problem as it is keyed in. Some operations are performed immediately while others are held pending until the rules say to perform them. To illustrate, consider the interpretive order of the following example:

Example: $4 \div 5^2 \times 7 + 3 \times 0.5^{\cos 60^\circ} = 3.241320344$

Press	Display	Comments
4 \div	4.	(4 \div) is stored
5 x^2	25.	(5 ²) special function x ² evaluated immediately
\times	0.16	(4 \div 5 ²) \div evaluated because \times is same priority as \div .
7 $+$	1.12	\times higher priority than $+$ so (4 \times 5 ² \times 7) evaluated, 1.12 $+$ stored
3 \times	3.	(3 \times) stored
.5 y^x	0.5	.5 y ^x stored
60 2^{nd} \cos	0.5	Cos 60° evaluated immediately
$=$	3.241320344	Completes all operations .5 ^{cos 60°} evaluated, then 3 \times .5 ^{cos 60°} next, then this is added to 1.12.

Thus, by entering the expression as it is written, the calculator correctly interprets it as

$$\{[(4 \div 5^2) \times 7] + (3 \times 0.5^{(\cos 60^\circ)})\}$$

The important things to remember here are that operations are enacted strictly according to their relative priority as stated in the rules. The calculator remembers all stored operations and recalls each and its associated number for execution at exactly the correct time and place. Once familiar with the order of these operations, you will find most problems are extremely easy to solve because of the straightforward manner in which they can be entered into the calculator. Additional control over the order of interpretation is provided through the use of parentheses.

Parentheses

There are sequences of operations for which *you* may need to instruct the calculator exactly how to evaluate the problem to produce the correct answer. Parentheses give you a way to “cluster” numbers and operations. By placing a series of numbers and operations in parentheses, you are instructing the calculator to interpret this expression first — down to a single number — and then proceed.



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To illustrate the benefit of parentheses, try the following experiment: Press (5×7) , and you will see the value 35 displayed. The calculator has evaluated 5×7 and replaced it with 35 even though the $=$ was not pressed. Because of this function of parentheses, the algebraic rules now apply their hierarchy of operations within each set of parentheses. Use of parentheses ensures that your problem can be keyed in just as you would have written it down. The calculator remembers each operation and evaluates each part of the expression as soon as all necessary information is available. When a close parenthesis is encountered, all operations back to the corresponding open parenthesis are completed. You should use parentheses if you have any doubts about how the calculator is going to handle an expression.

Even though expressions are normally written like $(3 + 2)(4 + 5)$ implying a multiply between parentheses sets, you must manually enter a multiply for the operation to take place. *Your calculator does not perform implied multiplication.*

Example: $4 \times (5 + 9) \div (7 - 4)^{(2 + 3)} = .2304526749$

Key in this expression and follow the path to completion.

Press	Display	Comments
4 \times (		4. $(4 \times)$ stored pending evaluation of parentheses
5 +		5. $(5 +)$ stored
9)		14. $(5 + 9)$ evaluated
\div		56. Hierarchy evaluates (4×14)
(		56. $(56 \div)$ stored pending evaluation of parentheses
7 -		7. $(7 -)$ stored
4)		3. $(7 - 4)$ evaluated
y^x (		3. Prepares for exponent
2 +		2.
3)		5. $(2 + 3)$ evaluated
$=$	.2304526749	$(7 - 4)^{(2 + 3)}$ evaluated then divided into $4 \times (5 + 9)$

There are limits on how many operations and associated numbers can be stored. Actually, as many as nine parentheses can be open at any one time and eight operations can be pending, but only in the most complex situations would this limit be approached. If you do attempt to open more than 9 parentheses or if the calculator tries to store more than eight operations, the display flashes.



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Example: $5 + \{8/[9 - (2/3)]\} = 5.96$

Press	Display	Comments
5 + (5.	
8 ÷ (8.	
9 - (9.	
2 ÷ 3)	.666666667	(2/3) evaluated
)	8.333333333	[9 - (2/3)] evaluated
)	0.96	8/[9 - (2/3)]
=	5.96	$5 + \{8/[9 - (2/3)]\}$

Because the **=** key has the capability to complete all pending operations whenever it is used, it could have been used here instead of the three **)** keys. Try working this problem again and pressing **=** instead of the first **)**.

Example: $3 \times \{4^{[2^{(-\sqrt[4]{7})}]}\} = 4.700043401$

Press	Display	Comments
CLR (	0.	
3 X (	3.	
4 y^x (	4.	
2 y^x (	2.	
7 INV y^x	7.	
4)	1.626576562	$\sqrt[4]{7}$
+/-	-1.626576562	$-(\sqrt[4]{7})$
)	.3238557891	$2^{-(\sqrt[4]{7})}$
)	1.566681134	$4^{.323...}$
)	4.700043401	$3 \times 4^{.323...}$

Each time a closed parenthesis is encountered, the contents are evaluated back to the nearest open parenthesis and are replaced with a single value. Knowing this you can structure the order of interpretation for whatever purpose you may want. Specifically, you can check intermediate results.



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DUMMY OPERATION WITH PARENTHESES

An additional technique to use with parentheses is the **CE** *dummy operation*. **CE** has the ability to reenter the display value a second time without having to key in the value again. Specifically, it can bring a value into a parenthesis set if it is needed twice in succession in an expression. Follow the example below.

Example: $3.296214 + (3.296214 \times 6) = 23.073498$

Press	Display	Comments
CLR 3.296214 +	3.296214	
(CE X	3.296214	CE reenters 3.296214
6)	19.777284	
=	23.073498	

The long value 3.296214 had to be entered only once.

ALGEBRAIC FUNCTIONS

The simplest operations to describe and understand are single-variable functions. These functions operate on the display register value immediately replacing this value with its corresponding function value. These functions do not interfere with any calculations in progress and can therefore be used at any point in a calculation. The accuracy of these functions is discussed in *Appendix C* and in text where necessary.

Reciprocal

1/x — **RECIPROCAL** — Calculates the reciprocal of the value, x, in the display register by dividing x into 1. A flashing display results if $x = 0$.

Press	Display
3.2 1/x	0.3125

Note that as soon as one of the math function keys is pressed, the displayed value is immediately replaced with its corresponding function value.



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Logarithms

lnx — **NATURAL LOGARITHM** — Calculates the natural logarithm (base e) of the value, x, in the display register. The display flashes if $x \leq 0$.

2nd **log** — **COMMON LOGARITHM** — Calculates the common logarithm (base 10) of the value, x, in the display register. The display flashes if $x \leq 0$.

Example: $\log(1 + \ln 1.7) = .1848697249$

Press	Display
CLR	0
(1 +	1.
1.7 lnx)	1.530628251
2nd log	.1848697249

Powers of 10 and e

INV **lnx** — **NATURAL ANTILOG** (e^x) — Calculates the natural antilogarithm e^x , of the value, x, in the display register. $-227.9559242 \leq x \leq 230.2585092$ or the display will flash.

INV **2nd** **log** — **COMMON ANTILOG** (10^x) — Calculates the common antilogarithm 10^x , of the value, x, in the display register. $-99 \leq x < 99.999999998$ or the display will flash.

Example: $e^{(3 + 10^{0.3})} = 147.7116873$

Press	Display
CLR (3 +	3.
.3 INV 2nd log)	4.995262315
INV lnx	147.7116873

Angle Calculations

Your calculator provides maximum flexibility when performing calculations involving angles.

ANGULAR MODES

Angles can be measured in decimal degrees, radians or grads (right angle = $90^\circ = \pi/2$ radians = 100 grads) by pressing either **2nd** **Deg**, **2nd** **Rad** or **2nd** **Grad**. The calculator powers-up in the degree mode and stays in that mode until altered by one of the other choices. Once in a certain angular mode, all entered and calculated angles are measured in the units of that mode until another mode is selected or until the calculator is turned off. **CE** and **CLR** do not affect the angular mode.

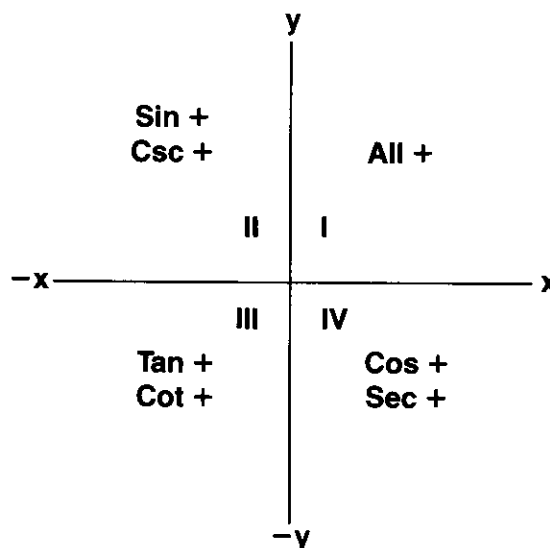
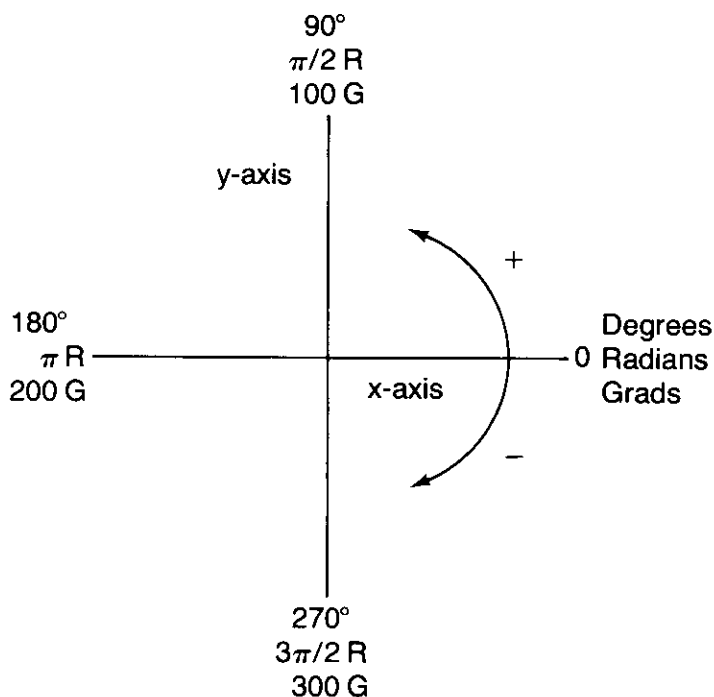
The angular mode has absolutely no effect on calculations unless the trigonometric functions or polar to rectangular conversions are being performed. Selecting the correct angular mode is easy to do — **AND EASY TO FORGET**. *Neglecting this step is responsible for a large number of errors in operating any calculation device that offers a choice of angular units.*



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TRIGONOMETRIC FUNCTIONS

2nd **sin**, **2nd** **cos**, **2nd** **tan** — **SINE, COSINE, TANGENT** — Calculates the sine, cosine or tangent of the value in the display register. All angles are measured from the X-axis. Measure counterclockwise for positive angles, clockwise for negative, as shown below.



The diagram on the right shows in which quadrant, I-IV, the listed trigonometric functions are positive. Those functions not listed in a particular quadrant have negative values.

When measuring angles, remember that each angle has an equivalent with the opposite sign. For instance $-45^\circ = 315^\circ$.

If your angle is expressed in degrees, minutes and seconds, the **D.M.S** key can convert it to decimal form for you. See Conversions on page V-30. Be sure your calculator is in the degree mode. If in doubt, press **2nd** **Deg**.

Example: $\sin 30^\circ 13' 48'' + \tan 315^\circ = -0.4965275891$

Press	Display
30.1348 2nd D.M.S	30.23
2nd sin +	.5034724109
315 2nd tan	-1.
=	-.4965275891



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Trigonometric values can be calculated for angles greater than one revolution. As long as the trig function is displayed in standard format rather than in scientific notation, all digits displayed in standard display format are accurate to ± 1 in the 10th digit for the range of $\pm 36,000$ degrees, $\pm 200\pi$ radians or $\pm 40,000$ grads. In general, the accuracy decreases one digit for each decade outside of this range. If the argument x is greater than $\pm 3.6 \times 10^{14}$ degrees (4.0×10^{14} grads) or $\pm 6.2799993 \times 10^{12}$ radians, no partial rotation is recognized. See Appendix C for more on accuracy.

The other trig functions can be calculated almost as easily.

cot =	2nd	tan	1/x
sec =	2nd	cos	1/x
csc =	2nd	sin	1/x

INVERSE TRIGONOMETRIC FUNCTIONS

INV — **INVERSE** — Preceding another key, it reverses the function of that key. When used with the trig functions, the inverse of those functions is obtained. For example, arcsine (\sin^{-1}) is obtained by pressing **INV** **2nd** **sin**.

The inverse trig functions calculate the angle whose functional value is in the display. The largest angle resulting from an arc function is 180 degrees (π radians or 200 grads). Because these functions have many angle equivalents, i.e., $\arcsin .5$ for 30° , 150° , 390° , etc., the angle returned by each function is restricted as follows:

ARC FUNCTION	RANGE OF RESULTANT ANGLE
$\arcsin x$	0 to 90° , $\pi/2$ radians, or 100G
$\arcsin (-x)$	0 to -90° , $-\pi/2$ radians, or $-100G$
$\arccos x$	0 to 90° , $\pi/2$ radians, 100 G
$\arccos (-x)$	90° to 180° , $\pi/2$ to π radians, or 100 to 200 G
$\arctan x$	0 to 90° , $\pi/2$ radians, or 100G
$\arctan (-x)$	0 to -90° , $-\pi/2$ radians, or $-100G$

For $\arcsin x$ and $\arccos x$, $-1 \leq x \leq 1$ or the display will flash.

Example: $\pi/4 + \tan^{-1}(.2\pi) = 1.34638028$

Press	Display
2nd Rad	0
2nd π \div	3.141592654
4 +	.785391634
(.2 X 2nd π)	.6283185307
INV 2nd tan	.5609821161
=	1.34638028

The selection of the radian mode could have been made at any point before **INV** **2nd** **tan**. It is generally best, though, to select the angular mode at the start of a problem. This assures that the mode is correctly set before you get involved in keying in the problem. The angular mode, whenever selected, only affects angle measurements.



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The inverses of the other trig functions can be calculated as follows.

$$\begin{aligned} \operatorname{arccot} &= \boxed{1/x} \boxed{\text{INV}} \boxed{2\text{nd}} \boxed{\tan} \\ \operatorname{arcsec} &= \boxed{1/x} \boxed{\text{INV}} \boxed{2\text{nd}} \boxed{\cos} \\ \operatorname{arccsc} &= \boxed{1/x} \boxed{\text{INV}} \boxed{2\text{nd}} \boxed{\sin} \end{aligned}$$

DEGREE, RADIAN, GRAD CONVERSIONS

It is frequently necessary to convert angular values from one unit of measurement to another. Use the following table of conversion factors for the purposes you need.

FROM \ TO	degrees	radians	grads
degrees		$\times \frac{\pi}{180}$	$\div 0.9$
radians	$\times \frac{180}{\pi}$		$\times \frac{200}{\pi}$
grads	$\times 0.9$	$\times \frac{\pi}{200}$	

These operations can be performed in any angular mode setting of the calculator.

Example: Convert 120 degrees to radians and grads.

Press	Display	Comments
120 \times $\boxed{2\text{nd}}$ $\boxed{\pi}$ $\boxed{\div}$	376.9911184	
180 $\boxed{=}$ $\boxed{\times}$	2.094395102	Radians
200 $\boxed{\div}$ $\boxed{2\text{nd}}$ $\boxed{\pi}$ $\boxed{=}$	133.3333333	Grads
$\boxed{\times}$	133.3333333	
.9 $\boxed{=}$	120.	Degrees

Because of the independence of these conversions from the angular mode of the calculator, you must be extremely careful when using the results for further calculations. *The angular mode must be selected to match the units of the results.*



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Integer And Absolute Value

2nd **Int** — **INTEGER** — Discards the fractional part of the number in the display register. **INV** **2nd** **Int** discards the integer portion of the number in the display register.

2nd **|x|** — **ABSOLUTE VALUE** — Makes the value in the display register positive.

Example: Find the absolute value of the integer portion of $-13/5$.

Press	Display
13 +/- ÷	-13.
5 =	-2.6
2nd Int	-2.
2nd |x|	2.

These functions are particularly useful in programming sequences.

Remember that the integer sequence operates on the value in the display register not the displayed value. This means that when **2nd** **Int** is pressed and 4.9999999999 is in the display register (which rounds to 5 in the display) that 4 will be the integer that remains in the display. To obtain a 5 in the display after **2nd** **Int**, press **EE** **INV** **EE** first to truncate the nondisplayed digits.

In scientific notation, only the actual fractional part of a number is discarded by the integer key, not the apparent fraction. For instance, 1.2345×10^3 **2nd** **Int** yields 1.234×10^3 . Actually 1234.5 becomes 1234.

Square And Square Root

x² — **SQUARE** — Calculates the square of the number in the display register. If $|x| \geq 10^{\pm 50}$, the display will flash.

√x — **SQUARE ROOT** — Calculates the square root of the number in the display register. If x is negative, the display will flash.

Example: $[\sqrt{3.1452 - 7 + (3.2)^2}]^{1/2} = 2.239078197$

Press	Display
CLR (0.
3.1452 √x -	1.773471173
7 +	-5.226528827
3.2 x²	10.24
)	5.013471173
√x	2.239078197



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Roots and Powers

y^x — **POWERS** — Raises the display register value, y to the x power. The entry sequence is y **y^x** x followed by an operation or equals key. If $y < 0$, the display will flash.

$\text{INV } y^x$ — **ROOTS** — ($\sqrt[x]{y}$ or $y^{1/x}$) — Takes the x root of the value, y , in the display register. The entry sequence is y **$\text{INV } y^x$** x followed by an operation or equals key. If $y < 0$ or $x = 0$ or if $y = 0$ and $x < 0$, the display will flash.

These math functions do not act on the display register immediately. They require entry of a second value followed by an operation before the function can be realized.

Example: $\sqrt[3]{2.36^{-.23}} = .9362893421$

Press	Display	Comments
2.36 y^x	2.36	Enter y for y^x
.23 $+/-$	-0.23	Enter x for y^x
$\text{INV } y^x$	.8207865654	Produces y for $\sqrt[x]{y}$
3 $=$	.9362893421	Enter x for $\sqrt[x]{y}$ and produce answer.

The y^x functions use logarithms to evaluate these functions and the standard mathematical definitions yield the following reactions to various x and y combinations. Quote marks indicate a flashing display.

Function Reaction

y	x	y^x	$\sqrt[x]{y}$
0	0	1.	"1."
0	- x	"9.9999999 99"	"9.9999999 99"
0	x	0.	0.
1	0	1.	"1."
y	0	1.	"9.9999999 99"
-1	0	"1."	"1."
- y	0	"1."	"9.9999999 99"
- y	$\pm x$	" $ y ^{\pm x}$ "	" $\sqrt[\pm x]{ y }$ "



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MEMORY CAPABILITIES

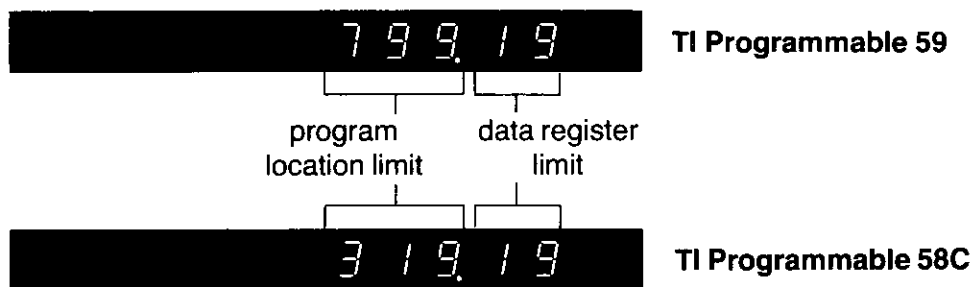
User-accessible data memory registers allow you to store or accumulate data for later use. These storage areas are generally just referred to as data memory or data registers as opposed to program memory where programs are stored. You can use the memory keys at any point in a calculation because they do not affect calculations in progress. Also, the memory contents of the TI Programmable 58C are not lost when the unit is turned off or when battery power is removed for short periods.

It is usually arbitrary what values are stored where in data memory except that registers 01-06 are used internally if you are working mean and standard deviation calculations. If you want to preserve any values and perform these statistical calculations, use memory registers other than 01-06. If you are using very many data registers for storage, you will probably need some form of bookkeeping to remember what values are stored in which registers.

Selection of Memory Size (Partitioning)

Throughout this discussion, information about the TI Programmable 58C will follow that for the 59 and are in parentheses in bold type.

When the calculator is first turned on there are 60 (**30**) registers reserved for data storage. The TI Programmable 58C retains the selected partitioning in the *Constant Memory* and does not change when the calculator is turned off or on. The data registers are part of the memory storage area where programs are stored as well as data. You can partition this area 10 registers at a time into different ratios of program to data space according to your needs. Enter the number of sets of 10 registers you need for data storage and press **2nd** **Op** **17**. For example, for 20 data registers, press **2** **2nd** **Op** **17** and the display shows the following:



This shows that there are 20 registers available for data storage, 00-19, and 800 (**320**) locations set aside for program storage. **Remove all fix-decimal, scientific notation and engineering formats before partitioning.** Actually, there are 8 program locations in each register not requested for data storage.

To check the current placement of the partition at any time, press **2nd** **Op** **16** and the existing partition is displayed in the format shown above. For more on partitioning, see *Storage Capacity and Partitioning* on page V-42.

Because you can use up to 100 (**60**) data registers, you must specify which data register you are using by entering its 2-digit address, **XX** immediately after pressing any memory related key. Failure to enter a memory address results in a flashing of the current display value. You can, however, use a short form of addressing and enter a single digit address if the address is less than 10 then follow it with a nonnumeric key entry. This totally flexible memory system can manipulate data in a variety of ways.



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Clearing Data Memory

2nd **CMs** — **CLEAR DATA MEMORY** — Instructs the calculator to clear all data memory registers as defined by the current partition.

Use of this key does not affect the T-register, program memory, memory partitioning, the display, or calculations in progress.

Storing And Recalling Data

STO **XX** — **STORE** — Stores the display register value into memory register **XX**. Any previously stored data in register is cleared.

RCL **XX** — **RECALL** — Recalls and displays the value stored in data register **XX** and retains the value in register **XX**. A recalled number can be used as a number entry in any mathematical expression.

Example: Store and recall 3.012 in memory 22.

Press	Display
3.012 STO 22	3.012
CLR	0
RCL 22	3.012

Use of these keys can save you keystrokes by storing long numbers that are to be used several times.

Example: Evaluate $3x^2 - x - 7.1$ for $x = 2.9467281$

Press	Display
CLR 3 X	3.
2.9467281 STO 12	2.9467281
x² -	26.04961949
RCL 12	2.9467281
- 7.1 =	16.00289139

The long value of x only had to be entered once. The storage and recall did not interfere with calculations in progress.



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You can also use the data memories to hold intermediate results as well as repetitive numbers.

