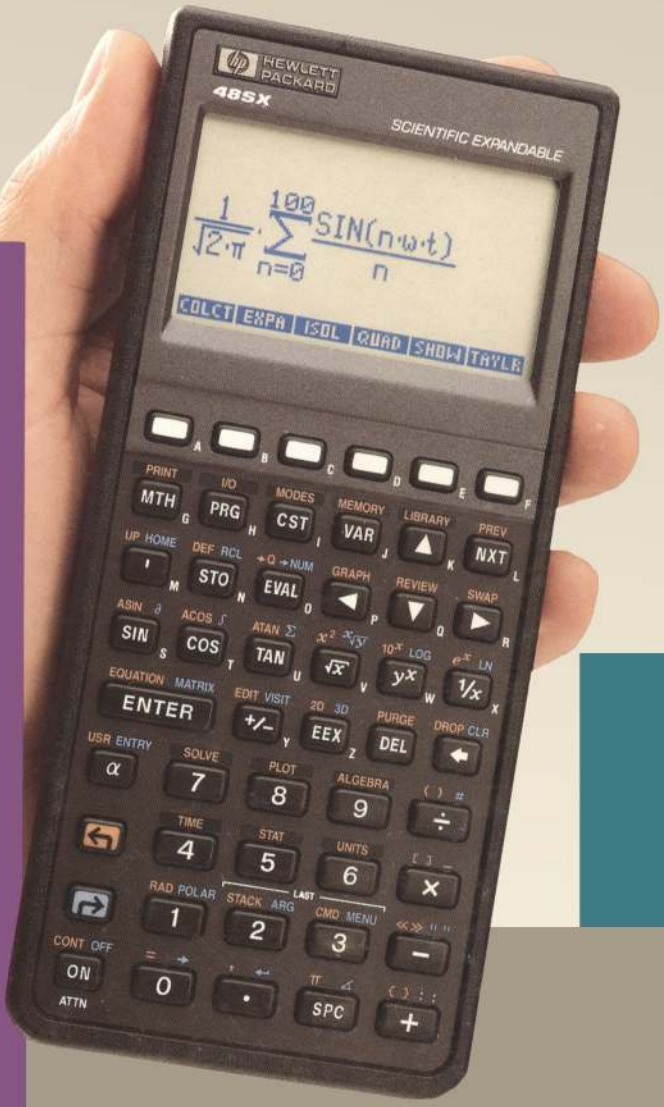
HEWLETT PACKARD

HP 48SX
Scientific Expandable



Owner's Manual
Volume II

HP 48SX Scientific Expandable Calculator

Owner's Manual
Volume II

HEWLETT PACKARD

Edition 4 July 1990
Reorder Number 00048-90003

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For warranty and regulatory information for this calculator, see pages 673 and 676.

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Corvallis Division
1000 N.E. Circle Blvd.
Corvallis, OR 97330, U.S.A.

Printing History

Edition 1	January 1990	Mfg. No. 00048-90004
Edition 2	April 1990	Mfg. No. 00048-90059
Edition 3	May 1990	Mfg. No. 00048-90062
Edition 4	July 1990	Mfg. No. 00048-90078

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Part 4

Programming

25

Programming Fundamentals



A program is an object defined by « » delimiters. A program is itself composed of objects and commands whose execution is *delayed* until the program is executed. Because a program is an object, it can be:

- Placed on the stack.
- Stored in a variable.
- Executed repeatedly.
- Executed by another program.

The following example calculates the volume of a sphere, first using keystrokes and then using a program.

Example: Calculations with Keystrokes and with a Program. The volume of a sphere of radius r is calculated by:

$$V = \frac{4}{3}\pi r^3$$

To do one calculation, you can use the following keystrokes. (Assume you have already placed the radius on the stack.)

3 [y^x] [←][π] [×] 4 [×] 3 [÷] [→][→NUM]

Each time you press a command key, it is immediately executed, leaving an intermediate result on the stack.

If you want to calculate the volumes of many spheres, you can create a program. The following program assumes the radius is on the stack at the start of program execution:

```
« 3 ^ π * 4 * 3 / →NUM »
```

After keying in the « » delimiters (by pressing [←][« »]), you use the same keystrokes to enter the subsequent objects and commands as you did before. However, the objects and commands that you type are simply listed in the command line—their execution is delayed until you execute the program itself.

Because the program is an object, you can place it on the stack and save it in a variable. To place the program on the stack, press [ENTER]. To store the program in a variable named *VOL*, type ' VOL [STO]. Now you can calculate the volume of any sphere simply by placing the radius on the stack and executing *VOL* (select the VAR menu and press VOL). You can execute *VOL* as many times as you want; it acts like a built-in command.

VOL is a program of the simplest form; a series of objects and commands, written in the same order as you would type them from the keyboard. In following chapters, you'll learn about more advanced HP 48 programming features:

- Conditional expressions (chapter 26).
- Looping structures (chapter 27).
- Flags (chapter 28).
- Interactive programs (chapter 29).
- Error trapping (chapter 30).

This chapter covers basic HP 48 programming concepts:

- Entering and executing programs.
- Editing programs.
- Using local variables in programs.
- Stack manipulation of data in programs.

- Using subroutines.
- Single-step execution of programs.

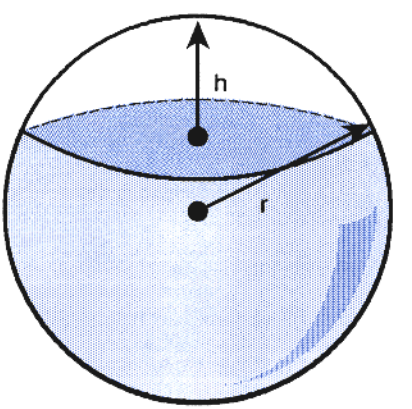
The *Programmer's Reference Manual* for the HP 48 (part number 00048-90054) contains useful programming information, including complete syntax information for all HP 48 commands.

Entering and Executing a Program

Entering a Program

To define the beginning of a program, press [←] [« »]. The PRG annunciator appears, indicating Program-entry mode. In this mode, pressing the key for any command now writes the command's name in the command line. (You can also type the command name into the command line with alpha characters.) Only nonprogrammable operations such as [←] and [VAR] are executed.

The following program, *SPH*, calculates the volume of a spherical cap of radius *r* and height *h*.



The volume is calculated by $V = \frac{1}{3}\pi h^2(3r - h)$.

In this and following chapters on programming, "stack diagrams" are used as appropriate to show what arguments must be on the stack before a program is executed and what results the program leaves on the stack. Here is the stack diagram for *SPH*.

Arguments	Results
2: 1:	2: 1: *volume*

The diagram indicates that *SPH* takes no arguments from the stack and returns the volume of the spherical cap to level 1. (*SPH* assumes that you have stored the numerical value for the radius in variable *R* and the numerical value for the height in variable *H*.)

Program listings are shown with program steps in the left column and associated comments in the right column. Remember, you can either press the command keys or type in the command names to key in the program. In this first listing, the keystrokes are also shown.

Program:	Keys:	Comments:
«	◀ « »	Begins the program.
'1/3	' 1 ÷ 3	Begins the algebraic expression to calculate the volume.
*π*H^2	× ◀ π × H y^x 2	Multiplies by πh^2.
*(3*R-H)'	× ◀ ( ) 3 × R − H ▶ ▶	Multiplies by $3r - h$, completing the calculation and ending the expression.
→NUM	▶ →NUM	Converts π to a number.
»		Ends the program.
	ENTER	Puts the program on the stack.
	' SPH STO	Stores the program in variable *SPH*.

Executing a Program

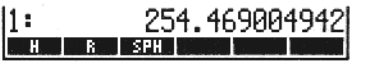
There are several ways to execute *SPH*:

- Type SPH in the command line, then press [ENTER].
- Select the VAR menu, then press SPH.
- If the program or the program name is already in level 1, press [EVAL].

Example: Executing a Program from the VAR Menu. Use *SPH* to calculate the volume of a spherical cap of radius r = 10 mm and height h = 3 mm.

First, store the data in the appropriate variables. Then select the VAR menu and execute the program. The answer is returned to level 1 of the stack.

10 [ ] R [STO]
3 [ ] H [STO]
[VAR] SPH



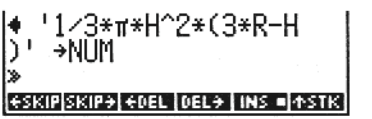
Editing a Program

Follow the same rules to edit a program as you do to edit any other object (see "Displaying Objects For Viewing or Editing" on page 66).

Example: Editing a Program. Edit *SPH* so that it stores the number in level 1 into variable *H* and the number in level 2 into variable *R*.

Use the VAR menu and [VISIT] to call *SPH* to the command line for editing.

[VAR]
[ ] SPH
[↱] [VISIT]



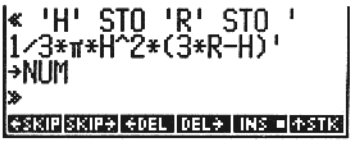
Move the cursor past the first program delimiter and insert the new program steps.