Example: Evaluate $\frac{\sin(3x/2) - \cos(3x/2)}{x}$ for $x = 20.6821776$ degrees

Press	Display	Comments
2nd CMs ((3 X	3.	
20.6821776 STO 14	20.6821776	Store x in register 14
÷ 2) STO 17	31.0232664	Store 3x/2 in register 17
2nd SIN -	.5153861069	
RCL 17	31.0232664	Recall 3x/2 from register 17
2nd COS) ÷	-.3415719789	
RCL 14	20.6821776	Recall x from register 14
=	-.0165152812	Answer

Attempting to use a register beyond the partition causes the display to flash.

Direct Register Arithmetic

You can store a displayed number at any time during a calculation without affecting the calculation in any way. Additionally, you can add, subtract, multiply and divide the display register value with any data register. The display register itself is not changed. A flashing display following one of these operations indicates that you have exceeded the calculator's operating limit in that register (assuming that you did not call for a register number outside of the current partition that also flashes the display).

SUM XX — MEMORY SUM — adds the display register value to the contents of data register **XX** and stores the result in **XX**.

INV SUM XX — MEMORY SUBTRACT — Subtracts the display register value from the contents of data register **XX** and stores the result in **XX**.

2nd Prd XX — MEMORY PRODUCT — Multiplies the contents of data register **XX** by the display register value and stores this product in **XX**.

INV 2nd Prd XX — MEMORY DIVIDE — Divides the contents of data register **XX** by the display register value and stores the result in **XX**.

These capabilities eliminate the lengthy recall perform operations, store-again sequences.

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AN IN-DEPTH ANALYSIS OF FEATURES AND FUNCTIONS

Example: Evaluate $x^2 + 9$ for $x = -1, 2,$ and 3 and total the results.

Press	Display	Memory 3
1 \pm/\mp x^2 $+$	1.	0
9 $=$ STO 03	10.	10
2 x^2 $+$	4.	10
9 $=$ SUM 03	13.	23
3 x^2 $+$	9.	23
9 $+$	18.	23
RCL 3	23.	23
$=$	41.	23

Notice that the first evaluation was placed in memory 03 using the STO key. This is a recommended procedure when performing direct register arithmetic to ensure that you are accumulating only the values you need in that particular register. The STO clears any previous content of that register before storing the new value.

Example: The percentage of students completing each year at a particular college is 76.8% first year, 81.3% second year, 92.2% third year and 95.9% last year. What percentage of the students graduate and what percentage complete their third and fourth years?

Press	Display
.768 \times	0.768
.813 \times	0.624384
.922 STO 11 \times	0.575682048
.959 2nd Prd 11 $=$	0.552079084
RCL 11	0.884198

About 55% of the students that enter the school graduate. Over 88% of those entering their junior year graduate.



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AN IN-DEPTH ANALYSIS OF FEATURES AND FUNCTIONS

Memory/Display Exchange

2nd **Exc** **XX** — **MEMORY EXCHANGE** — Exchanges the contents of data register **XX** with the display register. The display value is stored and the previously stored value is displayed.

The exchange key has several uses in addition to saving keystrokes. You can use it to examine two results without losing either. Also, numbers can be temporarily stored in **XX** and used as needed.

Example: Evaluate $A^2 + AB + 2B^2$ for $A = .258963$ and $B = 1.255632$

Press	Display	Comments
.258963 STO 13	0.258963	Store A in register 13
x² + 1.255632 X	1.255632	Enter B
2nd Exc 13	0.258963	Store B, recall A
+ 2 X	2.	
RCL 13	1.255632	Recall B from register 13
x² =	3.545447504	Answer



AN IN-DEPTH ANALYSIS OF FEATURES AND FUNCTIONS
SPECIAL CONTROL OPERATIONS

There are a series of operations accessed through use of the **Op** key that can greatly boost the capabilities of your calculator. Some of these special operations can be used in any calculator mode while others are designed for a specific mode or for use with optional **PC-100A or PC-100C Print Cradle**.

Each special control operation is called by pressing **2nd Op nn** where **nn** is the 2-digit code assigned to each operation (short form addressing can be used here). Brief code descriptions are listed below with complete definitions following. When **nn >39** (40 for the TI Programmable 58C) the display flashes.

Code nn	Function
00*	Initialize print register
01*	Enters 10 digits in display as 5 alphanumeric codes for far left quarter of print column.
02*	Enters 10 digits in display as 5 alphanumeric codes for inside left quarter of print column.
03*	Enters 10 digits in display as 5 alphanumeric codes for inside right quarter of print column.
04*	Enters 10 digits in display as 5 alphanumeric codes for far right quarter of print column.
05*	Print the contents of the print register.
06*	Print last 4 characters of OP 04 with current display value.
07*	Plot a * in column 0-19 as specified by the display.
08*	List the labels currently used in program memory.
09	Bring previously specified library program into program memory.
10	Apply signum function to display register value.
11	Calculate variances.
12	Calculate slope and intercept.
13	Calculate correlation coefficient.
14	Calculate new y prime (y') for an x in the display.
15	Calculate new x prime (x') for a y in the display.
16	Display current partition of memory storage area.
17	Repartition memory storage area.
18	If no error condition exists in a program, set flag 7 .
19	If an error condition exists in a program, set flag 7 .
20-29	Increment a data register 0-9 by 1.
30-39	Decrement a data register 0-9 by 1.
40*	Sets flag 7 if the print cradle is attached (TI Programmable 58C only).

*Designed specifically for use with optional **PC-100A or PC-100C Print Cradle**



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Printer Capabilities — Op 00-08

These control operations are designed for use with the optional PC-100A or PC-100C printer. The printer increases the flexibility of your calculator by providing "hard copy" results of your calculations. The control operations further expand the benefit of the printer by furnishing the options to print alphanumeric messages, to plot data and to list the labels present in a program along with their program locations. The next section on *PRINTER CONTROL* on page VI-7 details the use of each of these special control operations.

Analysis of Library Program (Downloading) — Op 09

Pressing **2nd** **Pgm** **mm** **2nd** **Op 09** brings a copy of library program **mm** into program memory. Here the keyboard operations for program analysis and editing can be used to dissect and alter the program for your particular needs. Beware of the effects that editing has on absolute addressing and combined key codes. When a library program is brought into program memory, it replaces any instructions previously occupying those locations beginning at location 000. There are no provisions for transferring a program from program memory onto the library module. If a program is too large to download into program memory because of either placement of the partition or memory size itself, the library program does not download and the display flashes. The display also flashes if program **mm** is not on the module currently in the calculator or if the module is not in the calculator. Programs of a proprietary library cannot be downloaded.

Signum Function — Op 10

Special control **Op 10** applies the signum function to the value "x" currently in the display register and responds with the following.

Display Register Value x	Display Response
$x > 0$	1.
$x = 0$	0.
$x < 0$	-1.

Statistics — Op 11-15

The special control operations 11-15 are used for statistical analysis and are discussed fully in the following section on *CONVERSIONS AND STATISTICS*.



AN IN-DEPTH ANALYSIS OF FEATURES AND FUNCTIONS

Partitioning — **Op** 16-17

Pressing **2nd** **Op** **16** immediately displays the current partition location between program and data memories. The last location of program memory and the highest numbered data register currently available are displayed, separated by a decimal point. The TI Programmable 59 is initially partitioned at 479.59, the TI Programmable 58C at 239.29. However, the TI Programmable 58C retains any partition selected unless changed or the battery pack is removed for an extended period.

To repartition the memory area, enter the number of sets of 10 data registers needed and press **2nd** **Op** **17** and the new partition is displayed as above. **Remove all fix-decimal, scientific notation and engineering formats before partitioning.** See *Storage Capacity and Partitioning* in the GENERAL PROGRAMMING section.

Test Operations — **Op** 18-19

Operations 18 and 19 are designed to monitor the error status of a program that is running. When encountered in a program, **2nd** **Op** **18** sets flag 7 if no error condition exists. **2nd** **Op** **19** sets flag 7 if an error condition does exist. Flag 7 can then be monitored by the “if flag” test instruction and appropriate action can then be taken from the results of the test. If the test is false, flag 7 is not changed. See the programming section *Flags* on page V-65 for more information.

Increment/Decrement Data Registers — **Op** 20-29/30-39

The OP instruction also allows you to increment or decrement the contents of any data register 0-9 by 1.

To increment register **n** by 1, press **2nd** **Op** **2n**, where **n** is a data register number 0-9.

To decrement register **n** by 1, press **2nd** **Op** **3n**, where **n** is a data register number 0-9.

Each time either of these sequences is pressed or encountered in a program the contents of register **n** are appropriately adjusted by 1 regardless of the content of register **n**.

For example, **2nd** **Op** **34** subtracts 1 from the contents of data register 4.

Printer Test Operation — **Op** 40 (TI Programmable 58C only)

If the TI Programmable 58C is attached to the PC-100A or PC-100C printer the sequence **2nd** **Op** **40** will cause flag 7 to be set. Without the printer attached, this operation code has no effect on flag 7.



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AN IN-DEPTH ANALYSIS OF FEATURES AND FUNCTIONS

CONVERSIONS AND STATISTICS

There are several mathematical sequences that have been programmed into your calculator. These calculations use up to 4 pending operations and 1 level of the subroutine return register. The pending-operation registers used by these functions are the same registers used by the alphanumeric printing operations. Be sure alphanumeric data entered with **2nd** **Op** 03 or **2nd** **Op** 04 is printed before using Conversion or Statistic functions.

Conversions

Your calculator can readily convert between the polar and rectangular coordinate systems. It can also transform angles expressed in degrees, minutes and seconds to decimal degrees and vice versa.

ANGLE CONVERSIONS

2nd **D.MS** — **DEGREES, MINUTES, SECONDS TO DECIMAL DEGREES** — Converts an angle measured in degrees, minutes and seconds to its decimal degrees equivalent. **INV** **2nd** **D.MS** reverses this conversion. Minutes and seconds can each be any two-digit number. This conversion operates on the displayed value only.

The input format for degrees, minutes and seconds is to a place decimal point between the degrees and minutes, **DD.MMSSsss**. Occasionally, when converting to the degree, minute-second format, minutes or seconds may indicate 60 due to rounding. This simply indicates to round up to the next highest degree (or minute for 60 seconds).

Press	Display	Comments
47.131272 2nd D.MS	47.2202	DD.dddd
INV 2nd D.MS	47.131272	DD. MMSSsss

DD represents degrees and **dd** is for the decimal fraction of a degree. **MM** is minutes and **SSsss** is for seconds and fractional parts of seconds. The trig functions only recognize decimal degrees not minutes and seconds. So the D.MS conversion must be performed on all angle measurements involving minutes and seconds. Be sure to use two digits each for minutes and seconds. For instance, 5°4'3" must be entered as 5.0403 to be interpreted correctly.

POLAR/RECTANGULAR SYSTEM CONVERSIONS

x↔t — **x EXCHANGE t** — Exchanges the display register value **x** with the T-register value **t**. This key is used for data entry with coordinate conversions, statistics and certain conditional testing procedures in programming.

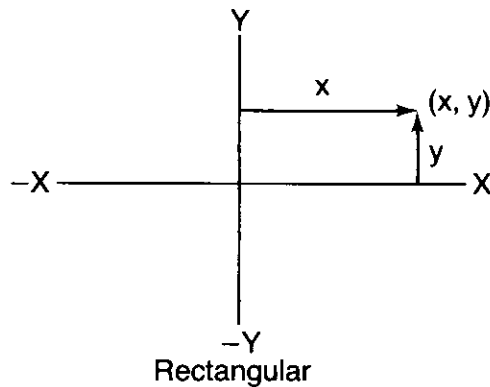
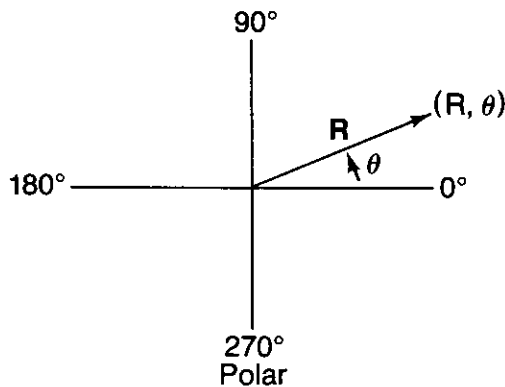
This T-register is independent of all other storage areas, but functions essentially like a data register. It is only externally accessible through the **x↔t** key that places the display register value into the T-register and brings the contents of the T-register into the display register and the display as well.

2nd **P↔R** — **POLAR/RECTANGULAR** — Converts polar coordinates to rectangular. **INV** **2nd** **P↔R** converts rectangular coordinates to polar.



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The polar/rectangular conversion is used to convert from polar coordinates which describe any point by a radius “R” and an angle theta “ θ ” to rectangular coordinates which describe any point by two vectors “x” and “y” measured at right angles to each other.



Polar To Rectangular Sequence

- Enter “R”
- Press $\boxed{\text{x} \rightarrow \text{t}}$
- Enter “ θ ”
- Press $\boxed{2\text{nd}} \boxed{\text{P} \rightarrow \text{R}}$ to display “y”
- Press $\boxed{\text{x} \rightarrow \text{t}}$ to display “x”

Rectangular to Polar Sequence

- Enter “x”
- Press $\boxed{\text{x} \rightarrow \text{t}}$
- Enter “y”
- Press $\boxed{\text{INV}} \boxed{2\text{nd}} \boxed{\text{P} \rightarrow \text{R}}$ to display “ θ ”
- Press $\boxed{\text{x} \rightarrow \text{t}}$ to display “R”

Be sure to set the desired **angular mode** for θ whether input or calculated.

The “ θ ” calculated from the rectangular to polar sequence is:

$$\left. \begin{array}{l} -90^\circ \\ -\pi/2 \text{ rad} \\ -100 \text{ grad} \end{array} \right\} \leq \theta < \left\{ \begin{array}{l} 270^\circ \\ 3\pi/2 \text{ rad} \\ 300 \text{ grad} \end{array} \right.$$

This says that calculated angles that occur in the fourth quadrant are displayed as negative angles.

This conversion routine monitors the angular mode of the calculator to determine the angular units desired for both entry and retrieval of data.

Example: Convert to rectangular coordinates:

$$R = 5, \theta = 30^\circ$$

Set angular mode to degrees.

Press	Display	Comments
$\boxed{5} \boxed{\text{x} \rightarrow \text{t}}$	0.	Enter “R”
$\boxed{30} \boxed{2\text{nd}} \boxed{\text{P} \rightarrow \text{R}}$	2.5	Enter “ θ ”, display value of “y”
$\boxed{\text{x} \rightarrow \text{t}}$	4.330127019	Value of “x”



AN IN-DEPTH ANALYSIS OF FEATURES AND FUNCTIONS

Example: Convert to polar coordinates (radians):

$$x = 3, y = 4$$

Press	Display	Comments
CLR 2nd Rad	0	Set angular mode to radians
3 x\leftrightarrowt	0.	Store "x"
4 INV 2nd P\leftrightarrowR	0.927295218	Enter "y", display value of " θ " radians
x\leftrightarrowt	5.	Value of "R"

P \leftrightarrow R and D.MS \leftrightarrow DD.dd conversions each use one level of subroutine and up to 4 pending operations.

Polar/rectangular conversions are especially useful for vector computations.

Statistics

Many times it is desirable to express one variable in terms of another even though the variables may not be well defined functions of each other. These variables can be entered as points on a graph with the so-called independent variable carried on the x-axis and the dependent variable plotted on the y-axis. The collection of points can then be analyzed by finding the mean, standard deviation and variance of each of the variables. A straight line can be fitted to the points (linear regression) with the slope and intercept of the line accessible to the user. From here additional data points can be interpolated or extrapolated and a correlation coefficient is available to tell you how closely the line approximates the collection of data points.

DATA ENTRY

2nd **Pgm** **1** **SBR** **CLR** — Initializes calculator for statistics by zeroing data registers 01-06 and the T-register. A library module must, of course, be in the calculator for this sequence to work. Otherwise, you must clear data registers 01-06 and the T-registers manually or in your program.

x \leftrightarrow t — **x EXCHANGE t** — Exchanges the T-register value t with the display register value x. In statistics, enters the independent (x) variable into the calculator.

2nd **$\Sigma+$** — **STATISTICS SUM** — Assimilates each variable pair (x_i, y_i) into data registers 01-06.

INV **2nd** **$\Sigma+$** removes unwanted data point (pair of values).

To enter a single variable array of data, key in each value and press **2nd** **$\Sigma+$** . A faulty entry is removed by reentering the unwanted value (pair) and pressing **INV** **2nd** **$\Sigma+$** . After each entry (or removal) the total number of values entered is displayed.



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Two dimensional statistical data are entered using the following key sequence for each data point (x_i, y_i) , $i = 1, 2, 3 \dots N$.

x_i $\boxed{x \div t}$ y_i $\boxed{2nd}$ $\boxed{\Sigma+}$

The data point number i is displayed after each point is entered. To remove an unwanted data point, reenter **both the undesired x and y values again**, but press \boxed{INV} immediately before $\boxed{2nd}$ $\boxed{\Sigma+}$. The total number of points N input up to there is automatically decremented by 1.

As each data point is keyed in it is assimilated into data memory registers 01-06 as follows.

MEMORY REGISTER	CONTENTS
01	Σy } dependent variable
02	Σy^2 }
03	N
04	Σx } independent variable
05	Σx^2 }
06	Σxy

Data that have already been so grouped can be entered directly into these registers and analysis can begin immediately.

The calculator "SUMS" the incoming values into these memory registers. The contents of these registers should initially be cleared to prevent an erroneous accumulation of statistical data. The key sequence $\boxed{2nd}$ \boxed{Pgm} $\boxed{1}$ \boxed{SBR} \boxed{CLR} should be used to zero registers 01-06 and the T-register before data entry.

MEAN, VARIANCE AND STANDARD DEVIATION

After all the data are entered (or at any intermediate point after 2 or more data points have been entered), the mean, standard deviation and variance of each array of data can be calculated.

$\boxed{2nd}$ $\boxed{\bar{x}}$ — Calculates and displays the mean of the dependent (y-array) data. Press $\boxed{x \div t}$ next to display the mean of the independent (x-array) data.

\boxed{INV} $\boxed{2nd}$ $\boxed{\bar{x}}$ — Calculates and displays the standard deviation of the dependent (y-array) data. When $\boxed{x \div t}$ is pressed next, the standard deviation of the independent (x-array) data is displayed.

$\boxed{2nd}$ \boxed{Op} $\boxed{11}$ — Calculates and displays the variance of the dependent (y-array) data. When $\boxed{x \div t}$ is pressed next, the variance of the independent (x-array) data is displayed.



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AN IN-DEPTH ANALYSIS OF FEATURES AND FUNCTIONS

The following equations are used by the calculator.

$$\text{Mean of x-array} = \bar{x} = \frac{\sum x}{N} \qquad \text{Mean of y-array} = \bar{y} = \frac{\sum y}{N}$$

where N is the total number of data points entered.

$$\text{Standard Deviation of x-array} = \sigma_x = \left[\frac{\sum x^2 - \frac{(\sum x)^2}{N}}{N - 1} \right]^{1/2}$$

$$\text{Standard Deviation of y-array} = \sigma_y = \left[\frac{\sum y^2 - \frac{(\sum y)^2}{N}}{N - 1} \right]^{1/2}$$

$$\text{Variance of x-array} = \sigma_x^2 = \frac{\sum x^2}{N} - \bar{x}^2$$

$$\text{Variance of y-array} = \sigma_y^2 = \frac{\sum y^2}{N} - \bar{y}^2$$

For your convenience, the option has been provided to select N or N-1 weighting for standard deviation and variance calculations. N weighting results in a maximum likelihood estimator that is generally used to describe populations, while the N-1 is an unbiased estimator customarily used for sampled data.

The variance function uses N weighting and standard deviation uses N-1 weighting. Variance is the square of the standard deviation by definition. So, to find the variance with N-1 weighting, press **INV** **2nd** **\bar{x}** **x^2** and **$x \div t$** **x^2** and standard deviation with N weighting is likewise found by pressing **2nd** **0p** **11** **\sqrt{x}** and **$x \div t$** **\sqrt{x}** . See the table below for these key sequences.

Function	Weighting	Key Sequences	
		y-array	x-array
Mean		2nd \bar{x}	$x \div t$
Standard Deviation	N	2nd 0p 11 \sqrt{x}	$x \div t$ \sqrt{x}
Variance	N	2nd 0p 11	$x \div t$
Standard Deviation	N-1	INV 2nd \bar{x}	$x \div t$
Variance	N-1	INV 2nd \bar{x} x^2	$x \div t$ x^2



AN IN-DEPTH ANALYSIS OF FEATURES AND FUNCTIONS

For single variable data, you do not need to use the \bar{x} key as this key is needed only for entering and displaying attributes of independent variables (x-array). Memory registers 01-06 and the T-register are all still used.

Example: Analyze the following test scores: 96, 81, 87, 70, 93, 77

Press	Display	Comments
2nd Pgm 1 SBR CLR	0	Initialize
96 2nd $\Sigma+$	1.	1st Entry
81 2nd $\Sigma+$	2.	2nd Entry
97 2nd $\Sigma+$	3.	3rd Entry (incorrect)
97 INV 2nd $\Sigma+$	2.	Remove 3rd Entry
87 2nd $\Sigma+$	3.	Correct 3rd Entry
70 2nd $\Sigma+$	4.	4th Entry
93 2nd $\Sigma+$	5.	5th Entry
77 2nd $\Sigma+$	6.	6th Entry
INV 2nd \bar{x}	9.879271228	Standard Deviation
2nd \bar{x}	84.	Mean
2nd Op 11	81.33333333	Variance
RCL 01	504.	Total of Scores (Σy stored in R ₁)

Note that the standard deviation can be calculated first even though the mean is used to determine the standard deviation.

Example: A quantity of tubing has been ordered cut into 100 cm long sections to be checked for length accuracy and uniformity that should be 6.0 gm/cm \pm 0.01. The test requires that 6 samples be analyzed at a time.

Sample	1	2	3	4	5	6
Length (cm)	101.3	103.7	98.6	99.9	97.2	100.1
Weight (gm)	609	626	586	594	579	605

What is the average weight of the samples taken? How accurate is the cutting machine? What is the uniformity of the samples?



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Press	Display	Comments
2nd Pgm 1 SBR CLR	0	Initialize
101.3 x↵	0.	Enter x_1
609 2nd Σ+	1.	Enter y_1
103.7 x↵	102.3	Enter x_2
626 2nd Σ+	2.	Enter y_2
98.6 x↵	104.7	Enter x_3
586 2nd Σ+	3.	Enter y_3
99.9 x↵	99.6	Enter x_4
594 2nd Σ+	4.	Enter y_4
97.2 x↵	100.9	Enter x_5
579 2nd Σ+	5.	Enter y_5
100.1 x↵	98.2	Enter x_6
605 2nd Σ+	6.	Enter y_6
2nd x̄	599.833333	Average of y array (weight)
÷ x↵	100.133333	Average of x array (length)
=	5.990346205	Average uniformity (gm/cm)
INV 2nd x̄	17.05774509	Weight deviation
x↵	2.240238083	Length deviation

The average weight of the samples is about 599.8 grams. The machine is cutting the length to about 100.1 centimeters. The uniformity is better than 5.99 grams/centimeter, easily within the acceptable tolerance. In addition, the standard deviation of the weights of the various pieces is about 17 grams with the lengths deviating by about 2¼ centimeters on the average.