[▶] [ ] H [▶] [STO]
[ ] R [▶] [STO]



Save the edited version of *SPH* in the variable. To verify that the changes were saved, recall *SPH* to the command line.

ENTER
↑ SPH
→ VISIT



No further changes need to be made, so press ATTN to abort the editing session or ENTER to resave the program.

The edited version of *SPH* now takes two arguments from the stack, the height from level 1 and the radius from level 2.

Using Local Variables

The program *SPH* in the previous section uses global variables for data storage and recall. There are disadvantages to using global variables in programs:

- After program execution, global variables that you no longer need to use must be purged if you want to clear the VAR menu and free user memory.
- You must explicitly store data in global variables prior to program execution, or have the program execute STO.

In this section, you'll see how *local variables* address the disadvantages of global variables in programs. Local variables are temporary variables *created by a program*. They exist only while the program is being executed and cannot be used outside the program. They never appear in the VAR menu.

To create local variables, you must use the following sequence of command and objects, called a *local variable structure*:

1. The → command (press → →).
2. One or more variable names.
3. A procedure (an algebraic expression or a program) that includes the names. This procedure is called the *defining* procedure.

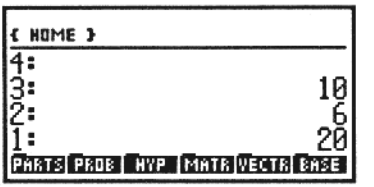
The structure looks like this:

« → *name*$_1$ *name*$_2$ . . .*name*$_n$ « *program* » »

or

« → *name*$_1$ *name*$_2$ . . .*name*$_n$ '*algebraic expression*' »

When the → command is executed in a program, *n* values are taken from the stack and assigned to variables *name*$_1$, *name*$_2$, ... *name*$_n$. For example, if the stack contains:



then:

- → a creates local variable *a* = 20.
- → a b creates local variables *a* = 6 and *b* = 20.
- → a b c creates local variables *a* = 10, *b* = 6, and *c* = 20.

The defining procedure then uses the local variables to do calculations.

(By convention, this manual uses lowercase names for local variables.)

The following program *SPHLV* calculates the volume of a spherical cap using local variables. The defining procedure is an algebraic expression.

Arguments	Results
2: *r* 1: *h*	2: 1: *volume*

Program:	Comments:
«	
→ r h	Creates local variables *r* and *h* for the radius of the sphere and height of the cap.
'1/3*π*h^2*(3*r-h)'	Expresses the defining procedure. In this program, the defining procedure for the local variable structure is an algebraic expression.
→NUM	Converts π to a number.
»	
ENTER ' SPHLV STO	Stores the program in variable *SPHLV*.

Example: Executing a Program That Uses Local Variables. Use *SPHLV* to calculate the volume of a spherical cap of radius $r = 10$ mm and height $h = 3$ mm.

Place the data on the stack in the correct order, then select the VAR menu and execute the program.

10 ENTER 3
VAR SPHLV



The preceding program and example demonstrate the advantages of local variable structures:

- The → command stores the value(s) from the stack in the corresponding variable(s) — you do not need to explicitly execute STO.
- Local variables automatically disappear when the defining procedure for which they are created has completed execution. Consequently, local variables do not appear in the VAR menu and occupy user memory only during program execution.
- Local variables exist only within their defining procedure — different local variable structures can use the same variable names without conflict.

Evaluation of Local Names. Local names are evaluated differently than global names. When a global name is evaluated, the object stored in the corresponding variable is itself evaluated. (You've seen how programs stored in global variables are automatically evaluated when the name is evaluated.)

When a local name is evaluated, the object stored in the corresponding variable is returned to the stack but is *not* evaluated. When a local variable contains a number, the effect is identical to evaluation of a global name, since putting a number on the stack is equivalent to evaluating it. However, if a local variable contains a program, algebraic expression, or global variable name, that object *must be explicitly evaluated* (by executing EVAL) after it is returned to the stack.

Scope of Local Variables. Local variables exist *only* in the procedure for which they are defined. The following sample program illustrates the availability of local variables in *nested* defining procedures (procedures within procedures).