LINEAR REGRESSION

2nd **Op** 12 — Calculates and displays the y-intercept of the line fitted to the data points. **x↵** when pressed after **2nd** **Op** 12 displays the slope of the line fitted to the data points. Data points that depict a vertical line are a special case that has no y-intercept and has an infinite slope and is an invalid operation for this calculator. Calculating the correlation coefficient (**2nd** **Op** 13) detects a vertical or horizontal line by flashing the display.

2nd **Op** 13 — Calculates and displays the correlation coefficient of the individual data points in relation to the line fitted to these points. The value will be between -1 and 1 with ±1 being a perfect correlation. If the slope of the line is 0 or infinite, the display flashes. This condition can be monitored in a program through use of **2nd** **Op** 19 and program flags.

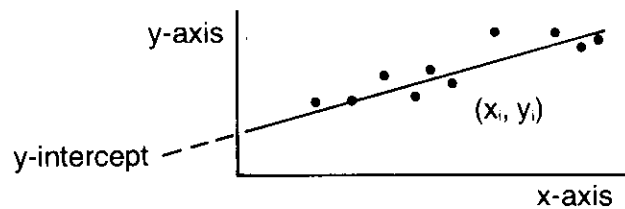
2nd **Op** 14 — Computes and displays a linear estimate of y' on the linear regression line corresponding to an x entry from the keyboard. If the previously input data represent a vertical line (infinite slope), new y' values should not be calculated.

2nd **Op** 15 — Computes and displays a linear estimate of x' on the regression line corresponding to a y entry from the keyboard. If the slope is 0, the display flashes.



AN IN-DEPTH ANALYSIS OF FEATURES AND FUNCTIONS

Data entry for linear regression is the same as for mean, standard deviation and variance calculations that can also be used here. Actually, once a data set is entered, all the statistical functions can be used to analyze the data. Linear regression allows you to analyze one variable's relationship to another. The method is to perform a least-squares linear regression which is designed to minimize the sum of the squares of the deviations of the actual data points from the straight line of best fit. In practice, a plot of the data points is made and a line is constructed that uniformly divides the data points. The square root of the squares of their perpendicular offsets is minimized.



This line is described by $y = mx + b$, where m is the slope of the line and b is the y-intercept.

Because the data are seldom perfectly linear, you can measure how well the line fitted to the data actually does approximate the data. This measure is called the correlation coefficient and may be calculated from the variables and the linear equation parameters.

The slope and y-intercept of the regression line are determined as follows:

$$\text{slope} = \mathbf{m} = \frac{\sum xy - \frac{\sum x \sum y}{N}}{\sum x^2 - \frac{(\sum x)^2}{N}}$$

$$\text{y-intercept} = \mathbf{b} = \frac{\sum y - m \sum x}{N}$$

$$\text{The correlation coefficient} = \mathbf{R} = \frac{m \sigma_x}{\sigma_y}$$

Additional data points can be predicted simply by choosing some new x or y value and the calculator computes a corresponding y or x value on the regression line. This process uses the line equation $y = mx + b$, where m (slope) and b (y-intercept) are determined from the data previously submitted.



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AN IN-DEPTH ANALYSIS OF FEATURES AND FUNCTIONS

Example: A life insurance company has found that the volume of sales varies according to the number of sales people employed.

Number of sales people	7	12	3	5	11	8
Sales in thousands/mo.	99	152	81	98	151	112

How many sales people does this company need for \$200,000 monthly sales? What monthly sales should 15 sales people generate?

Press	Display	Comments
2nd Pgm 1 SBR CLR	0	Initialize
7 x↔t	0.	First x value
99 2nd Σ+	1.	Data point 1
12 x↔t	8.	Second x
152 2nd Σ+	2.	Data point 2
3 x↔t	13.	etc.
81 2nd Σ+	3.	
5 x↔t	4.	
98 2nd Σ+	4.	
22 x↔t	6.	Incorrect entry.
151 2nd Σ+	5.	
22 x↔t	23.	} Remove incorrect entry.
151 INV 2nd Σ+	4.	
11 x↔t	21.	
151 2nd Σ+	5.	
8 x↔t	12.	
112 2nd Σ+	6.	
200 2nd Op 15	17.81578947	People needed for \$200,000 sales.
15 2nd Op 14	176.5561798	Sales for 15 people
2nd Op 12	51.66853933	Y-intercept of line
x↔t	8.325842697	Slope of line

The slope and y-intercept have been calculated so that the line can be plotted, if desired. The slope is incremental sales per person. The y-intercept is independent sales.

Of special interest is that by performing any of the math functions on one or both elements of the random-variable pair, other types of regression are available. For example, by taking the logarithm of one of the variables before entering it as a data point, you can obtain a semi-logarithmic curve fit. These variations can be achieved by using natural logarithms, exponentials, roots and powers and reciprocal.



AN IN-DEPTH ANALYSIS OF FEATURES AND FUNCTIONS

When initially analyzing your data, you must select the type of curve that characterizes your particular situation. Actually you can try several types of curves to see which best fits your needs.

Example: A city published the following census data. Predict the population in the year 1980 and predict the year the population will be 50,000 inhabitants.

Year	1930	1940	1950	1960	1970
Population	3221	5361	9212	15410	27612

Population data characteristically follow an exponential curve of the form $y = ae^{bx}$. Taking the log of both sides of this equation yields $\ln y = \ln a + bx$. Therefore, by plotting x vs. $\ln y$ (semilog), we can plot a straight line.

Press	Display
2nd Pgm 1 SBR CLR	0.
1930 x^{→t}	0.
3221 lnx 2nd Σ+	1.
1940 x^{→t}	1931.
5361 lnx 2nd Σ+	2.
1950 x^{→t}	1941.
9212 lnx 2nd Σ+	3.
1960 x^{→t}	1951.
15410 lnx 2nd Σ+	4.
1970 x^{→t}	1961.
27612 lnx 2nd Σ+	5.
1980 2nd Op 14 INV lnx	46081.80979
50000 lnx 2nd Op 15	1981.524472

The population in 1980 should be about 46,080 and the town should have 50,000 residents by 1981.

TREND-LINE ANALYSIS

For data that have been collected at periodic intervals, such as yearly or daily, or data accumulated per event, the calculator can automatically increment the value of x by 1 for each data point entered. The calculator initially assigns whatever value is in the T-register for the x value of the first data point, then adds 1 for the second, 1 for the third, etc. All data points are entered by pressing **2nd** **Σ+** only. The starting x value can be set to any number by entering the first x value, then letting the calculator increment from there: x_1 **x^{→t}**, y_1 **2nd** **Σ+**, y_2 **2nd** **Σ+**, y_3 **2nd** **Σ+**, etc.

To remove an unwanted data entry, press **x^{→t}** **-** **1** **=** **x^{→t}** and then enter the unwanted y value.



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AN IN-DEPTH ANALYSIS OF FEATURES AND FUNCTIONS

Example: A computer dating service has the following annual profits:

Year	1962	1963	1964	1965-1970	1971	1972	1973	1974
Profit in millions	-2.1	-0.3	0.8	inactive	2.9	2.8	3.6	4.0

What profit can be expected in 1980 and when will the company break the \$10 million mark?

Press	Display	Comments
2nd Pgm 1 SBR CLR	0.	Initialize
1962 x↔t	0.	Initialize x
2.1 +/- 2nd Σ+	1.	1962 loss
.3 +/- 2nd Σ+	2.	1963 loss
.8 2nd Σ+	3.	1964 gain
1971 x↔t	1965.	Reinitialize x
2.9 2nd Σ+	4.	1971 gain
2.8 2nd Σ+	5.	1972 gain
3.6 2nd Σ+	6.	1973 gain
4 2nd Σ+	7.	1974 gain
1980 2nd Op 14	6.52181966	
10 2nd Op 15	1988.297788	

In 1980 the company can expect \$6.5 million profit and to reach the \$10 million mark in 1988.

Any of the statistical capabilities can be used for any of the statistical calculations. Mean, standard deviation, variance, slope and y-intercept could have been calculated in the preceding example.

STATISTICS IN CALCULATIONS

Statistical operations can be performed during complex calculations. You can have as many as 4 pending operations and still perform statistical calculations. (Statistics requires up to four levels of processing internally.) For instance, some insurance company may compute its overhead by the formula $3 + 2 \times 1.2^{(4 + N)}$ where N is the number of people needed for \$200,000 sales. Simply key in $3 + 2 \times 1.2^{(4 +$ then with the example from page V-38, calculate x' for y = 200. After projecting the number of people for \$200,000 sales, press **=** to complete the calculation. Notice that four operations are pending while the statistics is being calculated.

Statistical calculations also use one level of subroutine when used in a program. More about subroutines later.



AN IN-DEPTH ANALYSIS OF FEATURES AND FUNCTIONS**GENERAL PROGRAMMING****Programming Your Calculator**

To solve a problem from the keyboard, you determine a sequence of operations and functions needed to give you the solution to that problem and key your solution into the calculator. Programming is little more than entering the learn mode and telling the calculator to remember the resulting key sequence. What actually happens is that the keystrokes are stored in locations in *program memory* and each becomes a *program instruction*. The series of keystrokes (instructions) is now a *program*. When the instructions of the program are executed (run) they produce the same result that the equivalent manual keystrokes would have yielded. Once stored, this program can be exercised again and again by supplying new sets of variables instead of entering all the program keystrokes. This not only saves you input time, but decreases the chances of making an entry error, which would further interfere with the problem solving process.

The program stays in program memory until it is replaced by another program, cleared by pressing **2nd** **CP** or the calculator is turned off. Meanwhile, the program can be used whenever you need it. For example, while performing a series of manual operations, you may find you need an answer from a stored program. Simply call and execute the program, then return to your calculations with the program results.

The program stays in program memory until it is replaced by another program, cleared by pressing **2nd** **CP** or the calculator is turned off (TI Programmable 59 only). Meanwhile, the program can be used whenever you need it. For example, while performing a series of manual operations, you may find you need an answer from a stored program. Simply call and execute the program, then return to your calculations with the program results.

The *Constant Memory* feature of the TI Programmable 58C retains the program memory when the power switch is turned off, or when the battery pack is removed or discharged for a short period. The power switch **must be off** in the latter case. The data memory contents, partitioning and fix-decimal setting are also saved by the TI Programmable 58C *Constant Memory* feature. If you interrupt a running program by turning off the TI Programmable 58C, any pending calculation, flag status, subroutine status, t-register content, or angular status may be lost. **Always stop a running program before turning off the TI Programmable 58C.**

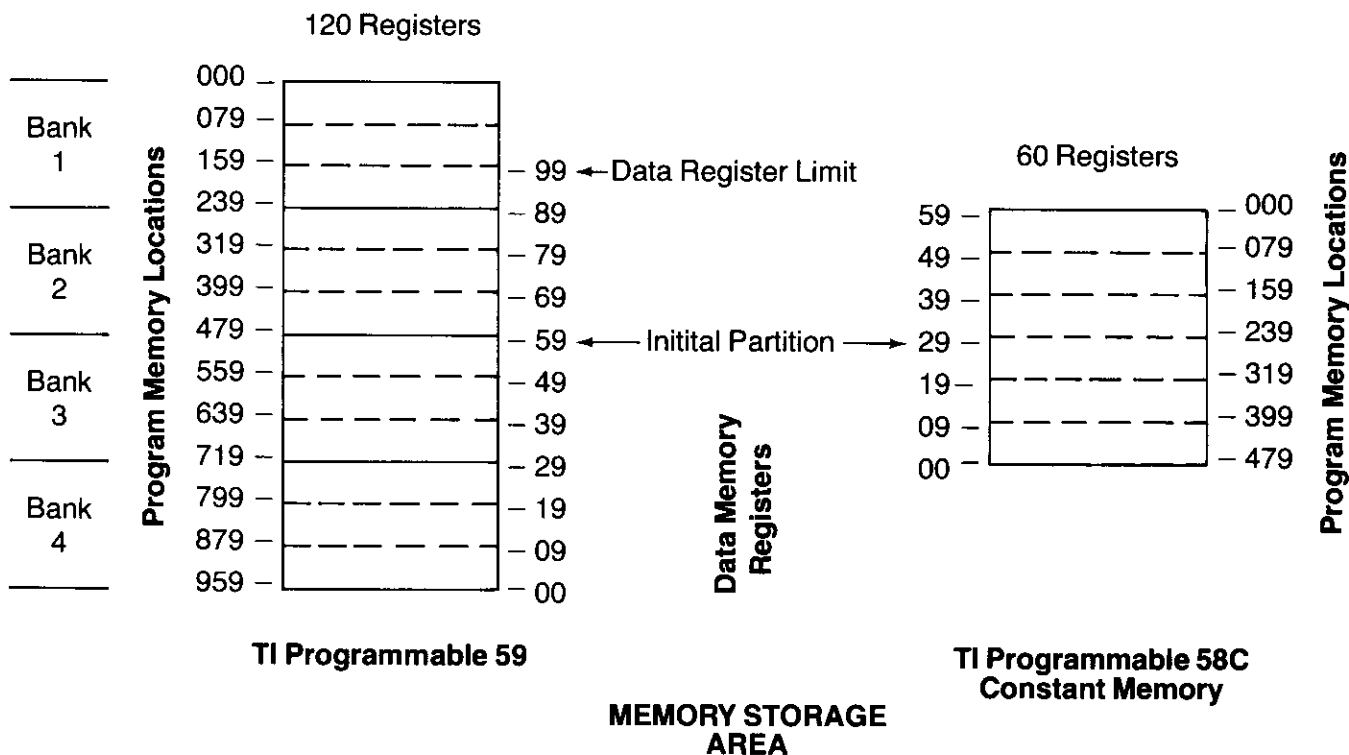
This calculator contains a highly sophisticated system for programming — yet it is easy to use. A thorough understanding of the calculator structure will provide you with a problem solving device with capabilities approaching those of a minicomputer.



AN IN-DEPTH ANALYSIS OF FEATURES AND FUNCTIONS

Storage Capacity and Partitioning

There is a memory storage area within your calculator. This area is for data storage and program storage.



Throughout the remainder of this section, information about the TI Programmable 58C will follow that for the 59 and will be in parentheses in bold numbers.

There are 120 (**60**) registers available for storage in the memory storage area. Initially, there is an even split between program and data memory with 60 (**30**) registers for each. Eight program instructions can be stored in each register of program memory. So you can have a $8 \times 60 = 480$ ($8 \times 30 = 240$) step program with 60 (**30**) registers left for data storage.

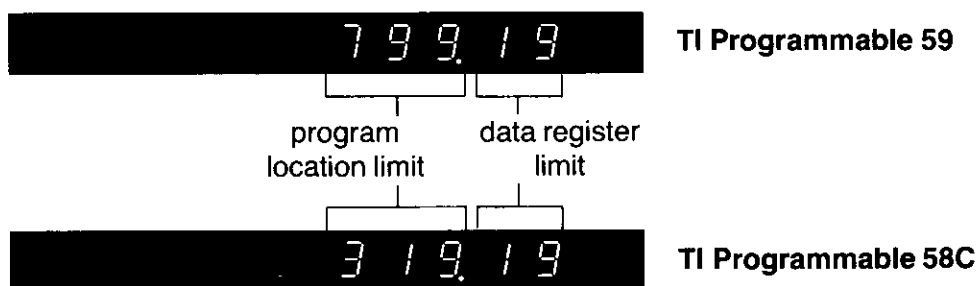
You can partition this memory storage area into the ratio you desire in sets of 10 register increments. For example, you can use all 120 (**60**) registers for a program, $120 \times 8 = 960$ ($60 \times 8 = 480$) program locations and no data registers or you can partition so that you have 100 (**60**) data registers and $20 \times 8 = 160$ (**0**) program locations or other combinations. The only restriction to the system is that a maximum of 100 (**60**) data registers can be used because each memory operation requires a two-digit address, therefore only registers 00-99 (**00-59**) can be used.

All 60 registers of the TI Programmable 58C are included in the *Constant Memory* feature and are not lost by turning the calculator off.



AN IN-DEPTH ANALYSIS OF FEATURES AND FUNCTIONS

To partition the storage area, enter the number of sets of 10 data registers you need, 0-10 (0-6), and press **2nd** **Op** **17**. Remove all fix-decimal, scientific notation and engineering formats before partitioning. For 20 data registers, press 2 **2nd** **Op** **17** and the display is as follows.



This shows that there are 20 registers, 00-19, available for data storage and 800 (**320**) locations 000-799 (**000-319**), allocated for program storage.

To check the current placement of the partition at any time, press **2nd** **Op** **16** and the existing partition is normally displayed in the format shown above.

Basic Program Control Functions

Understanding several basic control functions will allow you to begin programming your calculator.

LRN — **LEARN** — Pressing this key once puts the calculator in the learn mode of operation. This allows you to begin writing a program into program memory which can be run later. Pressing **LRN** again puts the calculator back under keyboard control and restores the display to its original state. You cannot enter the learn mode if a protected program is in program memory (TI Programmable 59 only), or if the partitioning is set such that there are no program steps available (TI Programmable 58C only).

2nd **CP** — **CLEAR PROGRAM** — When pressed from the keyboard, it clears all locations of program memory, clears the subroutine-return register, resets all flags, clears the T-register and resets the program pointer to 000. It also removes program protection (TI Programmable 59 only). When encountered within a program, it only zeros the T-register.

R/S — **RUN/STOP** — Reverses the status of processing. Pressing **R/S** starts program processing at the current position of the program pointer. Pressing **R/S** while a program is running stops the program, however, the exact stopping position of the program pointer cannot be predetermined. Entering **R/S** as a program instruction in the learn mode will cause program processing to stop at that point when the program is running.

IMPORTANT: Multiple use of **R/S** allows for data entry or a look at intermediate results as indicated on page IV-6. Ordinarily, the program will continue at the next instruction when **R/S** is pressed to restart the program. However, this automatic advance to the next instruction is cancelled if a Solid State Software program is called or if a conversion or statistic keyboard function is used while the program is stopped. In these cases, **R/S** must be pressed twice to restart the program. Conversions and Statistic functions are described on pages V-30 through V-40.



The Details

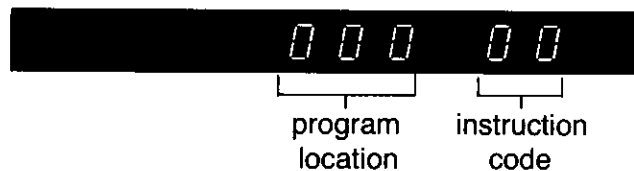
AN IN-DEPTH ANALYSIS OF FEATURES AND FUNCTIONS

[RST] — **RESET** — Instructs the calculator to reset the program pointer to location 000 of program memory (even from a library module), clears the subroutine return register and resets all program flags. It is also used to exit from a library program if it seems unable to do so by itself. When **[RST]** is used for this purpose, all results are lost except those stored in the data registers.

[2nd] [Pause] — **PAUSE** — When encountered during program execution, causes the current value of the display register to be displayed for a portion of a second. Pause instructions can be used wherever needed, even consecutively to make the display visible for longer periods. When held down on the keyboard during program execution, it displays the result of each program step. This key is inoperative when running a library program or a protected program.

Learn Mode

Once a calculation sequence has been determined, select the learn mode by pressing **[2nd] [CP] [LRN]**, then key the sequence into program memory. **[2nd] [CP]** assures that the program is keyed in beginning at location 000. When you enter the learn mode, the display has the following format.



Program locations begin at 000 and number consecutively up to your partition. Initially, program memory contains zeros in all locations and zeros remain in all locations that are not deliberately changed.

Each location usually contains an operation, an address or just a single digit.

An instruction key code (or just key code) is a two-digit number assigned to each operation according to its actual location on the keyboard. The calculator normally indicates 00 as the key code when a program is being keyed in. This is because, as a complete instruction is entered, the calculator automatically steps to the *next* available location. Instruction key codes are detailed in the section on program editing.

Keeping track of exactly where you are in program memory is the function of the program location pointer (or program pointer). In the learn mode, this indicator moves through program memory displaying the next location to be used.

After keying a program into program memory, press **[LRN]** again to return the calculator to keyboard control where the variables can be entered and program execution started.



AN IN-DEPTH ANALYSIS OF FEATURES AND FUNCTIONS

Entering Your Program

The sequence for keying your program into program memory is:

1. From the keyboard press **[RST]** or **[2nd] [CP]**. Either sequence positions the program pointer to 000, the first location of program memory. The **[2nd] [CP]** sequence also clears program memory.
2. Press **[LRN]** to place the calculator in the learn mode. The special five-digit display identifies this mode.
3. Key in your program completely: one step at a time, including all necessary **[2nd]** and **[INV]** prefixes. The display indicates the *next* location available for an instruction, not the one you just keyed in.
4. Make sure your program did not exceed program memory size. When the last location is filled, the calculator automatically switches to keyboard control where the special display is conspicuously absent.
5. Switch from the learn mode to keyboard control by pressing **[LRN]** again.
6. Run a test problem with known results to be sure the program is correct and edit your program if necessary.

The following example illustrates the previous comments.

Example: Create a program to calculate the volume of a right circular cylinder of radius “r” and height “h”.

Necessary equation: $V = \pi r^2 h$

Desired Program Operation: Enter “r”
 Start Program
 Halt for “h” entry
 Calculate volume, halt and display the answer



AN IN-DEPTH ANALYSIS OF FEATURES AND FUNCTIONS

Key Sequence	Display	Comments
2nd CP	0	Sets program pointer to location 000 and erases program memory
LRN	000 00	Places calculator in learn mode and begins program entry
x²	001 00	r ² (r will be entered before program execution)
X	002 00	
2nd π	003 00	Occupies 1 keystroke
X	004 00	πr ² in display register
R/S	005 00	Halts for "h" entry
=	006 00	Calculates result
R/S	007 00	Stops program, "V" displayed
RST	008 00	Return to instruction at 000
LRN	0	Returns to keyboard control

The last two keystrokes entered have specific functions. The **R/S** key halts processing and displays the final answer. The **RST** key provides a natural return to location 000 when "r" is entered for a new set of variables and **R/S** is pressed.

The **R/S** key has the effect of reversing the current status of program execution. If while running a program, the **R/S** key is either pressed or occurs as an instruction, processing ceases and there is immediate transfer to keyboard control. Then by pressing **R/S** on the keyboard, the program is restarted and calculations resume from the point where processing was suspended. The program location pointer is left wherever it happened to be at the time of program interruption, thus allowing processing to restart with no adverse effect on calculations, assuming that you do not change anything.

Running Your Program

When running a program, the instructions are executed in sequential order beginning at the current location of the program pointer. (Advantageous exceptions will be discussed later.) To initiate this processing simply press the **R/S** (Run/Stop) key. The program pointer keeps up with exactly where processing is in the program. If the calculator attempts to execute past the program boundary, processing halts and the display flashes. Therefore, programs should end with a **R/S** (or with an **INV** **SBR** or a transfer, both to be discussed later).

With the volume problem in program memory, let's run the program.

For r = 3 and h = 9, calculate the volume.

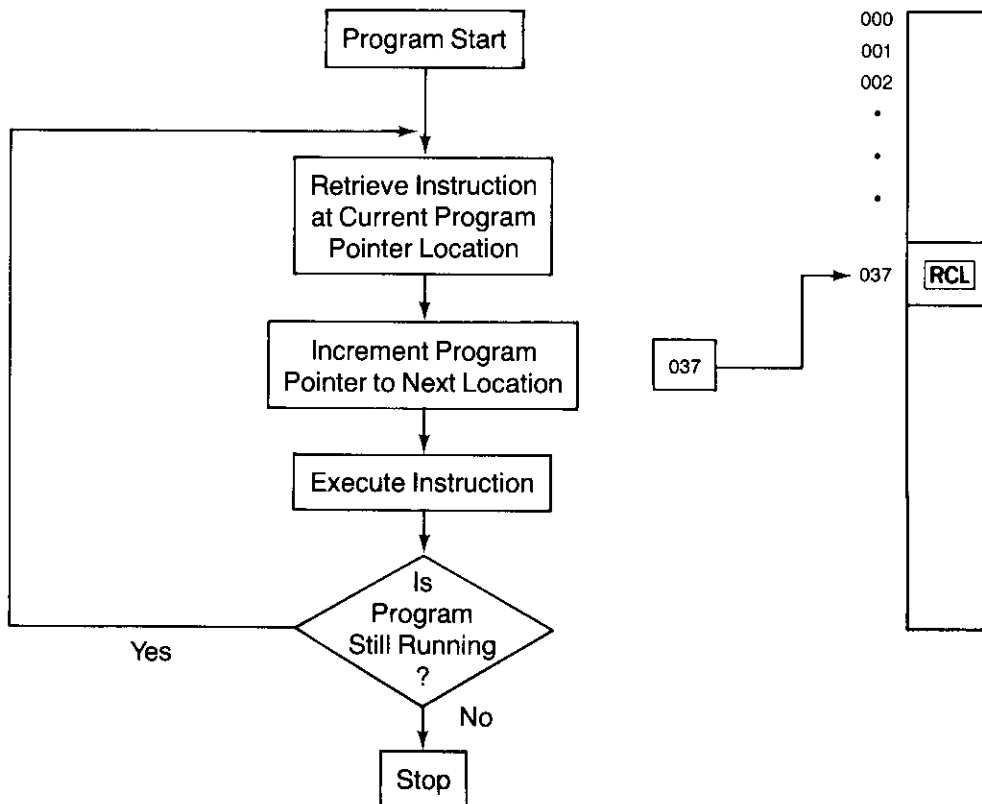


AN IN-DEPTH ANALYSIS OF FEATURES AND FUNCTIONS

Press	Display	Comments
RST	0	Positions program pointer to 000
3	3	Enter "r"
R/S	(blank)	Begins program execution
	28.27433388	πr^2 — value in display register when R/S encountered, halting program
9	9	Enter "h"
R/S	(blank)	Resumes processing
	254.4690049	Program halts, displays "V".

Note that the display is blank (except for a dim "[" in the far left of the display) while a program is being executed. This blank time varies widely depending upon the program being run and the power source being used.

When executing a sequence, the program pointer controls the flow of processing by pointing to each instruction as it is to be executed, as follows.



Program Location Pointer

As additional programming capabilities are introduced, the role of the program location pointer will be expanded.



The Details

AN IN-DEPTH ANALYSIS OF FEATURES AND FUNCTIONS

Working With Programs

[SST] — **SINGLE-STEP** — Causes the program pointer to be incremented by one. In the learn mode, pressing this key causes the next storage location to be displayed. Pressing this key from the keyboard causes the program to be executed one step at a time with the result of each step being displayed.

[BST] — **BACK-STEP** — In the learn mode, pressing this key causes the program pointer to decrement by one and show the code of the instruction stored there. This key is inoperative from the keyboard and when a program is running.

These keys are inoperative when running library programs.

In the process of keying in a program or looking at it after it is in program memory, two instructions are available that allow movement from instruction to instruction within the program. Pressing the single-step key **[SST]** in the learn mode increments the program location pointer by one, displaying the next location number and instruction code without affecting the stored instructions in any way. Pressing it repeatedly, therefore allows you to sequentially step through the program memory, observing the codes for the instructions stored there.

Similar to the single-step key, the back-step key **[BST]** causes the program location pointer to decrement by one location each time it is pressed. A common use of this key is to go back and verify that an instruction just keyed in is the one desired. (You must then press **[SST]** to go to the next location.) The back-step and single-step instructions combine to provide free movement in program memory to permit you to efficiently check out and “debug” your programs.

The single-step instruction is usable from the keyboard as well as in the learn mode. When pressed while under keyboard control, the effect of **[SST]** is to cause actual execution of the stored program, one instruction at a time. Each time **[SST]** is pressed, the instruction located at the current position of the program pointer is executed and the program location pointer is advanced just as if the program had been running. The display shows the calculated values resulting from that instruction. Sometimes several single-step keystrokes are necessary before anything appears to happen, but this is only because the operation in process is a multistep one. For example, the sequence + RCL 09 would take three single-step keystrokes before the recall of the memory register 09 content would actually take place.

As you single-step and back-step through a program while in the learn mode, you see a key code number stored at each location to represent the various instructions.

Instruction Codes (Key Codes)

In the learn mode, the display shows you where the program location pointer is positioned and the instruction presently residing in that location. The instruction is represented by a two-digit code that usually comes directly from the key's location on the calculator keyboard. The first digit denotes one of the nine rows of keys (numbered 1 through 9 from top to bottom) in which the key is located. The second digit establishes which of the columns contains the key (numbered from left to right 1 through 5). For example, the **[STO]** key is in row 4 column 2 so its instruction key code is 42. Second functions add 5 to a particular row-column address, i.e., **[2nd] [sin]** is code 38 because it is above **[x²]**, code 33. For the far right column of keys, second functions add 5, but do not carry to change the row number. i.e., **[2nd] [E]** is code 15 + 5 = 10, not 20. The digit keys 0-9 are designated by the codes 00 through 09.



AN IN-DEPTH ANALYSIS OF FEATURES AND FUNCTIONS

Keyboard And Instruction Key Codes

Key	Key Code	Key	Key Code	Key	Key Code	Key	Key Code	Key	Key Code
A	16	B	17	C	18	D	19	E	10
A	11	B	12	C	13	D	14	E	15
2nd	Merged	INV	27	log	28	CP	29	CLR	20
		INV	22	Inx	23	CE	24	CLR	25
Pgm	36*	P→R	37	sin	38	cos	39	tan	30
LRN	None	x↔t	32	x²	33	√x	34	1/x	35
Ins	None	CMs	47	Exc	48*	Prd	49*	Ind	40 (or merged)
SST	None	STO	42*	RCL	43*	SUM	44*	y^x	45
Del	None	Eng	57	Fix	58*	Int	59	|x|	50
BST	None	EE	52	(	53	)	54	÷	55
Pause	66	x=t	67*	Nop	68	Op	69*	Deg	60
GTO	61*	7	07	8	08	9	09	X	65
Lbl	76*	x≠t	77*	Σ+	78	x̄	79	Rad	70
SBR	71*	4	04	5	05	6	06	-	75
St flg	86*	If flg	87*	D.MS	88	π	89	Grad	80
RST	81	1	01	2	02	3	03	+	85
Write	96	Dsz	97*	Adv	98	Prt	99	List	90
R/S	91	0	00	.	93	+/-	94	≡	95

*Keys requiring instructions or addresses to be complete.

Note: The **Ind** instruction is sometimes numerically merged with the code of the key it is used with.

There is a mylar sheet called a "Key Code Overlay" that comes with your calculator. When placed over the keys, it shows the key code associated with each key.



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Key Codes In Numerical Order

Key Code	Key	Key Code	Key	Key Code	Key
00	0	39	2nd cos	72	STO 2nd Ind
↓	↓	40	2nd Ind	73	RCL 2nd Ind
09	9	42	STO	74	SUM 2nd Ind
10	2nd E	43	RCL	75	-
11	A	44	SUM	76	2nd l b |
12	B	45	y*	77	2nd x≥t
13	C	47	2nd CMs	78	2nd Σ+
14	D	48	2nd Exc	79	2nd \bar{x}
15	E	49	2nd Prd	80	2nd Grad
16	2nd A'	50	2nd |x|	81	RST
17	2nd B'	52	EE	83	GTO 2nd Ind
18	2nd C'	53	(	84	2nd Op 2nd Ind
19	2nd D'	54	)	85	+
20	2nd CLR	55	÷	86	2nd St flg
22	INV	57	2nd Eng	87	2nd If flg
23	Inx	58	2nd Fix	88	2nd D.MS
24	CE	59	2nd Int	89	2nd π
25	CLR	60	2nd Deg	90	2nd List
27	2nd INV	61	GTO	91	R/S
28	2nd log	62	2nd Pgm 2nd Ind	92	INV SBR
29	2nd CP	63	2nd Exc 2nd Ind	93	.
30	2nd tan	64	2nd Prd 2nd Ind	94	+/-
32	x:t	65	X	95	=
33	x²	66	2nd Pause	96	2nd Write
34	√x	67	2nd x=t	97	2nd Dsz
35	1/x	68	2nd Nop	98	2nd Adv
36	2nd Pgm	69	2nd Op	99	2nd Prt
37	2nd P→R	70	2nd Rad		
38	2nd sin	71	SBR		

Through normal usage you will become familiar enough with the more common instruction codes that constant reference to these tables will not be necessary. Most key codes can always be quickly determined by reference to the calculator keyboard or the "Key Code Overlay."



AN IN-DEPTH ANALYSIS OF FEATURES AND FUNCTIONS

Keystroke Storage

Most instructions occupy one location in program memory. Some instruction sequences do, however, allow several keystrokes to occupy a single location. The **2nd** key is combined with the instruction following it to occupy one location as has been explained. The two-digit addresses accompanying instructions for data memory, program library access and special control operations are combined to occupy one location. For instance, **RCL 16** occupies only 2 locations as does **2nd Pgm 12** with **2nd Pgm** placed in one location and the program number 12 in the next. The calculator automatically does this for you.

Unconditional transfer addresses (discussed on page V-56), like **GTO 123** are stored **GTO** in one location, 01 in the next and 23 in the next. As you key in this sequence, the calculator assimilates the keystrokes, placing them in the correct locations. No special effort on your part is required.

Sometimes when the indirect key **Ind** is used with another instruction, indirect combines with that instruction to occupy one location, and is assigned a different instruction code. These new codes are not based on the instructions' position on the keyboard, but are assigned key codes of the keyboard locations of the numbers. For example, **STO 2nd Ind** is single-location code 72. These special assignments are handled internally by the calculator and are listed in the numerical order of key codes on the previous page. The indirect instructions affected are:

Key Sequence	Key Codes
2nd Pgm 2nd Ind	62
2nd Exc 2nd Ind	63
2nd Prd 2nd Ind	64
STO 2nd Ind	72
RCL 2nd Ind	73
SUM 2nd Ind	74
GTO 2nd Ind	83
2nd Op 2nd Ind	84

The indirect instructions that are not affected by this merging simply store the instruction code of **2nd Ind** based on its keyboard location, 40, after the code of the instruction it is used with. For instance, **2nd x=t 2nd Ind** is stored with **2nd x=t**, code 67, in one location and **2nd Ind**, code 40 stored in the next. Uses of indirect sequences are explained in the next section.

EDITING PROGRAMS

2nd Nop — **NO OPERATION** — In the learn mode, entry of this key may be used to delete an unwanted instruction or to provide spacing between program parts for later additions. Program execution simply performs no operation when this instruction is encountered. Use of this key does not interfere or alter any key, execution sequence or data entry except when used as a label.

2nd Del — **DELETE** — In the learn mode, removes the displayed instruction and moves each following instruction up one location so that the gap is eliminated. The program pointer does not move when this key is used.



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AN IN-DEPTH ANALYSIS OF FEATURES AND FUNCTIONS

2nd Ins — **INSERT** — In the learn mode, moves all instructions down one location beginning with the displayed location through to the end of program memory. Used to create room to insert a new instruction.

In the process of working with a program in program memory, you have the following capabilities:

1. Step through the program, forward or backward, displaying the instructions stored in the various locations.
2. Replace any instruction with any other.
3. Delete a displayed instruction and close up the gap.
4. Make a space for a new instruction to be inserted.

These instructions allow you to make corrections or modifications to a program with an absolute minimum amount of effort.

Replacing an Instruction with Another

A keystroke input at any point in an existing program, while in the learn mode, writes over the instruction previously stored in that location. As you are single-stepping or back-stepping through your program and discover an unwanted instruction, simply press the correct instruction and it will instantly replace the one that was displayed.

Deleting an Instruction

Any instruction can be removed from the program completely through use of the delete instruction **2nd Del**. In the learn mode, a displayed instruction can be deleted and all following instructions are moved up one location so that the gap is removed from the program. As a consequence of closing the gap, a zero is pulled into the last location in program memory. As much of a program can be deleted as necessary. See example on page V-54 for precautions in deleting instructions.

Inserting an Instruction

If you need to insert an instruction somewhere in your program, press **2nd Ins** to move all instructions beginning with the one displayed down one location creating a hole for a new instruction. Now just key in your new instruction. This operation can be performed repetitively adding sections of code to your program. Each time this option is used, though, the instruction in the last available location of program memory is lost.

A no-operation instruction **2nd Nop** is available to delete an instruction from a location and leave a no-op code in its place. This code is ignored when encountered in the execute mode except when it is used as a label. Use of this key can reserve a particular point in a program that is subject to frequent change. This makes program alteration possible without using the delete and insert options that change program locations.



AN IN-DEPTH ANALYSIS OF FEATURES AND FUNCTIONS

Example: Key in and edit $x^2 + 3x - 2$ to be solved several times for different values of x . Assume x to be in the display when program execution is started.

Press	Display	Comments
LRN	000 00	Enter learn mode
STO	001 00	Store x for later use
1	001 00	
x^2	003 00	
-	004 00	Incorrect entry
BST	003 75	Back step to 003
+	004 00	Replace - with +
4	005 00	Incorrect entry
X	006 00	
BST	005 65	Back step to incorrect entry
BST	004 04	
3	005 65	Replace 4 with 3
SST	006 00	Single step past correct X
X	007 00	
RCL	008 00	
1	008 00	
BST	008 01	Discover X entered twice
BST	007 43	Back step to location 006
BST	006 65	
2nd Del	006 43	Deletes X , bring RCL from 007 to 006, etc.
SST	007 01	Single step past RCL
SST	008 00	Single step past 1
2	009 00	
=	010 00	
BST	009 95	Realize - missed
BST	008 02	Back step to location 008
2nd Ins	008 00	Vacates 008 moving 2 = down
-	009 02	Insert -
SST	010 95	Single step past 2
SST	011 00	Single step past =
R/S	012 00	Halts program, displays answer
RST	013 00	Goes to location 000 for next problem
LRN	0	Exit learn mode



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AN IN-DEPTH ANALYSIS OF FEATURES AND FUNCTIONS

Now to verify that the program has been entered correctly, single-step through the program. The complete program should be as follows.

Location and Key Code	Key Sequence
000 42	STO
001 01	1
002 33	x²
003 85	+
004 03	3
005 65	X
006 43	RCL
007 01	1
008 75	-
009 02	2
010 95	=
011 91	R/S
012 81	RST

Be very careful of what you edit because of merged key codes. Consider the following sequence.

Location and Key Code	Key Sequence
.	
.	
.	
019 95	=
020 42	STO
021 12	1 2
022 61	GTO
.	
.	
.	

If the STO is deleted, the register number 12 now becomes B (code 12). If the 12 needs to be replaced with 13, positioning the pointer to 021 and entering 13 places the 1 in 021 and the 3 in 022 not 13 in 021. To achieve this change you can either enter **STO 13** from location 020 on or enter a C (code 13) at location 021. This clever entry of C to get code 13 in 021 is a very useful editing technique for altering program instructions.



AN IN-DEPTH ANALYSIS OF FEATURES AND FUNCTIONS

LABELING PROGRAM PARTS

2nd **Lbl** — **LABEL** — Used only in the learn mode to label segments of a program. This key instructs the calculator to use the next keyboard entry as a marker and not as an instruction to be performed.

Using labels is similar to using tabs in a notebook. These are especially useful for programs with more than one part that you can run separately or sequentially. There are two types of labels, user-defined labels and common labels.

User-Defined Keys as Labels

A series of keys at the top of the keyboard, **A** – **E** and **2nd** **A** – **2nd** **E**, are called user-defined keys. Labeling a segment of your program with one of these keys allows you to press that key in the calculate mode and have that program segment accessed instantly. You actually define the function of that key so that it acts like the other functions on the keyboard. The sequence may completely fill program memory or can be short as in the previous example. If that example is still in your calculator, give the program a user-defined label.

Press	Display	Comments
LRN	0	Return to calculate mode
RST	0	Return to 000
LRN	000 42	Enter learn mode
2nd Ins	000 00	Move program down 2 locations
2nd Ins	000 00	
2nd Lbl	001 00	Place Lbl in 000
A	002 42	Place A in 001

Now the program is labeled A and can be run by entering an x value into the display and pressing **A**.

1 A	2.	Expression evaluated for x = 1
1 +/- A	-4.	For x = -1
6 A	52	For x = 6
3.2 EE	3.2 00	
12 A	1.024 25	For x = 3.2 × 10 ¹²
2nd π ÷	3.1415927 00	
.03 = A	1.1278386 04	For x = π/.03

Each of the user-defined keys can be assigned to a program sequence and executed at will. Whether a user-defined key is pressed from the keyboard or encountered while running a program, relocation is made to the area of the program labeled with that user-defined key and processing is performed.



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Common Labels

Almost any key on the keyboard (including second functions) may be used as a label. Only the following keys cannot be used as labels: **2nd**, **LRN**, **Ins**, **Del**, **SST**, **BST**, **Ind** and the numbers 0-9. You should also avoid using **R/S** as a label because of its ability to start program execution.

These labels are assigned just as are the user-defined labels. But, program segments tagged with common labels cannot be accessed quite as easily from the keyboard as are the user-defined labels. You can have a segment labeled **cos**, for instance. Pressing **2nd** **cos** on the keyboard is an executable command so the cosine of the display is taken. Common labels are primarily designed for use within programs for transfer purposes although they can be accessed from the keyboard.

Pressing **GTO** **2nd** **cos**, for instance, sends the program pointer to the instruction immediately following label "cos." **SBR** **2nd** **cos** does the same, and also starts processing at that point as would pressing **GTO** **2nd** **cos** **R/S**.

In general, you can use as many different labels as you need (there are 72 available) in a program. **No label can be used to label more than one program segment**, but any label can be called as often as necessary.

All labels including their key codes that are used in the current program memory can be listed on the PC-100A or PC-100C Printer along with the locations in program memory. Simply press **GTO** **0** or **RST** (to position the program pointer to location 000), then press **2nd** **Op** **08** and the table is printed out.

TRANSFER INSTRUCTIONS

Up to this point, when a program is executed, processing begins at 000 and progresses sequentially until a Run/Stop instruction is encountered. There are a series of keys called transfer instructions that allow you to interrupt this consecutive flow of processing. There are two types of transfers — unconditional and conditional. The unconditional transfer instructions immediately relocate the program pointer to the requested location. Conditional transfers perform a test on the program status and transfer only under certain conditions.

Unconditional Transfer Instructions **GTO** and **SBR**

GO TO INSTRUCTION

GTO **N** or **nnn** — **GO TO INSTRUCTION** — When used in a program, Go To instantly diverts the flow of processing to label **N** or program location **nnn**. **N** can either be a user-defined label or a common label. From the keyboard, Go To positions the program location pointer to the part of the program labeled **N** or to location **nnn**, but does not start program execution. The keyboard use of this key is useful for rapid access to any part of a program for editing or other purposes.



AN IN-DEPTH ANALYSIS OF FEATURES AND FUNCTIONS

Transferring to a specific program location (nnn) is called *absolute addressing*.

Example: Write a program to count by fours.

Key Sequence	Comments
2nd CP	Clear program memory, reset to location 000
LRN	Enter learn mode
2nd Lbl SUM	Program segment labeled SUM
+ 4 =	Adds 4 to each result
2nd Pause	Pauses and displays number
GTO SUM	Goes to label SUM and the sequence repeats
LRN	Exit learn mode
GTO SUM	Pointer directed to label SUM from the keyboard.

Now simply press **R/S** and you'll see 4, then 8, then 12, etc. The calculator performs the sequence +4 = over and over until you press **R/S** again.

This program could have been done several ways. Let's assume that each sequence begins at location 000.

Key Sequence	Key Sequence	Key Sequence	Key Sequence
2nd Lbl	+	2nd Lbl	+
SUM	4	C	4
+	=	+	=
4	2nd Pause	4	2nd Pause
=	GTO	=	RST
2nd Pause	0	2nd Pause	
GTO	0	C	
SUM	0		
Common Label	Absolute Addressing	User-Defined Label	Reset



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AN IN-DEPTH ANALYSIS OF FEATURES AND FUNCTIONS

The common label method is the one used initially. You can see that when you use absolute addressing, no labels are needed. But, if this segment was lower in program memory and editing occurred at some lesser location number, the absolute address would have to be changed. The user-defined label transfers to Label C and automatically performs the calculation. This method does fill up the subroutine return register discussed below.

A three-digit absolute address is merged into two locations when it is stored. For instance, **GTO 126** is stored in three locations **GTO 01 26**. If you are working with addresses less than 100 only the significant part of an address need be entered. Pressing **GTO 7** is the *short-form* address which automatically stores the sequence in the proper three locations **GTO 00 07** as soon as a **nonnumeric** key is pressed. But, at least one digit must always be submitted or GTO will accept the next entry as a label.

SUBROUTINES

SBR N or **nnn** — **SUBROUTINE** — A *subroutine* is a sequence of instructions which can be written to define a mathematical or logical operation separate from the main portion of your program. The main program or another subroutine can at any time call and execute this sequence. Subroutines are designed for program situations that contain one or more series of steps that are used over and over. Instead of having to write the series each time it is needed, it can be written once and called whenever necessary. After a subroutine has been called and its function completed, control is returned to the program address following the subroutine calling sequence.

In the learn mode **SBR** programs a transfer to a subroutine labeled **N** or location **nnn**. When encountered while the program is running, the flow of processing is immediately diverted to the subroutine called. The location number following the subroutine call is stored in the *subroutine return register*. **INV SBR** terminates each subroutine and processing transfers back to the location stored in the subroutine return register where processing continues. **INV SBR** acts like a Run/Stop if not used in a subroutine. The subroutine return register can hold six return locations allowing one subroutine to call another. Each time a subroutine is completed, the associated return address is removed from the subroutine return register, making room for another subroutine if needed.

When this instruction is used from the keyboard, the program transfers to the requested label or location and processing begins automatically.