Program:	**Comments:**
`«`	Starts the outer program.
`. . . . . .`	For these arbitrary program steps, no local variables are available.
`→ a b c`	Creates local variables *a*, *b*, and *c*.
`«`	Starts the defining procedure (a program) for local variables *a*, *b*, and *c*. This procedure is nested in the outer program. Local variables *a*, *b*, and *c* are available in this procedure.
`a b + c +`	
`→ d e f`	Defines local variables *d*, *e*, and *f*.
`'`	Starts the defining procedure (an algebraic expression) for local variables *d*, *e*, and *f*. This procedure is nested in the defining procedure for local variables *a*, *b*, and *c*. Local variables *a*, *b*, *c*, *d*, *e*, and *f* are

	available in this procedure.
`a/(d*e+f)`	
`'`	Ends the defining procedure for local variables *d*, *e*, *f*. Local variables *d*, *e*, and *f* no longer exist.
`a c / -`	Local variables *a*, *b*, and *c* remain available.
`»`	Ends the defining procedure for local variables *a*, *b*, and *c*. Local variables *a*, *b*, and *c* no longer exist.
`... ...`	For these arbitrary program steps, no local variables are available.
`»`	Ends the outer program.

Since local variables *a*, *b*, and *c* already exist when the defining procedure for local variables *d*, *e*, and *f* is executed, they are available for use in that procedure. However, suppose that the defining procedure for local variables *d*, *e*, and *f* calls a program that you previously created and stored in global variable *P1*.

Program:	**Comments:**
`«`	
`... ...`	
`→ a b c`	
`«`	
`a b + c +`	
`→ d e f`	Defines local variables *d*, *e*, and *f*.
`'`	Starts the defining procedure for local variables *d*, *e*, and *f*.
`P1+a/(d*e+f)`	The defining procedure executes the program stored in variable *P1*.

```
'                                    Ends the defining procedure for
                                     local variables d, e, and f.
 . . . . . .
»
 . . . . . .
»
```

The six local variables are *not* available in program *P1* because they did not exist when you created *P1*. The objects stored in the local variables are available to program *P1* only if you put those objects on the stack as arguments for *P1* or store those objects in global variables.

Conversely, program *P1* can create its own local variable structure with local variables *a*, *c*, and *f*, for example, without conflicting with the local variables of the same name in the procedure that calls *P1*.

Programs That Act Like User-Defined Functions. In this chapter you've learned that the defining procedure for a local variable structure can be either an algebraic expression or a program. In chapter 10, you learned that a user-defined function is a program that consists solely of a local variable structure whose defining procedure is an algebraic expression.

A program that *begins with a local variable structure whose defining procedure is a program* acts like a user-defined function in two ways: It takes numeric or symbolic arguments, and takes those arguments either from the stack or in algebraic syntax. However, it does *not* have a derivative. (The defining program must, like algebraic defining procedures, return *only one* result to the stack.)

The advantage of using a program as the defining procedure for a local variable structure is that a program can contain commands not allowed in algebraic expressions. For example, the loop structures described in chapter 27 are not allowed in algebraic expressions. The program *BER* in chapter 31 calculates a Bessel function approximation to 12-digit accuracy. *BER* uses a local variable structure whose defining procedure is an RPN program that contains a FOR...STEP structure and a nested IF...THEN...ELSE...END structure. *BER* is not differentiable, but the example in chapter 31 demonstrates that it can take its arguments either from the stack or in algebraic syntax.

Programs That Manipulate Data on the Stack

The programs *SPH* (page 471) and *SPHLV* (page 475) in this chapter use variables for data storage and recall. An alternative programming method manipulates numbers on the stack without storing them in variables. This method usually results in faster program execution time. There are several disadvantages of the stack manipulation method:

- As you write a program, the location of the data on the stack must be tracked. For example, data arguments must be duplicated if used by more than one command.
- A program that manipulates data on the stack is generally harder to read and understand than a program that uses variables.

The following program *SPHSTACK* uses the stack-manipulation method to calculate the volume of spherical cap. (*SPH* and *SPHLV* execute the same calculation.)

Arguments	Results
2: *r* 1: *h*	2: 1: *volume*

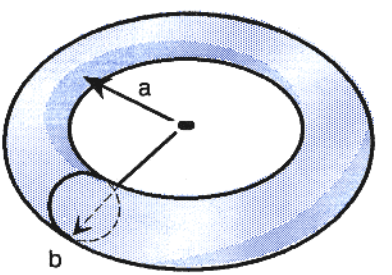
Program:	Comments:
«	
DUP	Makes a copy of the number in level 1 (the height).
ROT	Rotates the number now in level 3 (the radius) to level 1.
3 *	Multiplies the radius by 3.
SWAP -	Swaps the height into level 1 and subtracts, calculating $3r - h$.

`SWAP SQ *`	Swaps the copy of the height into level 1, squares it, and multiplies by $3r - h$.
`π * 3 /`	Multiplies by π and divides by 3, completing the calculation.
`→NUM`	Converts π to a number.
`»`	
ENTER ' SPHSTACK STO	Puts the program on the stack, then stores it in *SPHSTACK*.

Using Subroutines

Remember that a program is composed of objects and commands that are executed when the program is executed. Because a program is itself an object, it can be used by another program. When program *B* is used by program *A*, program *A calls* program *B*, and program *B* is a *subroutine* in program *A*.

This section introduces two programs to illustrate the use of subroutines. The first program, *TORSA*, calculates the surface area of a torus of inner radius *a* and outer radius *b*. *TORSA* is used as subroutine in the second program.



The surface area is calculated by:

$$A = \pi^2(b^2 - a^2)$$

Here is the stack diagram and program listing for *TORSA*.

Arguments	Results
2: *a* 1: *b*	2: 1: *area*

Program:	Comments:
«	
→ a b	Creates local variables *a* and *b*.
'π^2*(b^2-a^2)'	Expresses the defining procedure for the local variable structure.
→NUM	Converts π to a number.
»	
ENTER	Puts the program on the stack.
' TORSA STO	Stores the program in *TORSA*.

Program *TORSV* calculates the volume of a torus. It calls *TORSA* to execute part of the calculation.

The formula for the volume of a torus is:

$$V = \frac{1}{4}\pi^2(a + b)(b - a)^2$$

This equation can be rewritten as:

$$V = \frac{1}{4}\pi^2(b^2 - a^2)(b - a)$$

The quantity $\pi^2 (b^2 - a^2)$ in this equation is the surface area of a torus and can be calculated by executing *TORSA*.

Here is a stack diagram for *TORSV*.

Arguments	Results
2: *a* 1: *b*	2: 1: *volume*

Program:	Comments:
«	
→ a b	Creates local variables *a* and *b*.
«	Starts the defining procedure (a program) for the local variable structure.
a b TORSA	Puts the numbers stored in *a* and *b* on the stack as arguments for *TORSA*, then call *TORSA* to calculate the area $\pi^2(b^2 - a^2)$.
b a − * 4 /	Completes the volume calculation.
»	Ends the defining procedure.
»	Ends the program.
ENTER	Puts the program on the stack.
' TORSV STO	Stores the program in *TORSV*.

TORSV calls program *TORSA* to execute part of the volume calculation. *TORSA* is a subroutine in *TORSV*. In turn, another program can call *TORSV*.

Example: Executing a Program That Uses a Subroutine. Use *TORSV* to calculate the volume of a torus of inner radius $a = 6$ inches and outer radius $b = 8$ inches.

Place the data on the stack according to the stack diagram. Select the VAR menu and execute the program.

6 ENTER 8
VAR TORSV



Single-Step Execution of a Program

It's easier to understand how a program works if you execute it step by step, observing the effect of each step. Doing this can help you "debug" your own programs or understand programs written by others.

The operations for single-stepping through a program are contained in the PRG CTRL menu.

Single-Step Operations

Keys	Programmable Command	Description
↰ CONT	CONT	Resumes execution of a halted program.
PRG CTRL:		
DBUG		Takes as its argument the program or program name in level 1. Starts program execution, then suspends it as if HALT were the first program command.
SST		Executes the next object or command in the suspended program.
SST↓		Same as SST except when the next program step is a subroutine. When the next step is a subroutine, single-steps to the first step in that subroutine.

Single-Step Operations (continued)

Keys	Programmable Command	Description
NEXT		Displays the next one or two objects, but does not execute them.
HALT	HALT	Suspends program execution at the location of the HALT command in the program.
KILL	KILL	Cancels all suspended programs.

Single-Step Execution from the Start of the Program

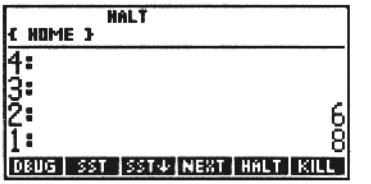
In many cases, you want to begin single-step execution at the beginning of a program. The general procedure is:

1. Put the program or program name in the command line or level 1.
2. Press [PRG] CTRL DBUG. Program execution is started, then suspended before execution of the first object or command. The HALT annunciator is displayed in the status area.
3. Optional: Press NEXT to display in the status area, but not execute, the next one or two program steps. The display persists until the next keystroke.
4. Press SST once to see the first program step displayed in the status area and then executed.
5. You can now:
   - Keep pressing SST to display and execute sequential steps.
   - Press NEXT at any time to display but not execute the next one or two program steps.
   - Press [←][CONT] to continue normal execution.
   - Press KILL to abandon further program execution.

Example: Single-Step Program Execution. Execute program *TORSV* step by step. Use the torus from the previous example (a = 6 inches, b = 8 inches).

Select the VAR menu and enter the data. Return the program name to the command line. Select the PRG CTRL menu and execute DBUG. The HALT annunciator turns on, indicating that program execution has been started, then suspended.