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Example: Evaluate $x^2 - 3x - 2$ for x_1 stored in R_{01} and x_2 stored in R_{02} and sum the two results into R_{03} .

Because $x^2 - 3x - 2$ is to be evaluated twice, write a subroutine to perform this task. Arbitrarily begin at location 030 by pressing **GTO 30** **LRN** and enter the following:

Location and Key Codes	Key Sequence	Comments
030 76	2nd Lbl	Program segment labeled CE
031 24	CE	
032 53	(
033 42	STO	Store incoming x for later use
034 05	5	
035 33	x^2	
036 75	-	
037 03	3	
038 65	X	
039 43	RCL	Recall x
040 05	5	
041 75	-	
042 02	2	
043 54	)	Evaluates expression
044 44	SUM	Sums results into register 03
045 03	3	
046 92	INV SBR	Returns to main program

Note that parentheses were used here to evaluate the expression. An equals could have been used, but it would have completed any pending operations in the main routine as well as these in the subroutine. Be safe and use parentheses. Now the main program can be written to input the "x" values in the proper place and display the results.



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Location and Key Codes	Key Sequence	Comments
000 43	RCL	Recall x_1
001 01	1	
002 71	SBR	Call subroutine CE
003 24	CE	
004 43	RCL	Recall x_2
005 02	2	
006 71	SBR	Recall subroutine CE
007 24	CE	
008 43	RCL	Recall answer in register 03
009 03	3	
010 91	R/S	Halts and display R_{03}
011 81	RST	Resets to 000 for next variables also zeros subroutine return register

When the subroutine is called, processing branches to label CE (location 030), completes the subroutine and returns to program location 004. The next subroutine returns to location 008. Processing always returns from the subroutine to the program location immediately following the subroutine instruction that called that subroutine.

Additionally, subroutines called by the main program can themselves call additional subroutines. The subroutine return register automatically keeps track of where each subroutine is to return upon completion.

After a program has been keyed in, pressing **RST** to return to location 000 also zeros the subroutine return register.

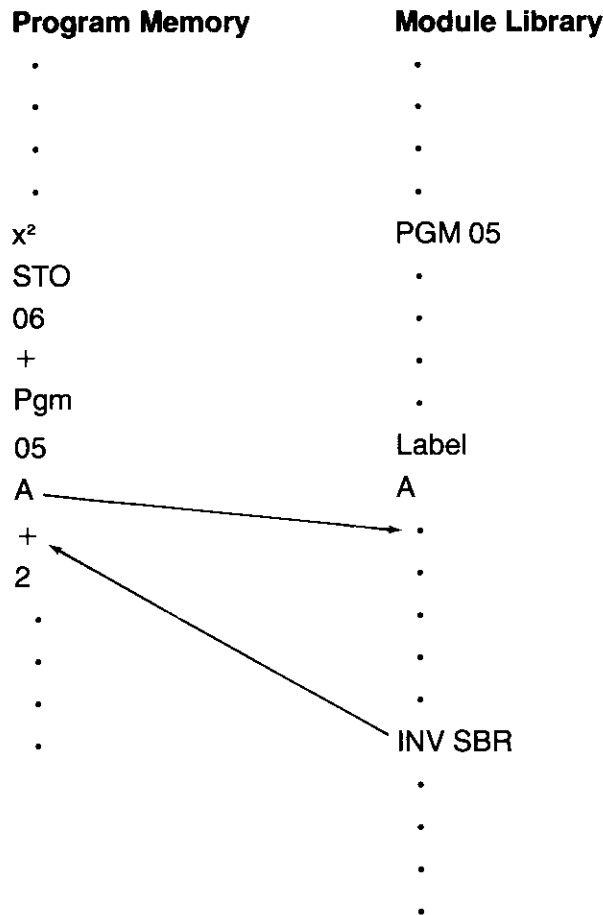
LIBRARY PROGRAMS AS SUBROUTINES

Any program on a library module in place in the calculator can be called as a subroutine. The programs on each module are designed specifically for this purpose with each part of every program being a subroutine. Each part is labeled, ends in **INV** **SBR** and most contain no Run/Stop instructions. See the library manuals for the labeling of each program part.



AN IN-DEPTH ANALYSIS OF FEATURES AND FUNCTIONS

You have seen how to access library programs from the keyboard. When running a program in program memory, you can call a library program and use any of its parts as a subroutine. If the part is labeled with a user-defined key, the program sequence **2nd Pgm mm, N** in program memory transfers to library program **mm** and continues program execution in the library program at label **N**. A common label in a library program is accessed by **2nd Pgm mm SBR N**. When the library program segment labeled **N** has completed its purpose, the program location pointer reverts back to the instruction immediately following the original point of departure from program memory and processing continues.



When encountered in a program, the instruction **2nd Pgm mm, N** behaves just like **SBR N** in that the address following this instruction is stored in the subroutine return register and processing immediately diverts to the section of the program labeled **N**. As soon as the sequence following label **N** is completed, processing returns to the last address stored in the return register. Following **2nd Pgm mm** with anything other than **SBR** or a user-defined key is not a valid key sequence and can cause unwanted results.



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Use of the library programs as subroutines greatly increases the calculating capacity of your calculator. There are some programming aspects that become critical when any two separate programs are brought together. The programs must not interfere with each other by attempting to use the same data memory registers or flags. A library program can also call other subroutines so you need to be sure that no more than 6 subroutine levels are used. You are usually safe if you use no more than three subroutine levels in program memory. Also, the display format of a library program could be in fix-decimal or scientific or engineering notation. The various uses of subroutines are briefly summarized below.

SUBROUTINE INSTRUCTIONS

From	To	Key Sequence
Program Memory or from one Library Program to another	Program Library	2nd Pgm mm , N (user defined label) or 2nd Pgm mm SBR N (common label) or 2nd Pgm mm R/S
Program Memory	Program Memory	SBR nnn or N
Program Library	Program Memory	2nd Pgm 00 , N (or nnn) or 2nd Pgm 00 SBR N or RST

Conditional Transfers (Test Instructions)

These instructions transfer program operation only if the value in the display register satisfies some specific condition: what is the status of the current value (stored in the display register) in relation to some other value (stored in the T-register mentioned earlier) or has processing been through enough steps (decrement and skip on zero instruction?).

T-REGISTER COMPARISONS

x=t	Exchanges display register value x with T-register value t.
2nd x=t N or nnn	Asks "Is the display register value exactly equal to the T-register value?"
INV 2nd x=t N or nnn	Asks "Is the display register value unequal to the T-register value?"
2nd x>t N or nnn	Asks "Is the display register value greater than or exactly equal to the T-register value?"
INV 2nd x>t N or nnn	Asks "Is the display register value less than the T-register value?"

When the answer is "yes" to any of the above questions the flow of processing branches to the address that immediately follows the instruction. If the answer is "no", processing skips the accompanying address and goes on to the next instruction.



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These tests do not affect pending operations, hence they can be used wherever desired in a program.

Example:

Location and Key Code	Key Sequence
022 43	RCL
023 01	1
024 95	=
025 77	2nd $x \geq t$
026 12	B
027 61	GTO
028 00	3
029 03	
030 76	2nd Lbl
031 12	B
032 91	R/S

In this sequence, the result produced at location 024 is tested in location 025 to see if it is greater than or equal to the value stored in the T-register. If the answer to the test is yes, the flow of processing jumps to label B where processing stops and the result is displayed. If the answer is no, the transfer to label B is skipped and GTO 003 transfers to location 003 where processing continues.

DECREMENT AND SKIP ON ZERO (DSZ)

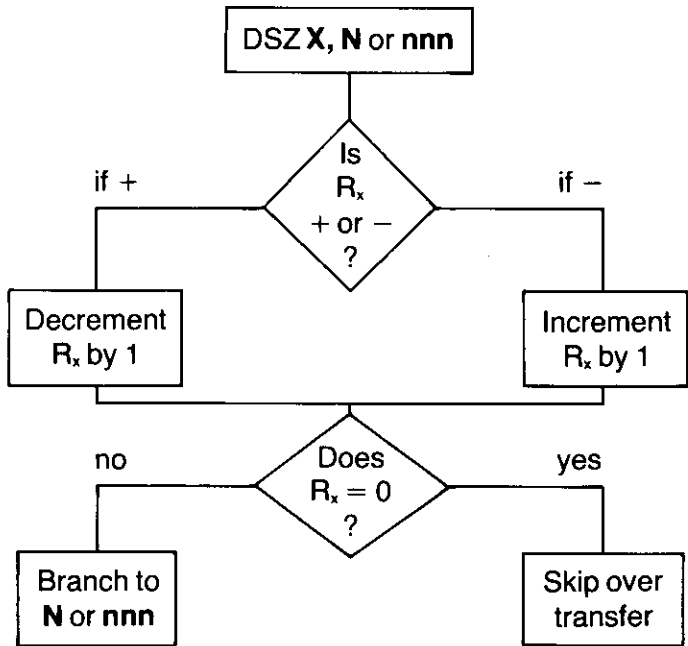
2nd **DSZ** **X, N** or **nnn** — **DECREMENT AND SKIP ON ZERO** — Decreases the magnitude of the contents of data register X (0-9) by one and processing transfers to label **N** or location **nnn** when $R_x \neq 0$. The transfer is skipped when R_x is zero. R_x here represents the contents of X.

NOTE: Conditional branches do not store a return address in the subroutine return register. If you need to call a subroutine and return on a conditional test, make the test the first step in the subroutine. For instance, **2nd** **$x=t$** **x^2** does not store a return address, but **SBR** **x^2** then **2nd** **Lbl** **x^2** **2nd** **$x=t$** does store a return address.



AN IN-DEPTH ANALYSIS OF FEATURES AND FUNCTIONS

This powerful programming instruction is an effective counter as well as a test instruction. If you need to iterate (repeat) a sequence y number of times, just store y in a data register (0-9) and program a DSZ test into the iterative sequence. After y iterations the looping ceases and the program continues. The DSZ instruction operates as follows:



Instruction encountered in program

Is R_x + or - ?

Reduce magnitude of R_x by one

Does $R_x = 0$?

If R_x is not 0, transfer to **N** or **nnn**
 If R_x is 0, skip the transfer and continue processing.

Understanding of this illustration shows that if you place the DSZ instruction at the beginning of a sequence, it counts then performs the calculation sequence. If placed at the end of the sequence, the function is performed then the count is made. All this means is that to obtain the correct number of passes, y, through a sequence, enter y into register X initially and perform DSZ last or perform DSZ first, but initially store y + 1 in register X.



AN IN-DEPTH ANALYSIS OF FEATURES AND FUNCTIONS

Example: Write a program to calculate F! (F-factorial) where $F! = 1 \times 2 \times 3 \times \dots \times F$. ($0! = 1$ by definition)

Location and Key Codes	Key Sequence	Comments
000 76	2nd Lbl	
001 15	E	
002 42	STO	Store F in register 00
003 00	0	
004 29	2nd CP	Zero T-register
005 67	2nd x=1	Test F = 0?
006 11	A	If yes, transfer to A
007 76	2nd Lbl	
008 12	B	
009 43	RCL	Recall F
010 00	0	
011 65	X	
012 97	2nd Dsz	Decrement R_{00} by 1
013 00	0	
014 12	B	If R_{00} is not within ± 1 , transfer to B
015 76	2nd Lbl	If R_{00} is within ± 1 , proceed to the end
016 11	A	
017 01	1	
018 95	=	
019 91	R/S	Stops and displays F!

To execute this sequence, simply enter an F number and press **E**. F must be less than 70 or the calculator overflows because $70! > 9.9999999 \times 10^{99}$.

FLAGS

2nd **St flg** **y** — **SET FLAG** — Raises or turns on flag number **y** where $0 \leq y \leq 9$. **INV** **2nd** **St flg** **y** lowers or zeros flag **y**, resets flag **y** to 0.

2nd **If flg** **y**, **N** or **nnn** — **FLAG SET TEST** — Tests flag **y** to see if it is raised (set). If so, transfer is made to label **N** or location **nnn**.

INV **2nd** **If flg** **y**, **N** or **nnn** — **FLAG NOT SET TEST** — Tests flag **y** and transfer to address **N** or **nnn** if **y** is not set.



The Details

AN IN-DEPTH ANALYSIS OF FEATURES AND FUNCTIONS

There are ten flags numbered 0 through 9 available for use in your programs. These flags are initially lowered (set to zero) and can be used to track which path the execution of a program took to completion or to control program options from the keyboard prior to execution. All flags are set to zero and the subroutine register is cleared when **RST** or **2nd CP** is pressed from the keyboard. The RST instruction in a program also zeros all flags.

Example: Design a program sequence to sum all incoming numbers, but print only the non negative ones and display the sum after each entry.

Location and Key Code	Key Sequence	Comments
018 76	2nd Lbl	
019 11	A	
020 77	2nd ≠t	"Is number nonnegative?"
021 12	B	If so, go to label B
022 86	2nd St fig	If negative, set flag 3
023 03	3	
024 76	2nd Lbl	
025 12	B	
026 44	SUM	Sum all numbers
027 12	1 2	
028 87	2nd If fig	"Is flag 3 set?"
029 03	3	
030 13	C	If yes (if number is negative), go to C
031 99	2nd Prt	If not, print number
032 76	2nd Lbl	
033 13	C	
034 22	INV	
035 86	2nd St fig	Reset flag 3 for next entry
036 03	3	
037 43	RCL	
038 12	1 2	
039 91	R/S	

Be sure that data register 12 is clear before entering a series of numbers. Entering a number and pressing **A** sums that number into data register 12, prints entry if it is positive and displays the total of all entries.



AN IN-DEPTH ANALYSIS OF FEATURES AND FUNCTIONS**FLAGS AND ERROR CONDITIONS**

Flag 8 has been earmarked to determine program operation according to the error condition status of a program. Normally, a program continues running even though an error condition has occurred. If flag 8 is set either from the keyboard or in a program, program execution is suspended when an error condition occurs.

2nd Op 18 says that if no error condition exists in a program, set flag 7.

2nd Op 19 says that if an error condition does exist in a program, set flag 7. Flag 7 can now be monitored to determine the error status of your program and appropriate responses can then be made. If either of these tests is false, flag 7 is not altered.

2nd Op 40 (TI Programmable 58C only) says that if the printer is attached, set flag 7. Flag 7 can be tested to detect presence of the printer within a program. If the printer is not attached, flag 7 is not altered.



The Details

AN IN-DEPTH ANALYSIS OF FEATURES AND FUNCTIONS

Indirect Addressing

2nd Ind XX — INDIRECT SUFFIX — When used after one of the following operations, recalls the contents of data register **XX** and uses these as the correct address for transferring or for the actual data register to use in processing.

Key Sequence	Key Codes	Purpose
STO Ind XX	72 XX	Indirect store
RCL Ind XX	73 XX	Indirect recall
EXC Ind XX	63 XX	Indirect exchange
(INV) SUM Ind XX	(22)74 XX	Indirect sum (subtract) from memory
(INV) PROD Ind XX	(22)64 XX	Indirect multiply (divide) into memory
GTO Ind XX	83 XX	Indirect go to
Pgm Ind XX	62 XX	Indirect program
Op Ind XX	84 XX	Indirect special control
SBR Ind XX	71 40 XX	Indirect subroutine
FIX Ind XX	58 40 XX	Indirect fix-decimal
(INV) x=t Ind XX	(22)67 40 XX	Indirect $x = t$ ($x \neq t$) test
(INV) x≥t Ind XX	(22)77 40 XX	Indirect $x \geq t$ ($x < t$) test
(INV) St flg Ind XX	(22)86 40 XX	Indirect set (reset) flag
(INV) If flg Ind yy, N or nnn	(22)87 40 yy, N or nnn	Indirect flag number set (reset) test
(INV) If flg y Ind XX	(22)87 y 40 XX	Indirect address, flag set (reset) test
(INV) If flg Ind yy Ind XX	(22)87 40 yy 40 XX	Indirect address and flag number, set (reset) test
(INV) Dsz Ind XX, N or nnn	(22)97 40 XX, N or nnn	Indirect DSZ register skip on zero (non-zero) test
(INV) Dsz X Ind XX	(22)97 X 40 XX	Indirect address, skip on zero (non-zero) test
(INV) Dsz Ind XX Ind XX	(22)97 40 XX 40 XX	Indirect DSZ register and address, skip on zero (non-zero) test

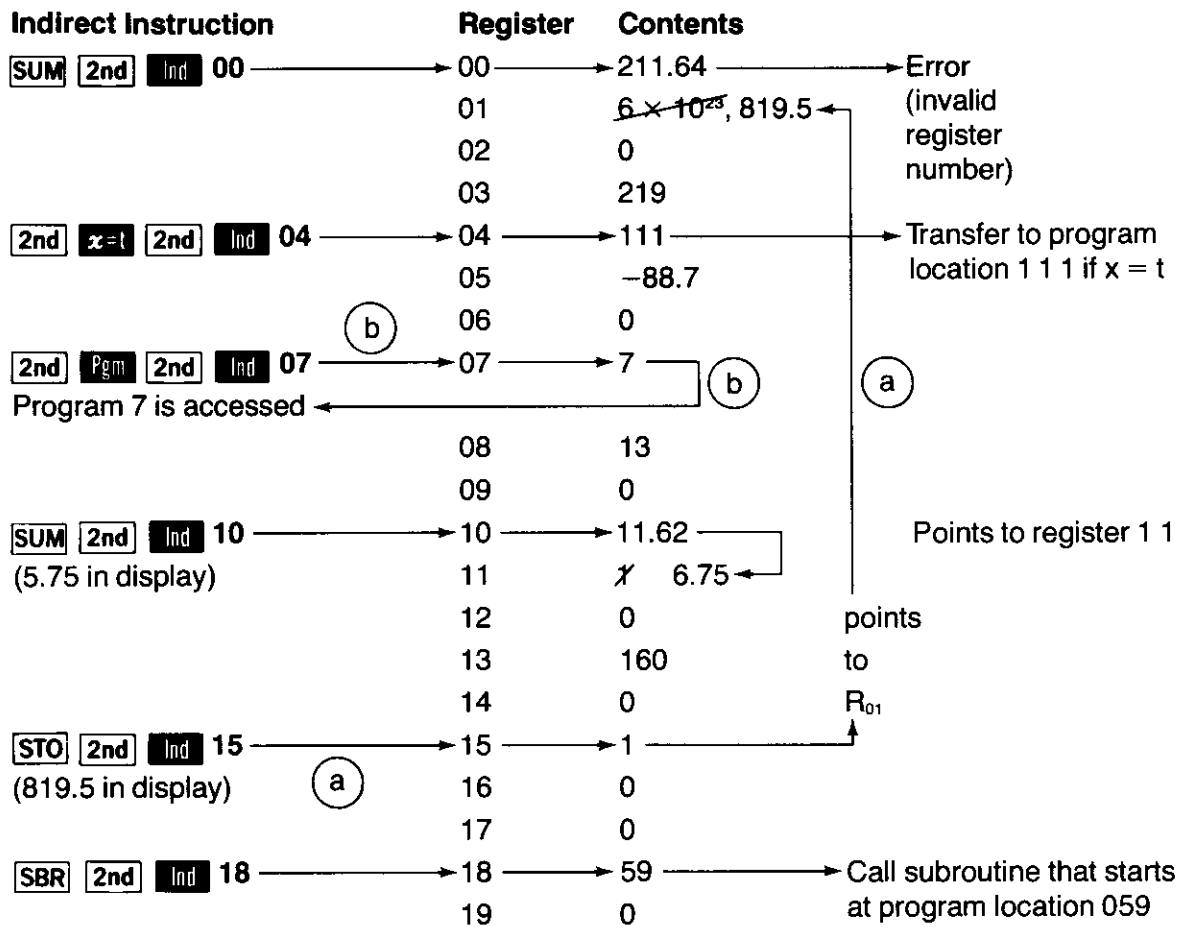
Notice that the indirect memory operations, PGM, Op and Go To instructions have assigned codes that do not represent their positions on the keyboard. These codes have been assigned to save program locations.



AN IN-DEPTH ANALYSIS OF FEATURES AND FUNCTIONS

The indirect instruction produces a transfer of memory address by finding it stored in data register XX. The effect of pressing **RCL** **2nd** **Ind** **04** would not be to recall the contents of register 04, but to use R_{04} as the requested memory address. If 27 is stored in register 04 then 27 becomes the memory address. The indirect address “points” to the actual address.

The diagram below illustrates these concepts graphically.



This diagram shows the effect of **2nd** **x=t** **2nd** **Ind** **04**. The result is to use the value in R_{04} (111) as the transfer address for the x = t instruction. The effect of **STO** **2nd** **Ind** **15** is shown as the path of events marked (a). The result is to store 819.5 into R_{01} , formerly containing 6×10^{23} . Finally, the result of **2nd** **Pgm** **2nd** **Ind** **07** in this example is marked (b). The pointer points back to data register 07 so that the result is to use the value 7 to access library program number 07.

It is implied that any pointer used as the consequence of an indirect instruction must point to a realizable address. Accordingly, the result of the **SUM** **2nd** **Ind** **00** in the example diagram would be an error — there is no data register 211.64. **SUM** **2nd** **Ind** **10** sums 5.75 into register 11, because only the integer portion of an indirect address is used.

If the value in the indirect register is less than zero, the calculator uses register 00. If the value is beyond the partition, processing halts and the display flashes.

VI

PRINTER CONTROL



The optional **PC-100A or PC-100C Print/Security Cradle*** can be used with your programmable calculator to perform a number of different printing tasks. With the calculator in place on the printer you can:

1. Print the contents of the display at any time.
2. List your program in program memory and the contents of all data registers.
3. Print results from any point of a running program.
4. Print each step of calculator operation by tracing calculations made from the keyboard or in a program.
5. List all program labels and the program location of each.
6. Print alphanumeric messages wherever needed.
7. Make a plot of data from the keyboard or automatically from a program.
8. Leave your desk without having to lock your calculator away. The printing unit provides security as well as power for your calculator.
9. The calculator's rechargeable battery can be charging while the printer is in use.

The calculator selection switch (PC-100A only) located in the storage/charging compartment of the printer should be set to "OTHER" for use with either the TI Programmable 58C or 59. The PC-100C is designed to be used only with the TI Programmable 58, TI Programmable 58C or TI Programmable 59.

Basic instructions for setting up the printer, mounting the calculator, changing the paper and service information are provided by the printer Owner's Manual. The section you are now reading describes the printing operations that can be performed by the calculator/printer combination. If you are using the PC-100A, use the program on page VI-12 of this manual for cleaning printheads as described in the printer Owner's Manual.

IMPORTANT: The *Constant Memory* feature of the TI Programmable 58C permits the battery pack to be removed (**be sure to stop a running program, turn off calculator and disconnect adapter/charger**) for mounting the calculator on the printer without affecting program and data memories. When using the PC-100A, the printer **power switch must be ON and the key in the lock position** to retain program/data memory contents. The PC-100C applies power to the calculator regardless of switch position, but always be sure the **key is in the lock position**.

*Note: The PC-100 Print Cradle does not operate with the TI Programmable 58C and 59.