VAR
6 ENTER 8 ENTER
' TORSV
PRG CTRL DBUG



Execute SST. The first program step is displayed in the status area, then executed.

SST



You can see that the first program step took the two arguments from the stack and stored them in local variables a and b.

Refer to the rules at the beginning of this section. You've executed the first four steps and can now choose one of the four alternatives described in step 5. For this example, continue single-step execution until the HALT annunciator disappears. Watch the stack and status area as you single-step through the program.

SST ... SST



Single-Step Execution from the Middle of the Program

You may want to start single-step execution at some point in the program other than the first step. To do so:

1. Insert the HALT command in the program. Place it where you want to begin single-step execution.
2. Execute the program. When the HALT command is executed, the program stops and the HALT annunciator is displayed.
3. Follow steps 3—5 on page 484.
4. When you want the program to run normally again, remove the HALT command from the program.

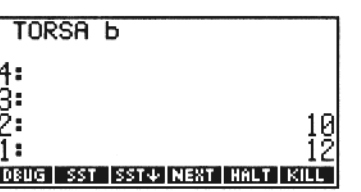
Single-Step Execution of Subroutines

SST executes the next step in a program. If the next step is a subroutine, SST executes that subroutine in one step. In the previous example, you used SST to execute subroutine *TORSA* in one step. However, you may want to single-step through a subroutine, executing each individual step rather than the program as a whole. To do so, use the SST↓ operation. SST↓ works just like SST, except when the next program step is a subroutine. In this case, SST↓ single-steps to the first step in the subroutine.

Example: Single-Step Execution of a Subroutine. Execute program *TORSV* step by step to calculate the volume of a torus of radii a = 10 inches and b = 20 inches. When you reach subroutine *TORSA*, execute it step by step.

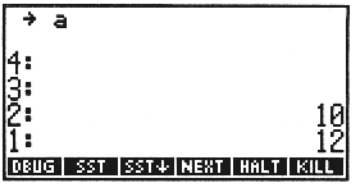
Select the VAR menu and key in the data. Return the program name to the command line, select the PRG CTRL menu, and execute DBUG. Execute the first four steps of the program, then check the next step.

VAR
10 ENTER 12
' TORSV
PRG CTRL DBUG
SST↓ (or SST) 4 times
NEXT



The next step is TORSA. If you now execute SST, *TORSA* will be executed. Since you want to *single-step* through *TORSA*, execute SST↓. Then verify that you are now at the first step of *TORSA*, not the next step of *TORSV*.

SST↓
NEXT



Execute SST or SST↓ repeatedly to single step through the remainder of the program, or at any time, press ↩ CONT to resume program execution.

26

Tests and Conditional Structures



This chapter describes commands and program structures that, used together, let programs ask questions and make decisions:

- *Comparison functions* and *logical functions* let a program test whether or not a specified condition exists.
- Program structures called *conditional structures* use test results to make decisions.

Example: Tests and Conditional Structures. The program in this example uses a test inside a conditional structure to execute the following task:

"If the two numbers on the stack have the same value, drop one of the numbers from the stack and store the other in variable V1. If, however, the numbers are not equal, store the number from level 1 in V1 and the number from level 2 in V2."

Program:	Comments:
«	Starts the program.
DUP2	Copies the numbers in levels 1 and 2.
IF	Starts the test clause of the conditional structure.
SAME	Tests if the numbers have the same value.
THEN	Ends the test clause and starts the true clause of the conditional structure. The true clause is executed only if the test is *true*.
DROP 'V1' STO	If the test is true (if the numbers are the same), then drops one of the numbers from the stack and stores the remaining number in *V1*.
ELSE	Starts the false clause of the conditional structure. The false clause is executed only if the test is *false*.
'V1' STO 'V2' STO	If the test is false, (if the numbers are not the same), then stores the level 1 number in *V1* and the level 2 number in *V2*.
END	Ends the conditional structure.
»	Ends the program.
ENTER ' TST STO	Puts the program on the stack and stores it in *TST*.

Enter the numbers 26 and 52, then execute *TST* to compare their values.

26 ENTER 52
VAR TST



Since the two number were not equal, the VAR menu now contains two new variables *V1* and *V2*. You can verify that the variables contain the numbers you entered by pressing both menu keys.

Program Tests

A test is an algebraic or a command sequence that returns a *test result* to the stack. A test result is either a `1` — which means the test was *true*, or a `0` — which means the test was *false*. For example, `'X<Y'` is a test. The same test could be executed as a command sequence: `X Y <`. In either case, if *X* contains 5 and *Y* contains 10, then the test is true, and `1` is returned to the stack. Conditional structures (discussed later in the chapter) use a test result to determine which clause of the structure to execute.

The commands used in tests can be categorized as follows:

- *Comparison functions*.
- *Logical functions*.
- *Flag-testing* commands. Flags and flag testing commands are discussed in chapter 28, "Flags."

These commands are located in the PRG TEST menu (press PRG TEST).

Comparison Functions

Comparison functions compare two objects.

Comparison Functions

Keys	Programmable Command	Description
PRG TEST (pages 1 and 2):		
<	<	Less than.
>	>	Greater than.
≤	≤	Less than or equal to.
≥	≥	Greater than or equal to.
==	==	Tests equality of two objects. For algebraics or names, returns an expression that can be evaluated to produce a test result based on numerical values.
≠	≠	Not equal. Like ==, but returns the opposite test result.
SAME	SAME	Like ==, but does not allow a comparison between the numerical value of an algebraic (or name) and a number.

<, >, ≤ and ≥ compare two real numbers, two binary integers, or two strings returning 1 (true) or 0 (false) based on the comparison. The order of the comparison is *level 2 test level 1*, where *test* is the comparison function. For example, if 6 is stored in *X*, 'X 5 <' removes 6 and 5 from the stack and returns 0. If one object is an algebraic (or name) and the other object is an algebraic (or name) or a number, <, >, ≤, and ≥ return an expression that must be evaluated to return a test result. For strings, "less than" means alphabetically previous. For example, "AAA" is less than "AAB".

== takes two objects from the stack and:

- If either object is not an algebraic or a name, returns 1 if the two objects are the same type and have the same value, or 0 otherwise. Lists and programs are considered to have the same value if the objects they contain are identical.
- If one object is an algebraic (or name) and the other object is an algebraic (or name) or a number, returns an expression that must be evaluated to return a test result.

(Note that == is used for comparisons, while = separates two sides of an equation.)

≠ works just like ==, except that the test results are opposite.

SAME returns 1 (true) if two objects identical. For example, 'X+3' 4 SAME returns 0 regardless of the value of *X* because the algebraic 'X+3' is not identical to the real number 4. For all object types other than algebraics and names, SAME works just like ==.

Using Comparison Functions in Algebraics. Comparison functions (except SAME) can be used in algebraics as *infix* functions. For example, if 6 is stored in *X*, 'X<5' →NUM returns 0.

Logical Functions

Logical functions return a test result based on the outcomes of two previously executed tests. Note that these four functions interpret *any non-zero argument* as a true result.

Logical Functions

Keys	Programmable Command	Description
PRG TEST (page 1):		
AND	AND	Returns 1 (true) if both arguments are true.
OR	OR	Returns 1 (true) if either or both arguments are true.
XOR	XOR	Returns 1 (true) if either, but not both, arguments are true.
NOT	NOT	Returns 1 (true) if the argument is 0 (false); otherwise, returns 0 (false).

AND, OR, and XOR are used to combine two test results. For example, if 4 is stored in *Y*, `Y 8 < 5 AND` returns `1`. First, `Y 8 <` returns `1` to the stack. AND removes `1` and `5` from the stack, interpreting both as true results, and returns `1` to the stack.

NOT returns the logical inverse of a test result. For example, if 1 is stored in *X* and 2 is stored in *Y*, `X Y < NOT` returns `0`.

Using Logical Functions in Algebraics. AND, OR, and XOR can be used as *infix* functions in algebraics. For example, `'3<5 XOR 4>7' →NUM` returns `1`.

NOT can be used as a *prefix* function in algebraics. For example, `'NOT Z≤4' →NUM` returns `0` if $Z = 2$.

Testing Object Types

The TYPE command (PRG TEST TYPE) takes any object as its argument and returns the number that identifies that object type. The table on page 97 in chapter 4 lists the HP 48 objects and their corresponding type number.

Conditional Structures

The HP 48 *conditional structures* let a program make a decision based on the result of a test or tests. Conditional structures are built with commands that work only when used in proper combination with each other. These commands are contained in the PRG BRCH menu (PRG BRCH).

The conditional structures are:

- IF...THEN...END.
- IF...THEN...ELSE...END.
- CASE...END.

The IF...THEN...END Structure

IF...THEN...END executes a sequence of commands only if a test evaluates to true. The syntax is:

IF *test-clause* THEN *true-clause* END

The test-clause can be a command sequence (for example, A B ≤) or an algebraic (for example, 'A≤B'). If the test-clause is an algebraic, it is *automatically evaluated* to a number (→NUM or EVAL isn't necessary).