SELECTIVE PRINTING

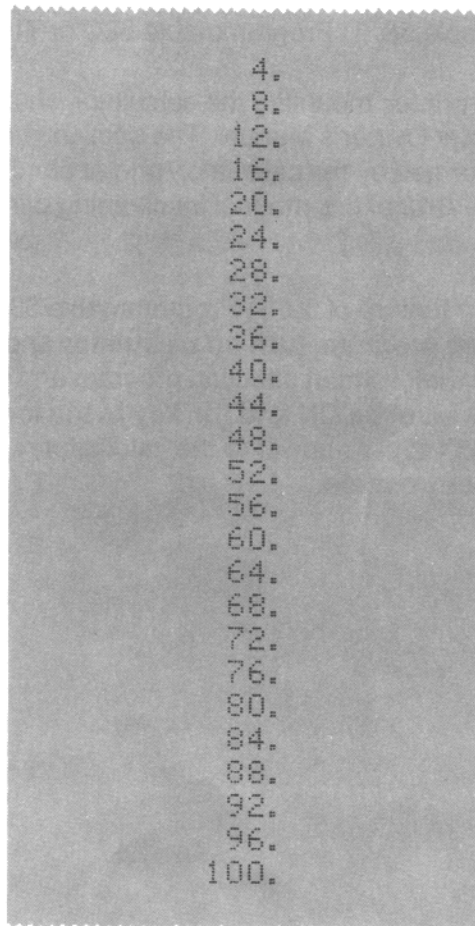
Whenever **2nd** **Prt** is pressed from the keyboard or encountered in a program, the display value is printed. Pressing the **PRINT** key on the printer is the same as pressing **2nd** **Prt** from the keyboard. If an error condition exists when these instructions are encountered, a question mark is printed to the right of the value printed.

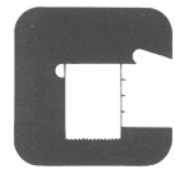
Consider the following program that prints multiples of 4:

Location and Key Code	Key Sequence
000 85	+
001 04	4
002 95	=
003 99	2nd Prt
004 81	RST

Enter some starting point and press **RST** **R/S** and the following is obtained.

Results

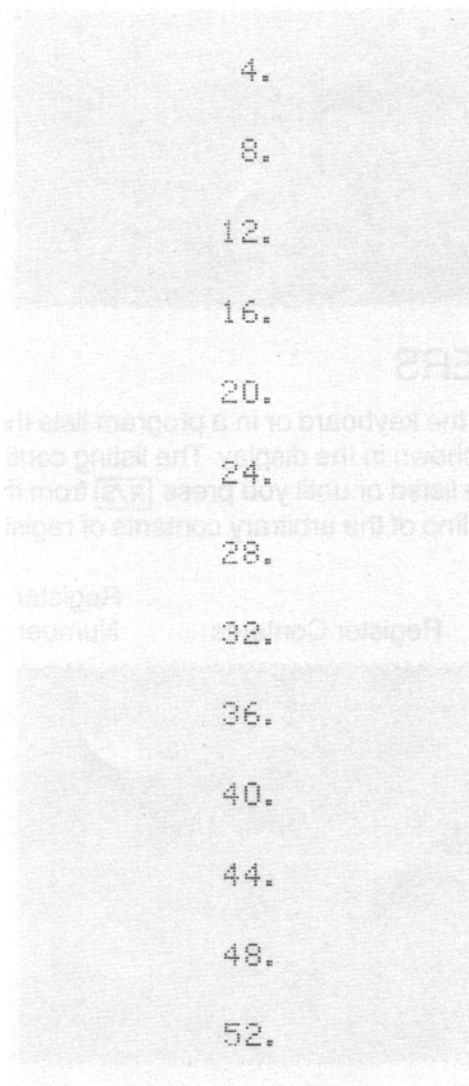




A special set of print instructions are in the library module, so if a printer is available, the entries and results from many library programs can be automatically printed.

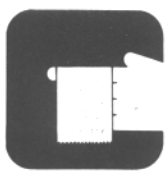
Segments of printed results can be separated by using the paper advance key **2nd Adv** on the calculator. When used from the keyboard or in a program, it advances the paper one blank space without printing. For instance, to separate our multiples of 4, insert **2nd Adv** into any location ahead of **RST** and you get the following. This instruction has no effect on calculations.

Results



To obtain additional space, simply repeat the instruction several times.

The **ADV↑** key on the printer can also create blank space. It continually advances the paper as long as the key is held down.



LISTING YOUR PROGRAM

To list a program, simply press **2nd** **List** from the keyboard. The program is then listed from the current position of the program pointer, to the end of program memory. You can manually stop the listing at any time by pressing **R/S**. For a complete program listing, press **RST** **2nd** **List**. The multiples of 4 program lists like this:

Program Location	Key Code	Key Symbol
000	85	+
001	04	4
002	95	=
003	99	PRT
004	98	ADV
005	81	RST
006	00	0
007	00	0

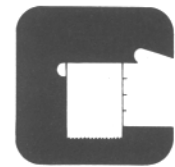
LISTING DATA REGISTERS

The sequence **INV** **2nd** **List** from the keyboard or in a program lists the contents of all data registers beginning with the register number shown in the display. The listing continues until the contents of the highest numbered data registers are listed or until you press **R/S** from the keyboard. Now the calculator is back under keyboard control. A listing of the arbitrary contents of registers 50 up to the partition at 59 is shown below.

Register Contents	Register Number
14.18181818	50
665.8568182	51
110.9761364	52
0.	53
0.	54
-5.5488068-12	55
0.	56
0.	57
1.	58
0.085106383	59

This listing was obtained by pressing **50** **INV** **2nd** **List**.

When this option is used in a program calculations cease, the requested data register contents are listed and the program stops, returning control to the keyboard.



TRACING YOUR CALCULATIONS

By pressing **TRACE** on the printer, you cause every step of a calculation to be printed. The calculated value and the instruction that created it are displayed. This is true for both keyboard calculations and program calculations.

The **TRACE** key is a latching switch which in the down position causes trace mode operation for all calculations. In this mode every new function or result is automatically printed. A number entry is only printed if followed by an operation or function. Operation in the trace mode continues until the **TRACE** key is pressed again to release it. When an error condition occurs, a question mark is printed to the right of the value printed.

With the "multiples of 4" program still in program memory, press the **TRACE** key on the printer. Now, press **CLR** **RST** **R/S** on the calculator to obtain the following "tracing" of the calculations that take place.

Display Register	Audit Symbols
0.	+
4.	=
4.	
4.	PRT
	RST
4.	+
4.	=
8.	
8.	PRT
	RST
8.	+
4.	=
12.	
12.	PRT
	RST
12.	+
4.	=
16.	
16.	PRT

The program (and consequently the tracing) was stopped by pressing **R/S**.

AUDIT TRAIL SYMBOLS IN TRACE MODE

Most of the symbols listed by the printer are easily identified while others are somewhat obscure. A complete list of all audit symbols and the key sequence that created each one follows.



Printer Listing	Key Sequence	Printer Listing	Key Sequence	Printer Listing	Key Sequence
A - E	A - E	ILOG	INV 2nd log †	RCL	RCL
A' - E'	2nd A' - 2nd E'	IND	2nd Ind	R/S	R/S
ADV	2nd Adv	INS	See Note Below	RST	RST
BST	See Note Below	INT	2nd Int	RTN	INV SBR
CE	CE	INV	INV	SBR	SBR
CLR	CLR	IPD*	INV 2nd Prd 2nd Ind †	SIN	2nd sin
CP	2nd CP	IP/R	INV 2nd P→R †	SM*	SUM 2nd Ind
CMS	2nd CMS	IPRD	INV 2nd Prd †	SST	See Note Below
COS	2nd cos	ISBR	INV SBR †	ST*	STO 2nd Ind
DEG	2nd Deg	ISIN	INV 2nd sin †	STF	2nd St flg
DEL	See Note Below	ISM*	INV SUM 2nd Ind †	STO	STO
DMS	2nd D.MS	ISTF	INV 2nd St flg †	SUM	SUM
DSZ	2nd Dsz	ISUM	INV SUM †	TAN	2nd tan
EE	EE	ITAN	INV 2nd tan †	WRT	2nd Write
ENG	2nd Eng	\bar{x}	INV 2nd \bar{x} †	X \approx T	x=t
EQ	2nd x=t ■	IXI	2nd |x|	X ²	x²
EX*	2nd Exc 2nd Ind	IY ^x	INV y^x †	\bar{x}	2nd \bar{x}
EXC	2nd Exc	LBL	2nd Lbl	IXI	2nd |x|
FIX	2nd Fix	LNx	Inx	1/X	1/x
GE	2nd x=t	LOG	2nd log	\sqrt{x}	\sqrt{x}
GO*	GTO 2nd Ind	LRN	See Note Below	y ^x	y^x
GRD	2nd Grad	LST	2nd List		
GTO	GTO	NOP	2nd Nop		
IEQ	INV 2nd x=t † ■	OP	2nd Op		
IGE	INV 2nd x=t † ■	OP*	2nd Op 2nd Ind		
I Σ +	INV 2nd Σ+ †	PAU	2nd Pause		
ICOS	INV 2nd cos †	PD*	2nd Prd 2nd Ind		
IDMS	INV 2nd D.MS †	PG*	2nd Pgm 2nd Ind		
IDSZ	INV 2nd Dsz †	PGM	2nd Pgm		
IFF	2nd If flg ■	P/R	2nd P→R		
IFIX	INV 2nd Fix †	PRD	2nd Prd		
IIF	INV 2nd If flg † ■	PRT	2nd Prt		
IINT	INV 2nd Int †	RAD	2nd Rad		
ILNX	INV Inx †	RC*	RCL 2nd Ind		

SYMBOLS

- Σ +
- π
-)
- (
-
- +
- \times
- \div
- =
- .
- +/-

NOTE: This instruction is only seen when its key is encountered while listing a program. Because the key code cannot be placed in program memory by pressing the key, the key code can only be a remnant from the edit of some other instruction and should be corrected.

† Printed in trace mode only.

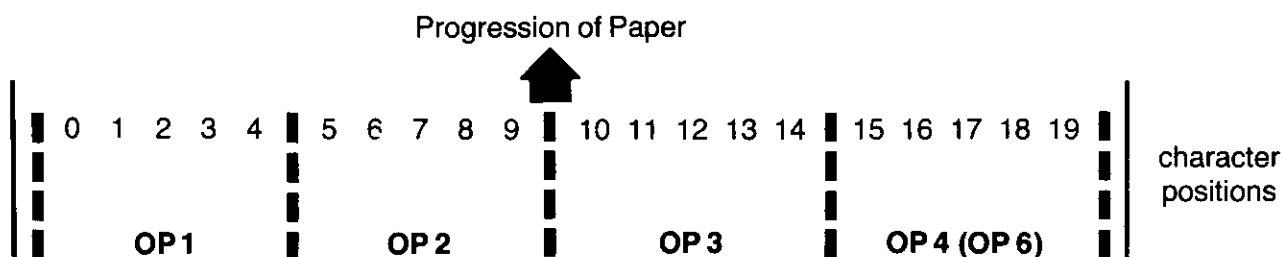
■ TI Programmable 58C only: The symbol "▲" prints during trace when a branch is taken.

SPECIAL CONTROL OPERATIONS FOR PRINTING

Special control operations 00 through 08 are specifically designed for use with the printer.

Alphanumeric Printing — Op 00-06

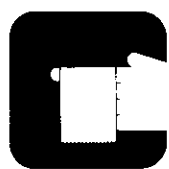
The first seven control operations allow you to create and print out alphanumeric messages. Twenty characters can be printed on each line. They are assembled and stored in groups of 5 characters at a time as shown below.



Each printed character is represented by a two-digit, row-column address code according to the following table:

		UNITS DIGIT							
		0	1	2	3	4	5	6	7
TENS DIGIT	0	blank	0	1	2	3	4	5	6
	1	7	8	9	A	B	C	D	E
	2	-	F	G	H	I	J	K	L
	3	M	N	O	P	Q	R	S	T
	4	.	U	V	W	X	Y	Z	+
	5	x	*	Γ	π	e	()	+
	6	†	%	‡	/	=	*	x	Σ
	7	²	?	÷	°	∏	∆	∏	Σ

For instance, A is code 13 and + is code 47. The codes for five characters (10 digits) can be entered into the display at a time. If you do not specify all 10 digits, zeros are assumed to precede the digits entered (each zero pair represents a blank space). To obtain spaces after some characters, simply enter pairs of zeros after the codes of the characters.



Once the display contains a series of character codes, press **2nd** **Op** **01**, **02**, **03** or **04** to tell the calculator exactly where on the line these characters are to be printed.

- 2nd** **Op** **01** — for far left quarter of line
- 2nd** **Op** **02** — for inside left quarter of line
- 2nd** **Op** **03** — for inside right quarter of line
- 2nd** **Op** **04** — for far right quarter of line

Pressing **2nd** **Op** **00** clears the print register. **2nd** **Op** **05** instructs the calculator to print the contents of the print register. Annotation can be used in the calculate mode to label segments of the paper tape or within a program for the same purpose.

Example: Title a paper tape " π^2 VS X% TESTS 3/22"

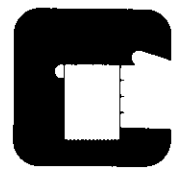
Symbol	π^2	VS	X%	TESTS	3/22
Code	53 70 00 42 36	00 44 61 00 37	17 36 37 36 00	04 63 03 03	

Press	Display	Comments
CLR 2nd Op 00	0.	Clear print register
5370004236 2nd Op 01	5370004236.	Store " π^2 vs" printing on far left 1/4
44610037 2nd Op 02	44610037.	Store "X% T" for printing on inside left 1/4
1736373600 2nd Op 03	1736373600.	Store "ESTS" for printing on inside right 1/4
463030300 2nd Op 04	463030300.	Store "3/22" for printing on far right 1/4
2nd Op 05	463030300.	Prints complete title on printer

Note that a blank is the first thing needed for the inside left quarter. Nonreplaced leading zeros in the print register produce this blank. On the far right 04 is the first character code needed, but only the 4 need be entered. The quarters can be loaded in any order and can be written over by another set of annotation.

You should note that the arithmetic 5th, 6th, 7th, and 8th pending-operation registers are used by the alphanumeric printing operations, Conversions and Statistics. Be sure alphanumeric character codes entered with **2nd** **Op** **03** or **2nd** **Op** **04** are printed before using Conversion or Statistic functions, or before exceeding 4 pending operations with arithmetic calculations.

Always remove fix-decimal, scientific notation and engineering display formats before attempting to enter alphanumeric messages. Also note that for the TI Programmable 59, **2nd** **Op** **00** through **2nd** **Op** **05** will discard the fractional part of the number in the display register in the same manner as the integer key. Only **2nd** **Op** **01** through **2nd** **Op** **04** discard the fractional part of the displayed number with the TI Programmable 58C.



A special-purpose control operation, **2nd Op 06**, prints the value currently in the display along with only the far right 4 characters on one line. This is especially useful to label program results.

Example: Design a program to calculate and label the pi approximation 22/7.

Location and Key Code	Key Sequence	
000 03	3	} P
001 03	3	
002 02	2	} I
003 04	4	
004 69	2nd Op	Store PI for printing
005 04	0 4	
006 02	2	
007 02	2	
008 55	÷	
009 07	7	
010 95	=	22 ÷ 7
011 69	2nd Op	Print
012 06	6	
013 91	R/S	

When this program is executed, the printer will produce 3.142857143 Pi.

*NOTE: USING FIXED DECIMAL NOTATION CAN
SCREW UP Op 06.*

** use FIX AFTER = signs
** cln fix breaks next
Op 06 routine.*



Plotting Data — **Op** 07

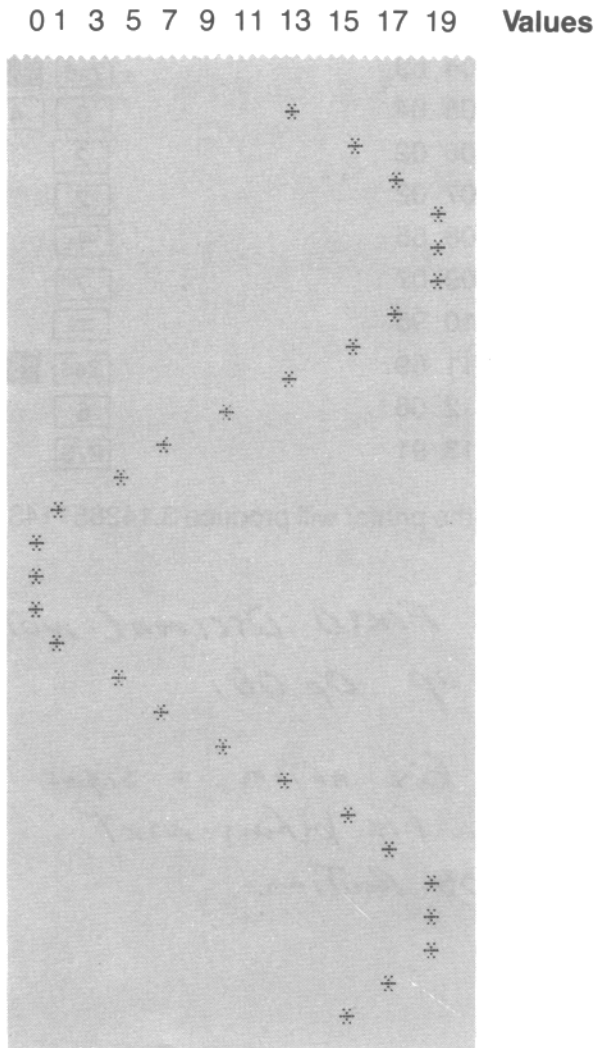
Special control operation 07 plots a * for current display value (0-19) in character position 0-19 with 0 being on the left. Primarily designed for use in a program, this operation allows you to plot curves or histograms. Only one * is plotted per line and the integer part of the value X to be plotted must be $0 \leq X < 20$. If the displayed value is not within this range, the value is not plotted and the display flashes when the program halts. Only the integer portion is plotted.

Example: Design a program to plot a sine curve sampled every 18 degrees.

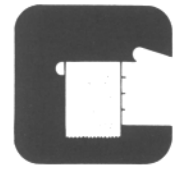
Key Sequence

2nd **Lbl**
A
RCL
1
2nd **sin**
+
1
=
X
9
.
9
=
2nd **Op**
0 **7**
1
8
SUM
1
A

Result



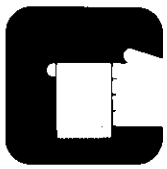
Notice that the sine of all angles is made positive by adding 1 to all sine values at location 004, 005. The values can now range from 0 to 2. If the values are scaled up by 9.9, the range is increased to 0 to 19.8, ideal for plotting purposes. The program is executed by storing a starting angle in register 01 then pressing **A**. The program continues until **R/S** is pressed.



List Program Labels Used — **Op 08**

To obtain a sequential listing of all labels and the locations at which they occur in program memory, press **2nd Op 08**. This listing begins at the current position of the program pointer, so to list all the labels, press **GTO 0** or **RST** before **2nd Op 08**. See the sample listing below.

Program Location	Key Code	Audit Symbols
001	11	A
018	12	B
062	19	D*
129	13	C
205	88	DMS
239	70	RAD
273	80	GRD
282	14	D
288	15	E
294	16	A*
300	10	E*
306	28	LOG



PRINTER HEAD CLEANING PROCEDURE

The procedure for cleaning the print head is given in the *CARING FOR THE PRINTER* section of the PC-100A Owner's Manual. The following program should be used for the TI Programmable 58 and 59.

Location and Key Code	Key Sequence
000 04	4
001 42	STO
002 00	0 0
003 09	9
004 42	STO
005 06	6
006 52	EE
007 01	1
008 00	0
009 94	+/-
010 22	INV
011 52	EE
012 35	1/x
013 76	2nd Lbl
014 11	A
015 84	2nd Op 2nd Ind
016 00	0
017 97	2nd Dsz
018 00	0
019 11	A
020 76	2nd Lbl
021 12	B
022 69	2nd Op
023 05	5
024 97	2nd Dsz
025 06	6
026 12	B
027 91	R/S

To run this sequence, press **RST** **R/S**. Repeat if necessary.

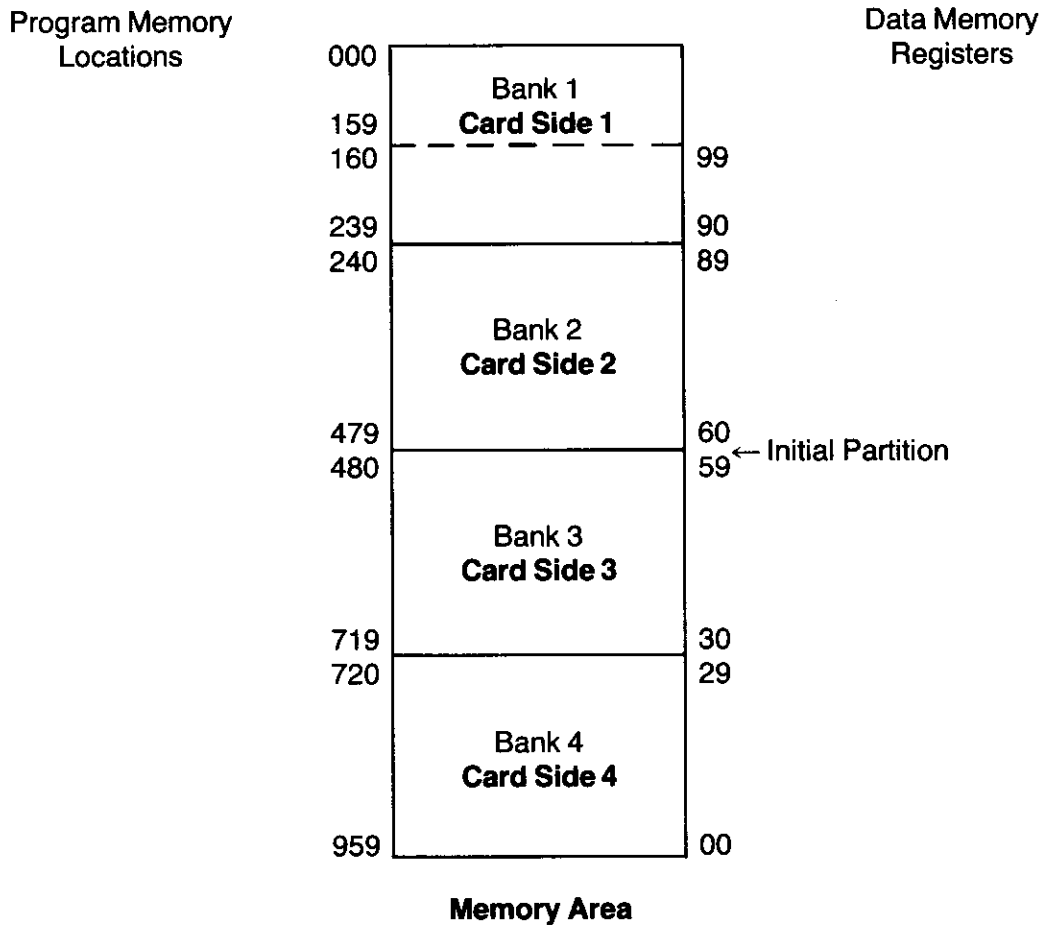
VII

MAGNETIC CARDS



TI PROGRAMMABLE 59 ONLY

You may permanently record any program and any data stored in the calculator on blank magnetic cards furnished with your calculator. As you should already know, your calculator is equipped with 120 storage registers which may be distributed between program memory and data memory. These registers are divided into four banks of thirty registers each. A card is designed to record two of these banks, one to a side.



NOTICE: To read a magnetic card, clear the display with **CLR**, select floating decimal with **2nd** **Fix** 9 if necessary, and insert the card into the lower slot on the right side of the calculator. The card reader turns on automatically and reads the card. See page VII-5 for details.



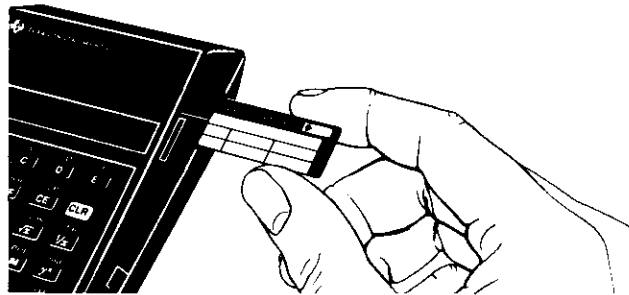
VII

Magnetic Cards

TI PROGRAMMABLE 59 ONLY

RECORDING CARDS

Magnetic cards are recorded using the **2nd** **Write** sequence. To record the contents of bank n ($n = 1, 2, 3$ or 4) onto card side n , press n **2nd** **Write** and insert the card (printed side up) into the lower slot in the right side of the calculator. Note that Fix 0 is the only fix-decimal option which will allow recording a card. If you are not sure of the display format, press **INV** **2nd** **Fix** before the recording key sequence.



The contents of that bank of registers, whether program information, data or both, are written onto the card. The card side you record always carries the bank number that the information is stored in. Only the integer portion of the displayed number is considered when **2nd** **Write** is pressed so fractional parts are ignored. For example, **2.31** **2nd** **Write** places the contents of bank 2 onto a card side that it labels 2. Any number of n whose magnitude is less than 1 or greater than or equal to 5 causes the display to flash and no recording takes place. So, be sure a 1, 2, 3 or 4 is in the display when you start to write a card.

When you insert a card into the calculator mechanism, do not restrict its advance once it is caught by the drive motor. The display remains blank until recording is completed, then the number of the recorded bank is displayed. If the bank number is flashing after writing, clear the display and perform the writing procedure again. If the display still flashes, your card may be faulty, try another card.

Once you have written on one edge of a card, you can write on the other by turning the card upside down and reinserting it into the same lower slot on the right. Remember to specify which bank of program memory you want to write on this side of the card before pressing **2nd** **Write**.

When recording data instead of a program, remember that data register 00 is at the end of bank 4 and the data registers number into bank 3, etc.

1 ◀		TEXAS INSTRUMENTS			▶ 2
<i>Commodity Spreads (Soybeans)</i>				<i>239.89</i>	
	<i>Limit</i>				
<i>Beans (¢)</i>	<i>Meal (¢)</i>	<i>Oil (¢)</i>	<i>Crush</i>	<i>Limit.</i>	



You should always label a magnetic card according to the information stored on it. In the upper corners of a card, spaces are provided to indicate the bank numbers recorded on that card. The arrow in each space shows which direction the card was entered into the calculator when recording the indicated bank. The space across the center of the card is available for a program title and other pertinent information such as the required partition. Below this line are two rows of boxes. The bottom five boxes may be used to indicate the function of the user-defined keys **A** through **E** within the recorded program. The upper row of boxes may be used similarly for the keys **2nd A** through **2nd E**.

Note that, when a register bank is recorded, the number of the bank and the current partitioning of the calculator are magnetically recorded on the card.

RECORDING MAGNETIC CARDS

Display When 2nd Write Pressed, Card Entered	Normal Program	Protected Program
1, 2, 3, 4	Writes a card side with this number from the bank of this number (program and/or data) and records current partition on card.	If bank contains only program, card is passed but not written — display number flashes. If bank contains some data, bank is recorded but not protected with minus side number on the card.
-1, -2, -3, -4	Writes and protects card side with this number from the bank with this number. Also records current partition on card.	If bank contains only program, card is passed but not written — display number flashes. If bank contains some data, bank is recorded with minus side number.
Any other number	Card is passed, but not recorded. Rightmost two integer digits of display are flashed.	Same as for normal program.

If the display is flashing when trying to write a card, the card is passed but no recording takes place and the rightmost two integer digits are flashed.

The calculator should not be in fix-decimal format when recording cards.

For any flashing display the drive motor continues to run until the card is removed.



Magnetic Cards

TI PROGRAMMABLE 59 ONLY

PROTECTING A PROGRAM

If you have confidential information in a program to be written on a card, you can protect that information by entering a negative bank number for **n** before recording your card. Pressing **n** **+/-** **2nd** **Write** writes a card whose program can be read back into program memory and executed, but that's all. Restrictions on its use once it is read back into the calculator are listed below.

- Program cannot be listed or traced by a printer
- Program labels cannot be listed
- Cannot enter learn mode, edit, repartition or rerecord the program
- Cannot single-step execute or hold the pause key down during execution

You cannot force the calculator to read a protected card side into the wrong memory bank. When one side of a protected program card is read into program memory, an internal program protection flag is set, initiating the above restrictions. The only way to eliminate these restrictions (reset the flag) is to press **2nd** **CP** or turn the calculator OFF. You can read or download over a protected program in program memory, but this does not reset the protection flag. The "new" program now is protected as was the previous one.

You cannot protect the contents of the data registers. Also, a memory bank that is partitioned somewhere in the middle cannot be protected. Data registers are positioned at the front of a bank and the calculator sees the whole bank as a data storage area.

A nonprotected program can be written onto a card previously containing a protected program using the normal card writing procedures mentioned earlier. The "new" program on the card is not protected.



READING CARDS

The drive motor of your calculator automatically pulls a magnetic card through the calculator when it is inserted into the card slot in the calculate mode. Whether or not the card is read depends upon the contents of the display register and the partitioning of the calculator as outlined below.

1. With zero in the display, any bank may be read providing the partitioning of the calculator and recorded program are the same. If the calculator is improperly partitioned, no read occurs, and the number of the bank recorded on the entered card is flashed in the display.
2. With n in the display the calculator may only read bank n . If any other bank number is on the card, the number read is flashed in the display and no read occurs. Again, if the partitioning is incorrect, the number of the entered bank is flashed in the display and the card is not read.
3. With $-n$ in the display any bank read into the calculator is placed in bank n without question. Even partitioning is ignored. Once a card is read the bank number magnetically recorded on the card is placed in the display. A protected card (negative card number) cannot be forced into any bank other than the one numbered on the card.

If zero flashes in the display after a card is entered, the calculator has detected a misread and the card should be reentered.

If any number other than zero or $\pm n$ ($n = 1, 2, 3$ or 4) is in the display when a card is entered, no read occurs, and the right two digits of the display flash.

READING A CARD FROM A PROGRAM

While running a program, **INV** **2nd** **Write** instructs the calculator to read a magnetic card in accordance with the above rules. A card can be inserted into the calculator card reader, but not read until the **INV** **2nd** **Write** instruction is encountered in the program. This allows data to be input where needed.

Remember that a card inserted into the card reader will automatically read when a program stops as a result of **INV** **SBR** or **R/S**.



Magnetic Cards

TI PROGRAMMABLE 59 ONLY

READING MAGNETIC CARDS

Display When Card Entered	Card with Normal Program	Card with Protected Program
0	Reads information into bank number listed on card if current partition matches that on card. If partition incorrect, card is passed, but not read — display flashes card side passed.	Same as for normal program
1, 2, 3, 4	Expects card with this side number to be read — displays that side number. If another side is entered or if partition is incorrect, card is passed but not read — display flashes card side passed.	If side passed numerically matches the display, card is read and side is displayed as negative. If another side is entered or if the partition is incorrect, card is passed but not read — display flashes card side passed.
-1, -2, -3, -4	Forces side read into this bank number regardless of card number or partition. A protected program cannot be forced into any bank.	Expects card with this side number to be read — displays that side number. If another side is entered or if partition is incorrect, card is passed but not read — display flashes card side passed.
Any other number	Card is passed but not read — rightmost two integers in display flash.	Same as for normal program

If the display is flashing any value when trying to read a card, the card is passed but not read and the rightmost two integers in the display are flashed.

The calculator should not be in fix-decimal format when reading cards.

Be sure your calculator battery pack is well charged or connected to an AC outlet before attempting any lengthy calculations. This is especially critical to the accuracy of reading and writing magnetic cards.

A flashing 0 in the display after reading a card indicates that the card has not been read correctly and should be reread.



CARING FOR MAGNETIC CARDS

CAUTION: Recorded magnetic cards may be damaged or altered if exposed to dust or foreign materials, permanent magnets, or electromagnetic fields (electric motors, power transformers, etc.).

Magnetic cards have the ability to retain information placed on them for an indefinite period of time. The recorded information does not tend to fade or weaken with age and will remain unchanged until actually altered by an external magnetic field. While the magnetic signal will not deteriorate, the physical characteristics of the card and the card drive unit in the calculator are susceptible to damage.

Handling Cards

Developing good habits in handling magnetic cards is important. A card which is physically marred, creased or dented may be useless for its intended purpose. However, physical degradation of a card generally results from an accumulation of mishaps or poor handling techniques.

There are numerous contaminants to consider. Ashes, food particles, drinks, dust and oil-based liquids are the most common contaminants to guard against. A card can be contaminated by placing it directly on a contaminated surface; or indirectly, by transferring the contaminants to the card with your fingers. Even the natural oils on your fingers will transfer to the cards and cause accumulation of dust and foreign particles. Note that using one contaminated card in the calculator may contaminate not only the calculator card reading mechanism, but also other cards which are used later. In some cases of extreme contamination by oily materials, the calculator card reading mechanism can be rendered inoperative and require repairs by a Texas Instruments Service Facility. The following simple instructions are important to assure maximum life of the magnetic cards.

1. Handle a card by its edges whenever possible.
2. Keep the cards away from magnets and sharp objects that could scratch the oxide coating.
3. Keep the card in the vinyl carrying case or other protective container while the card is not in use.
4. If a card is contaminated, clean it immediately.
5. Do not attempt to read or write visibly damaged or contaminated cards.



Magnetic Cards

TI PROGRAMMABLE 59 ONLY

Cleaning Cards

Contaminated card may be cleaned easily without using special cleaners or solvents. Petroleum based fluids such as lighter fluid should not be used to clean cards under any circumstances. Dust and foreign particles should be removed from a card with a soft dry cloth. Other forms of contamination may be washed from the card with warm water and a small amount of mild liquid detergent. Rinse the card and dry with a soft cloth.

Marking On Cards

The blank magnetic cards furnished with your calculator have areas designated for you to write numbers, symbols and abbreviated titles for your personal programs. You may write information temporarily on a card with a soft fine-lead pencil or a fine-point, felt-tip pen with washable ink. Of course, a felt-tip pen with non-washable or permanent ink will permanently mark your card. For best results, check with your local school supply outlet and ask for felt-tip pens that are used to write on transparencies. Most outlets carry a variety of colors with washable or permanent inks.

USING THE HEAD-CLEANING CARD

The specially marked head-cleaning card furnished with your calculator has an abrasive coating in place of the usual oxide. Using this card will remove any build-up of oxide or foreign particles from the magnetic read/write head in the calculator. This card should not be used as an all-purpose remedy for any difficulty experienced, as excessive use could change the characteristics of the read/write head. The *IN CASE OF DIFFICULTY* section of *Appendix A* gives instructions that should be used as the guide for when the head cleaning card may be used to remedy a difficulty. To use the card; insert it into the lower slot of the calculator as you would a regular card, and let the drive motor pull the card through the calculator. Press **CLR** if the display flashes after using the card. The head cleaning card should be used sparingly and no more than one time per difficulty. Be sure this card is clean before using it.

USING THE DRIVE ROLLER CLEANING CARD

The Drive Roller Cleaning Card is to be used about every 500 reads or when a card begins to slip or move at a nonuniform pace through the calculator. Press **1** **2nd** **Write** and insert the card. Hold onto the tail-end of the card moving it back and forth while the drive mechanism is in motion. Three or four seconds of this action should be sufficient to properly clean the roller. Withdraw the card and press **R/S**. If the drive motor continues running after removing the card, it may be necessary to turn the calculator off and on again.



USING THE CALCULATOR DIAGNOSTIC CARD

The CALCULATOR DIAGNOSTIC magnetic card may be used to check the functional status of the calculator and its magnetic card read/write operation. This diagnostic does not interact with or check the operation of a library module.

Calculator Test

To use the CALCULATOR DIAGNOSTIC card, read side 1 of the card by pressing **CLR** and inserting the card into the lower slot of the calculator. After the card is read, the display should show 1. Press **E** to perform the diagnostic. A display of $-.8888888888$ indicates the calculator passed the test. When run using the PC-100A Printer, the displayed value is also printed. A flashing display indicates the calculator failed the test. Repeat test to verify that problem is real. If so, perform the following Read/Write Test to see if the card reader is at fault.

Read/Write Test

This test may be more convenient to perform with the PC-100A Printer. Read side 2 of the CALCULATOR DIAGNOSTIC card by pressing **CLR** and inserting the card into the lower slot of the calculator. After the card is read, the display should show 2. If the Printer is used, press **GTO 240 2nd List** and verify that the calculator contains key code 77 in locations 240 through 479. This may be done manually by pressing **GTO 240 LRN** and **SST** to verify that 77 is in each location. Other than 77 at any location from 240 through 479 indicates a card reading problem. Repeat complete test procedure to be sure the problem is real.

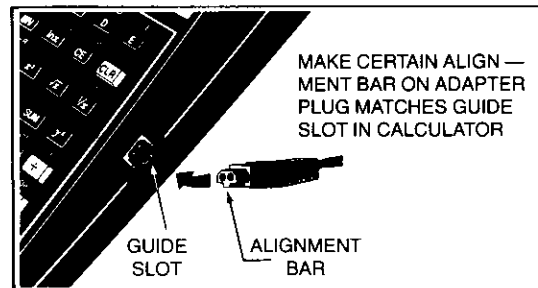
To check the card-write function of the calculator, read side 2 of the CALCULATOR DIAGNOSTIC card as described above. Now use a blank magnetic card, press **CLR 2 2nd Write** and insert blank card into the lower slot of the calculator. Press **2nd CP** and read the card just recorded into the calculator. Check that 77 is in locations 240 through 479. Repeat complete test if an error is found to be sure the problem is real.



MAINTENANCE AND SERVICE INFORMATION**BATTERY AND AC OPERATION**

Normal Operations — To ensure maximum portable operating time, connect the AC9131 Adapter/Charger to a standard 115V/60 Hz outlet, plug into calculator, and charge battery pack at least 4 hours with the calculator OFF or 10 hours with the calculator ON. The adapter/charger and battery pack may become warm when used on AC power. This is normal and of no consequence.

CAUTION: The calculator can be damaged if the adapter/charger is connected without the battery pack installed.



When the battery pack is fully charged, the calculator will operate approximately 2 to 3 hours before recharging is necessary. However, don't hesitate to connect the adapter/charger if you know or suspect the battery pack is nearly discharged. A battery pack near discharge can adversely affect all calculator operations. A discharged battery pack is typically indicated by a dim, erratic or blank display, or the card drive motor starts to run. If a battery pack becomes completely discharged while reading a card, the program on the card can be erased or altered.

If the symptoms of a discharged battery pack are observed on the TI Programmable 58C, **turning off** the calculator immediately may prevent losing program and data memory contents. Install a fresh battery pack or connect the charger as quickly as possible. **Always stop a running program, turn off the calculator and disconnect the adapter/charger before removing the battery pack.**

While individual cell life in a battery pack is difficult to predict, under normal use, rechargeable batteries have a life of 2 to 3 years or about 500 to 1000 recharge cycles.

Periodic Recharging — Although the calculator will operate indefinitely with the adapter/charger connected, the rechargeable battery pack can lose its storage capacity if it is not allowed to discharge occasionally. For maximum battery life, it is recommended that you operate the calculator as a portable at least twice a month, allowing the batteries to mostly discharge, then recharge accordingly.

Excessive Battery Discharging — If the calculator is left on for an extended period of time after the battery pack is discharged (accidentally left on overnight, for example), connect the adapter/charger for at least 24 hours with the calculator OFF. If this does not restore normal battery operation the battery pack should be replaced. Repeated occurrences of excessive battery discharging will permanently damage the battery pack. Spare and replacement BP-1A battery packs can be purchased from your local TI retailer or directly from Texas Instruments, P.O. Box 53, Lubbock, Texas, 79408.

Storage — If the calculator is stored or unused for several weeks the battery pack will probably need recharging before portable use. The battery pack will not leak corrosive material; therefore, it is safe to store the calculator with the battery pack installed.

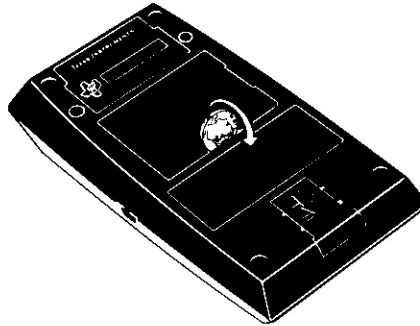


Appendix

A

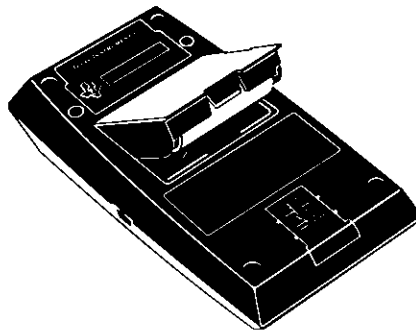
MAINTENANCE AND SERVICE INFORMATION

Battery Pack Replacement—The battery pack can be quickly and simply removed from the calculator. **Always stop a running program, turn off the calculator and disconnect the adapter/charger before removing the battery pack.** Hold the calculator with the keys facing down. Place a small coin (penny, dime) in the slot on the back of the calculator. A slight prying motion with the coin will pop the slotted end of the pack out of the calculator. The pack can then be removed entirely from the calculator.



The exposed metal contacts on the battery pack are the battery terminals. Care should always be taken to prevent any metal from coming into contact with the terminals thereby shorting the batteries. These terminals should be cleaned periodically with a pencil eraser to remove any corrosion that may have accumulated.

To reinsert the battery pack, place the rounded part of the pack into the pack opening so that the small step on the end of the pack fits under the edge of the calculator bottom. The slotted end of the pack will then be next to the caution instruction. A small amount of pressure on the battery pack will snap it properly into position.



MAINTENANCE AND SERVICE INFORMATION
IN CASE OF DIFFICULTY

In the event that you have difficulty with your calculator the following instructions will help you to analyze the problem. You may be able to correct your calculator problem without returning it to a service facility. If the suggested remedies are not successful, contact the Consumer Relations Department by mail or telephone (refer to *If You Have Questions or Need Assistance* later in this appendix). Please describe in detail the symptoms of your calculator.

If one of the following symptoms appears while operating with the optional printing unit, remove the calculator and reinstall the battery pack. If the symptom disappears when the calculator is removed from the printing unit, refer to the printing unit manual.

Symptom	Remedy
1. Display shows erroneous results, flashes erratic numbers, grows dim, goes blank, or the card reader runs continuously.	The battery pack is probably discharged. Refer to <i>Battery and AC Operation</i> at the first of this appendix.
2. Display is blank for no obvious reason.	Press and hold [R/S] momentarily. If display returns, the calculator was running a long program, hung in a loop, or waiting for a card to be inserted. Press and hold [RST] momentarily. If display returns, processing was in the library module, either hung in a loop (possibly because of a low battery) or was running a long program. The battery pack may be discharged or improperly installed.
3. Display flashes while performing keyboard operations.	An invalid operation or key sequence has been pressed or the limits of the calculator have been violated. See Appendix B for a list of these conditions.
4. Display flashes each time a library program is called.	Library program number does not exist. Consult library manual. Library module not properly installed. Refer to Section III of this manual.



MAINTENANCE AND SERVICE INFORMATION

Symptom

5. Display flashes or produces incorrect results when running a library program.

Remedy

The wrong program may have been called.

Improper operating procedure. Check related User Instructions in the library manual.

Partitioning is set for too few data registers to run the program.

Calculator is operating in Fix-Decimal display format. Press **INV** **2nd** **fix** and try program again.

Press **CLR** **2nd** **Pgm 1** **SBR** **=** to run the library diagnostic. If the result is flashing, check that library module is properly installed (see Section III) and press this sequence again.

6. Display flashes or produces incorrect results when running a personalized program in program memory.

An illegal operation, overflow or underflow occurred while the program was running. Appendices B, C and D may be useful in finding the problem.

One of the library programs has been called. Press **RST** and try again.

Press **CLR** **2nd** **Pgm 1** **SBR** **=** to perform the library diagnostic. If the result is flashing, review actions in symptom 5.

If program has been read from a magnetic card, perform the tests given in *Using the Calculator Diagnostic Card* at the end of Section VII. If the test results are good, check the magnetic card with your program for physical defects or contamination. Review actions in symptom 7.



MAINTENANCE AND SERVICE INFORMATION

Symptom

Remedy

7. Display flashes after reading or recording a magnetic card.

Improper procedure. Refer to Section VII.

Incorrect partitioning selected.

A reading error has been detected. If other cards read properly, check first card for physical defects or contamination, and clean or replace card as necessary. If the card was contaminated, see *Using the Driver Roller Cleaning Card* in Section VII. If other cards do not read properly, use the head cleaning card one time — refer to *Using the Head Cleaning Card*, *Using the Drive Roller Cleaning Card*, and *Using the Calculator Diagnostic Card* in Section VII.

8. Calculator will NOT go into learn mode, single step, list or record a card.

The program in the program memory is protected. See *Protecting a Program in Section VII*.

Incorrect partitioning selected.

When returning your calculator for repair, return the calculator, adapter/charger, library module and any magnetic cards which were involved when the difficulty occurred. For your protection, the calculator must be sent insured; Texas Instruments cannot assume any responsibility for loss of or damage to uninsured shipments.

Please include information on the difficulty experienced with the calculator as well as return address information including name, address, city, state and zip code. The shipment should be carefully packaged, adequately protected against shock and rough handling and sent to one of the Texas Instruments Service Facilities listed with the warranty.

NOTE: The P.O. box number listed for the Lubbock Service Facility is for United States parcel post shipments only. If you use another carrier, the street address is: Texas Instruments Incorporated
2305 University Ave.
Lubbock, Texas 79415

Out-of-Warranty Service. Because our Service Facility serves the entire United States, it is not feasible to hold units while providing repair estimates. For simplicity of operation, we have established flat-rate charges for all out-of-warranty repairs. To obtain the correct charges for a particular model, call our toll-free number listed in this section.



Appendix

MAINTENANCE AND SERVICE INFORMATION

Calculator Exchange Centers — If your calculator requires service, instead of returning the unit to a service facility for repair, you may elect to exchange the calculator for a factory-rebuilt calculator of the SAME MODEL by going in person to one of the exchange centers which have been established across the United States. A \$3.00 charge will be made by the exchange center for in-warranty exchanges. Out-of-warranty exchanges will be charged at the rates in effect at the time of the exchange. Please call the Consumer Relations Department for further details and the location of the nearest exchange center.

IF YOU HAVE QUESTIONS OR NEED ASSISTANCE

For General Information

If you have questions concerning calculator repair, accessory purchase or the basic functions of your calculator, please call our Consumer Relations Department at 800-858-1802 (toll free within the contiguous United States except Texas) or 800-692-1353 within Texas.

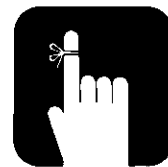
For Technical Assistance

For technical questions such as programming, specific calculator applications, etc., you can call 806-747-3841. We regret that this is **not** a toll-free number, and we cannot accept collect calls.

As an alternative, you can write to: Consumer Relations Department
Texas Instruments Incorporated
P.O. Box 53
Lubbock, Texas 79408

Because of the number of suggestions which come to Texas Instruments from many sources containing both new and old ideas, Texas Instruments will consider such suggestions only if they are freely given to Texas Instruments. It is the policy of Texas Instruments to refuse to receive any suggestions in confidence. Therefore, if you wish to share your suggestions with Texas Instruments, or if you wish us to review any calculator program key sequence which you have developed, please include the following statement in your letter:

"All of the information forwarded herewith is presented to Texas Instruments on a nonconfidential, nonobligatory basis; no relationship, confidential or otherwise, expressed or implied, is established with Texas Instruments by this presentation. Texas Instruments may use, copyright, distribute, publish, reproduce, or dispose of the information in any way without compensation to me."



ERROR CONDITIONS

A flashing display indicates that the displayable limits of the calculator have been violated or that an invalid calculator operation has been requested. Pressing **CE** or **CLR** stops the flashing. **CLR** also clears the display and pending operations. **CE** stops the flashing only, permitting further calculations with undisturbed pending operations. The display flashes for the following reasons:

1. Calculation entry or result (in display or memories) outside the range of the calculator, $\pm 1 \times 10^{-99}$ to $\pm 9.9999999 \times 10^{99}$. The exceeded limit is flashed, indicating underflow or overflow.
2. Inverse of a trigonometric function with an invalid value for the function such as $\sin^{-1} x$ with x greater than 1. The invalid value x is flashed.
3. Root or logarithm of a negative number. The root or logarithm of the absolute value of the number is flashed to indicate the sign error.
4. Raising a negative number to any power (or root). The power (or root) of the absolute value of the number is flashed.
5. Pressing two operation keys in succession. This affects $+$, $-$, \times , \div , y^x , and $\sqrt[y]{x}$. The last entered number is flashed.
6. Pressing **=** or **)** after $+$, $-$, \times , \div , y^x , or $\sqrt[y]{x}$. The last entered number is flashed.
7. Having more than 9 open parentheses or more than 8 pending operations. The 10th parenthesis or 9th operation is not accepted so processing can continue. The last displayed number is flashed.
8. Dividing a number by zero. "9.9999999 99" is flashed.
9. Calling for a special control operation outside the range 00-39.
10. Attempting to plot (**Op** 07) outside the range 00-19. The display value flashes.
11. Attempting to partition beyond the limits of the TI Programmable 58 (60 data registers, 00-59). The TI Programmable 59 uses 100 data registers if more than 10 sets are requested.
12. Attempting to transfer to unassigned label positions or outside of the program partition to nonexistent program locations causes the display to flash.
13. Attempting to download a library program where insufficient program memory space exists causes the display to flash.
14. Addressing a nonexistent library program number flashes the current display value.
15. In linear regression calculations, if the line parallels the y -axis, attempting to calculate the correlation coefficient will cause flashing. If the line parallels the x -axis, the display flashes when attempting to calculate x' or correlation.



Appendix

B

ERROR CONDITIONS

16. Calculation of slope, intercept, correlation, x' or y' with fewer than 2 data points entered. The last displayed number flashes in the display.
17. Having more than four pending operations during linear regression, trend-line analysis or statistical routines, or during polar/rectangular or degrees-minutes-seconds conversions.
18. 0^{-x} and $\sqrt[x]{0}$ produce flashing overflow "9.9999999 99".
19. Radius outside the range $10^{\pm 50}$ in rectangular to polar conversions. The angle is flashed.
20. Arguments that do not satisfy the following limits cause a flashing display.

Function	Limit
$\sin^{-1}x, \cos^{-1}x$	$-1 \leq x \leq 1$
$\ln x \log x$	$1 \times 10^{-99} \leq x < 1 \times 10^{100}$
e^x	$-227.9559242 \leq x \leq 230.2585092$
10^x	$-99 \leq x < 100$

21. Odd multiples of $\pm 90^\circ$, $\pm \pi/2$ radians, and ± 100 grads are undefined points of the tangent function. Small multiples result in an overflow condition; however, multiples of this function yield incorrect results without giving an error indication. See **Appendix C** for more details.
22. Incorrect reading or writing of cards flashes the display.

ERRORS ENCOUNTERED WHEN RUNNING A PROGRAM

When any of the foregoing errors occur in a program, what happens next depends upon the programmer. Program halts are not an automatic consequence of an error condition except for number 12 above. The program continues, using the value that would have flashed in keyboard operation for subsequent calculations, and the presence of an error will be signaled by flashing the "answer" obtained when the program halts. This may or may not be the correct answer, depending upon the problem and the type of error condition. However, it is the best selection which can be made without further instructions from the programmer. If the programmer desires he may instruct the calculator to cease execution when an error condition arises by setting flag 8 or by using the error tests, Op 18 and 19.



DISPLAYED RESULTS VERSUS ACCURACY

Calculators, like all other electrical and mechanical devices, must operate with a fixed set of rules within preset limits.

The basic mathematical tolerance of the calculator is controlled by the number of digits it uses for calculations. The calculator appears to use 10 digits as shown by the display, but actually uses 13 digits to perform all calculations. Combined with the built-in 5/4 rounding capability, these extra digits guard the ten-digit display to improve accuracy. Consider the following example in the absence of these guard digits.

$$1/3 \times 3 = .9999999999 \text{ (inaccurate)}$$

The example shows that $1 \div 3 = .3333333333$, when multiplied by 3, produces an inaccurate answer. However, a thirteen-digit string of nines will *round* to 1 when rounded to 10 places.

The higher order mathematical functions use iterative calculations. The cumulative rounding error is usually maintained below the ten-digit display so that no effect can be seen. The 13-digit representation of a number is three orders of magnitude from the displayed tenth digit. In this way the display assures that results are rounded accurately to ten digits.

Normally there is no need to even consider these guard digits. On certain calculations, however, the guard digits may appear as an answer when not expected. The mathematical limits of finite operation: word length, truncation and rounding errors do not allow the guard digits to always be completely accurate. Therefore, when subtracting two functions which are mathematically equal, the calculator may display a nonzero result.

Example: $\text{Sin } 45^\circ - \text{Cos } 45^\circ \neq 0$

Select degree mode

Press	Display
45 2nd SIN -	.7071067812
45 2nd COS	.7071067812
=	7.-13

The identical display results of $\text{sin } 45^\circ$ and $\text{cos } 45^\circ$ show that the functions are accurate to at least ten digits. The final result indicates a discrepancy in the thirteenth digit. The significance is that results smaller than entry or intermediate results off by a factor of 10^{-11} to 10^{-12} are potentially equal to zero.

The above fact is especially important when writing your own programs. When testing a calculated result to be equal to another value, such as **2=t**, precautions should be taken to prevent improper evaluation due to the guard digit differences. The sequence **EE** **INV** **EE** will truncate the guard digits of a result leaving only the rounded display value for further use.



DISPLAYED RESULTS VERSUS ACCURACY

For the standard display, results are accurate for all calculations that do not violate the restrictions listed in *Appendix B*, except as defined below.

TRIGONOMETRIC FUNCTIONS — All displayed digits in standard display format are accurate to ± 1 in the 10th digit for a $\pm 36,000$ degree range, $\pm 200 \pi$ radians and $\pm 40,000$ grads. When the argument range reaches $\pm 3.6 \times 10^{14}$ degrees ($\pm 6.2799993 \times 10^{12}$ radians or $\pm 4.0 \times 10^{14}$ grads) or more, no partial rotation is recognized. In general, the accuracy decreases one digit for each decade outside the specified accuracy range. An exception is the tangent of an odd multiple of $\pm 90^\circ$, $\pm \pi/2$ radians or ± 100 grads that results in an overflow condition because the function is undefined at these points. As you approach these limits, the accuracy of the tangent function decreases. For instance, $\tan 89.9999996$ is accurate through 6 places.

ROOTS AND POWERS — There can be some accuracy loss for roots and powers in calculations but only when the base y gets very close to 1 and the power x gets very large. For example, $.99999944^{-160000}$ is accurate through 8 digits, whereas $.99999944^{-400}$ is accurate throughout all 10 standard display digits.



TROUBLESHOOTING PROGRAMS

Even the most cautious programmer occasionally runs into a situation where things just aren't working properly. Your calculator provides a set of keys to make editing easy. The problem is to find the errors. Naturally, you should first check to see that the program has been keyed in correctly. If no inconsistencies are found then the remainder of this Appendix can probably help you. A list of common programming errors is given first. Once you have familiarized yourself with these suggestions, you may recognize your mistake. If not, continue on into *Program Diagnosis*, the next part of this section.

The optional PC-100A or PC-100C printer becomes especially useful here for listing your program or tracing calculations. Flag 9 can be set either manually or in a program to trace all program calculations. This helps detect the source of program errors.

BASIC CONSIDERATIONS

Algebraic Operating System

Most problems can be keyed into the calculator just as they are written, but this does not mean that they are interpreted in that same order. The algebraic hierarchy of the calculator causes an expression such as $2 + 3 \times 6$ to be interpreted as $(3 \times 6) + 2 = 20$, not $(2 + 3) \times 6 = 30$.

Another point to remember is that single-variable functions must *follow* the number being operated on. $\sin \pi$, for example, is evaluated by the sequence 2nd π 2nd sin.

Equals Command — =

The equals instruction completes *all* pending operations; hence it should be used with discretion, especially in subroutines.

The *lack* of an equals can also cause problems. Consider the expression $(2 \times 3)^2$. The sequence 2 X 3 x² causes the calculator to determine the value 2×3^2 . The sequence required here is either 2 X 3 = x² or (2 X 3) x².

Pending Operations

Your calculator can retain up to nine levels of parentheses and eight pending operations. However, some of the calculator's keyboard functions require the use of as many as four pending operations.

Polar/rectangular and degree format conversions are among these functions, as well as the statistical functions. An entry that exceeds the limits is simply ignored and the display flashes to let you know what has happened.

Multiple Labels

Each label may be used only once within a program. The label search mechanism always begins at location 000, not at the point where the label is called. Therefore, transfer always goes to the first label and a second use of that label could never be found.



Appendix

D

TROUBLESHOOTING PROGRAMS

Subroutine

Six subroutine levels are probably more than you will ever need. Calling a subroutine beyond the sixth level does *not* store a new return address in the subroutine return register. When **INV** **SBR** is encountered in a seventh level subroutine, processing returns according to the last or sixth address stored in the return register, which is, of course, not the place you expected. This condition, however, does not cause an error indication, so you may not be aware that an incorrect transfer has been made.

Keep in mind that a user-defined key is a subroutine call unless it is preceded by a transfer instruction such as **GTO** or **2nd** **⇌**.

Also, polar/rectangular and degree format conversions and statistics each require one level of subroutine.

Reset Instruction — **RST**

This instruction is very useful, but keep in mind all of the things it can do so you can avoid unintentional effects. **RST** performs four functions: positions the program pointer to location 000, resets all program flags, clears the subroutine return register and halts library programs, returning the pointer to program memory.

Statistical Functions

When using the preprogrammed statistical functions, data are *summed* into the contents of data registers R_1 - R_6 . Therefore, a program using these functions should not only avoid the use of these registers, but should clear them as well before starting data entry. Steps should also be taken to preserve the value stored in the T-register if it is needed later in the program. As mentioned above, these functions require up to four pending operations and one subroutine level.

Polar/Rectangular Conversions

Here the primary thing to remember is to select the correct angular mode. Again, these conversions use up to four pending operations and one subroutine level.

Angular Mode Selection

Your calculator powers-up in the degree mode. If you want angles to be interpreted in either radians or grads you need to instruct the calculator to do so with the appropriate keys. The calculator then remains in the selected angular mode until another is chosen. There is no visible indication of which angular mode the calculator is in.

Functions Operating on the Display Only

EE and **2nd** **D.MS** operate only upon the contents of the display, not the display register. That is, any guard digits and any digits suppressed by placing the calculator in a fix-decimal display format are lost when you use these instructions.



T-Register Comparisons

2nd **≠** and **2nd** **≥** compare the entire display register against the entire T-register when deciding whether or not to branch to a new location. As an illustration of the type of problem you may run into using these instructions, try the following sequence.

```

2nd Deg
45 2nd sin
↵
45 2nd cos
2nd ≠ 114
  
```

Now, if you enter the learn mode, you find that this transfer didn't take place even though $\sin 45^\circ$ and $\cos 45^\circ$ are mathematically equal. This is due to rounding that occurs in the guard digits when your calculator computes the values (see *Appendix C*). To prove this to yourself, subtract $\cos 45^\circ$ from $\sin 45^\circ$. You get a nonzero result, indicating that these values differed in the guard digits. Normally, you would never detect this difference, but you need to keep it in mind when working with conditional transfers. The sequence **EE** **INV** **EE** will truncate the guard digits of a result, leaving only the rounded display value for further use.

Also, you should be careful when using the **EE** and **2nd** **D.MS** functions where guard digits are discarded or altered.

Editing

You should use care when editing programs. Even simple changes, which may seem almost insignificant at one point, may cause complications elsewhere. Consider all possible effects that any change can make. Some things to watch out for are merged addresses, duplicate labels, merged instructions (like **INV** **SBR**), and addresses that can be interpreted as key codes. You cannot edit a protected program.

Remember that adding and deleting instructions invariably moves parts of the program up and down. Transfer instructions using absolute addressing should be corrected accordingly.

Partitioning

Be sure that the data registers and program memory you use are within your partition. A data register can hold 8 program instructions. Each pair of numbers in a data register is a potential instruction. So, be careful when repartitioning that the contents of a data register do not become 8 program instructions and vice versa.



TROUBLESHOOTING PROGRAMS

PROGRAM DIAGNOSIS

Keeping the above in mind, here are some suggestions for program diagnosis. The intention here is to suggest ways for you to evaluate programs that do not function properly.

Program Does Not Terminate

When a program does not terminate when expected, it is usually said to be “hung” in a loop. The best procedure is to step through the program analyzing each instruction and giving special attention to transfer statements. Though a branching instruction is likely to be the culprit, unconditional transfers should be checked first as an error here is easier to detect. Be wary of sequences such as

2nd **Lb/** **D** . . . **GTO** **D** . Here a conditional transfer is required to provide a way out of the loop. Examine conditional transfers next, especially if they are designed to begin or end a loop.

The **2nd** **DSZ** instruction shouldn't send a program into an infinite loop unless the program does something to alter the contents of the data register being decremented or the register value is $\geq 10^{10}$. Make sure that you allow this data register to go to zero. If a very large number is stored in the data register that is being decremented, the program may take an exceptionally long time to terminate and only appear to be hung in a loop. However, if the program is designed to determine the number of loops that are needed, you may want to check this calculation.

Conditional transfers making T-register comparisons should also be carefully examined. Usually, when you use a transfer of this type to control a loop, you expect your calculations to converge within predetermined limits. Naturally, if your calculations don't converge, the loop doesn't terminate. Check both the equations you are using and the instructions you are using to program these equations. Also, make sure that the correct test value is stored in the T-register. If the program is designed to determine this number, you should examine these calculations as well. One additional problem (discussed previously in *T-Register Comparisons* under *CONDITIONAL TRANSFERS* in Section V) is that these instructions compare the *entire* T-register against the *entire* display register before deciding whether or not to branch to a new location.

If you are using a library program as a subroutine, you can press **RST**. If the program stops then the library program was hung in a loop. In this event, see the user instructions of the library routine you used. Pressing **RST** is an emergency measure and should be used only as a last resort, because the stopping point cannot be predicted and the displayed value cannot be identified.

If you are unable to detect any error after completing this evaluation, refer to *Using the Calculator in Diagnosis* later in this section.



TROUBLESHOOTING PROGRAMS

Program Does Not Start

As shown on page IV-6, a straightforward method for entering a variable in a program is to stop the program with an R/S instruction. Ordinarily, the program will continue at the **next** instruction when the **R/S** key is pressed to restart the program. However, this automatic advance to the next instruction is cancelled if a Solid State Software program is called or if a Conversion or Statistics keyboard function is used while the program is stopped. In these cases the **R/S** key must be pressed **twice** to restart the program. Conversions and Statistics functions are described on pages V-30 through V-40.

Consistent Data Yields Inconsistent Results

Errors of this type are usually caused by conditional transfers that, when used improperly, can give correct results one time and not the next. As an illustration, consider the following example:

2nd Lbl	2nd If flg
A	3
≠	C
B	.
2nd St flg	.
3	.
2nd Lbl	2nd Lbl
B	C
.	.
.	.
.	.

Here, the programmer wants to skip a portion of the program if his original data was less than zero. Let's assume that the following set of data is entered into the program: 12, -16, 12. The program produces correct results when the first two entries are made; however, when 12 is entered a second time, the program yields an incorrect result. This is because entering -16 caused flag 3 to be set. Then, since the program includes no provision for resetting flag 3 when positive entries are made, 12 is treated as a negative entry when it is entered a second time. This situation may be remedied by placing the sequence **INV** **2nd** **St flg** **3** following **2nd** **Lbl** **A**.

Similar problems may occur with any transfer operation. Unfortunately, it isn't possible to give an example of each. As a general rule, however, the first thing to do when diagnosing a problem of this nature is to look for a pattern in the answers. In the above, for example, only positive entries produced wrong answers, and then only after a negative entry was made.



TROUBLESHOOTING PROGRAMS

Of course, not all errors of this type are caused by transfer operations. Consider a situation in which consistently different answers (e.g., increasing according to a recognizable pattern) result from entering the same data several times in succession.

```

2nd | Lbl
A
.
.
.
SBR
SUM
.
.
.
2nd | Lbl
SUM
SUM
1 | 2
.
.
.
INV | SBR

```

Here, the problem is caused by the careless use of a data register. If R₁₂ is never cleared, and unless the initial operation on this data register is a **STO** instruction, continuously increasing answers result.

As mentioned above, the key to this type of problem is to find a pattern in the answers. If you can't find a pattern without a lot of extra effort, see *Using the Calculator in Diagnosis*.



TROUBLESHOOTING PROGRAMS

In most cases, such situations may be avoided by incorporating an initialization sequence into each of your programs. A typical initialization procedure is shown below. It is called by simply pressing **E**.

Key Sequence	Comments
R/S	Ends sequence (location 000)
2nd Lbi E	
2nd CMs	Clears data memories
CLR	Clears display
2nd CP	Zeros T-register
INV 2nd Fix	Removes fix-decimal
RST	Resets all flags
	Clears subroutine register
	Sends program pointer to 000

Consistently Wrong Answers

It is possible that a program in which the same erroneous answer occurs consistently, regardless of what data you enter, has been written using an incorrect solution. However, if you have manually worked through your equations, found them valid for all cases, and can find no instruction error, then you should refer to the following section.

Using the Calculator in Diagnosis

Once you have determined what values should be computed and displayed, and where they should be stored at different stages of the program, your calculator can be used as the most efficient means of examining a malfunctioning program.

A strong word of caution: When you recall data register contents for examination at an inspection point, be sure that you restore the contents of the display register before continuing program execution. Otherwise, nonexistent program errors may appear to occur. It is a good idea to use **2nd** **Exc** to call the data to the display for examination and then replace it, using the same sequences. This returns the most recently calculated value to the display.

There are several instructions that you may use to analyze a program as it is running. Inserting **R/S** commands at various key points in a program is a quick method of finding where an error first appears. When the program stops, you should check not only the contents of the display, but those of the data and test registers as well.

When inserting **R/S** instructions it is easiest to start at the highest numbered program location end and work backwards. Inserting the Run/Stop in reverse order does not move around program locations yet to receive the instruction.



TROUBLESHOOTING PROGRAMS

Once a discrepancy is found, run the program again and stop at the **[R/S]** instruction ahead of the **[R/S]** where the error was detected. Now use the **[SST]** key to execute the program one step at a time until you find the exact location of the error. After the problem has been identified and the error corrected, delete the **[R/S]** instructions in the order they occur in program memory. Repeat this process until all errors have been found and corrected.

In place of using **[SST]**, you can hold down the **[GTO]** key. This inserts a pause between each step as it's executed, allowing you a brief but automatic look at the progress of the program. To use this option you must first start the program. To make sure that you observe the results of all program instructions, beginning with the first one, follow these three steps.

1. Press and hold down the **[R/S]** key.
2. While holding down the **[R/S]** key, press and hold the **[GTO]** key.
3. Release the **[R/S]** key.

The most easily diagnosed problem is one that results in an error condition. When this occurs, simply set flag 8 and run the program again. Now, when the error is encountered, the program halts.

Pressing **[LRN]** shows you the program location where the error occurred. (Processing actually stops with the program pointer on the first location following the error.) You should then be able to determine the nature of the error and make necessary correction.

Note: You may not single-step through a library program. When single-stepping through program memory that calls a library program, the display goes virtually blank while the library program is being executed. Once this routine is complete, you may continue to observe the main program using either **[SST]** or **[GTO]**. (If you are using **[GTO]**, do not release this key while a library routine is being executed or part of the main routine may escape inspection.)

Using the Printer in Diagnosis

The optional printer is another valuable aid in diagnosing a program. With your calculator on the print cradle, here's what you can do.

- (1) Press **[RST]** **[2nd]** **[List]** to obtain a complete listing of your program instructions including program location numbers, instruction codes, and instruction mnemonics. This saves you the trouble of single-stepping through a program in the learn mode and translating instruction codes into program instructions to verify that you've entered your program correctly.
- (2) Run a program with the printing unit in the trace mode. This enables you to easily follow the sequence of calculations step-by-step and discover exactly where the program deviates from the solution that you intended.
- (3) Press **XX** **[INV]** **[2nd]** **[List]** to obtain a list of data register contents beginning with R_{xx} . By stopping a program at various key points and performing this operation, you can easily verify that the data registers contain the right quantities at the right times.
- (4) Press **[RST]** **[2nd]** **[Op]** **08** and the printer lists all labels and their absolute addresses. By using this feature you won't have to search through entire program listings to find where your labels are located.



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