As a typing aid, press ← IF to key in:

```
IF
THEN
END
```

Example 1: IF...THEN...END. Both programs below test the value in level 1. If the value is positive it is made negative. The first program uses a command sequence as the test-clause:

```
« DUP IF 0 > THEN NEG END »
```

The value on the stack must be duplicated because the > command removes two arguments from the stack (the copy of the value made by DUP, and 0).

The next version uses an algebraic as the test clause:

```
« → x « IF 'x>0' THEN x NEG END » »
```

Example 2: IF...THEN...END. This program multiplies two numbers together if both are non-zero.

Program:	**Comments:**
«	
→ x y	Creates local variables *x* and *y* containing the two numbers from the stack.
«	
IF	Starts the test-clause.
'x≠0'	Tests one of the numbers and leaves a test result on the stack.
'y≠0'	Tests the other number, leaving another test result on the stack.
AND	Tests whether both tests were true.
THEN	Ends the test-clause, starts the true-clause.
x y *	If AND returns true, multiplies the two numbers together.

```
  END                          Ends the true-clause.
 »
»
```

The following program accomplishes the same task as the previous program:

```
« → x y « IF 'x AND y' THEN x y * END » »
```

The test-clause `'x AND y'` returns "true" if both numbers are non-zero.

How IF...THEN...END Works. IF begins the test-clause, which leaves a test result on the stack. THEN removes the test result from the stack. If the value is non-zero, the true-clause is executed. Otherwise, program execution resumes following END.

The IF...THEN...ELSE...END Structure

IF...THEN...ELSE...END executes one sequence of commands if a test is true, and another sequence of commands if that test is false. The syntax is:

IF *test-clause* THEN *true-clause* ELSE *false-clause* END

If the test-clause is an algebraic, it is automatically evaluated to a number (→NUM or EVAL isn't necessary).

As a typing aid, press [→] IF to key in:

```
IF
THEN
ELSE
END
```

Example 1: IF...THEN...ELSE...END. The following program takes a value x from the stack and calculates $\sin x/x$. At $x = 0$ the division would error, so the program returns the limit value 1 in this case:

```
« → x « IF 'x≠0' THEN x SIN x / ELSE 1 END » »
```

Example 2: IF...THEN...ELSE...END. This program, like example 2 for IF...THEN...END, multiplies two numbers together if they are both non-zero. However, the program returns the string "ZERO" if either value is 0.

Program:	**Comments:**
«	
→ n1 n2	Stores the values from levels 1 and 2 in local variables.
«	Starts the defining procedure for the local variable structure.
IF	Starts the test clause.
'n1≠0 AND n2≠0'	Tests *n1* and *n2*.
THEN	If both numbers are non-zero ...
n1 n2 *	... multiplies the two values.
ELSE	If both numbers are not non-zero ...
"ZERO"	... returns the string ZERO.
END	Ends the conditional.
»	Ends the defining procedure.
»	

How IF...THEN...ELSE...END Works. IF begins the test-clause, which leaves a test result on the stack. THEN removes the test result from the stack. If the value is non-zero, the true-clause is executed. Otherwise, the false-clause is executed. After the appropriate clause is executed, execution resumes following END.

The CASE...END Structure

The CASE...END structure lets you execute a series of *cases* (tests). The first test that returns a true result causes execution of the corresponding true-clause, ending the CASE...END structure. Optionally, you can include after the last test a default clause that is executed if all the tests evaluate to false.

The CASE...END structure has the syntax:

```
CASE
        test-clause1 THEN true-clause1 END
        test-clause2 THEN true-clause2 END
        ⋮
        test-clausen THEN true-clausen END
        default-clause (optional)
END
```

As typing aids, press ◀ CASE to key in:

```
CASE
THEN
END
END
```

and ▶ CASE to key in:

```
THEN
END
```

Example: The CASE...END Structure. The following program stores the level 1 argument in a variable if the argument is a string, list, or program.

Program:	Comments:
«	
→ y	Stores the argument in local variable *y*.
«	Starts the defining procedure.
CASE	Starts the case structure.
y TYPE 2 SAME THEN y 'STR' STO END	Case 1: If the argument is a string, stores it in *STR*.
y TYPE 5 SAME THEN y 'LIST' STO END	Case 2: If the argument is a list, stores it in *LIST*.
y TYPE 8 SAME THEN y 'PROG' STO END	Case 3: If the argument is a program, stores it in *PROG*.
END	Ends the case structure.
»	Ends the defining procedure.
»	

How CASE...END Works. When CASE is executed, test-clause$_1$ is evaluated. If the test is true, true-clause$_1$ is executed, and execution skips to END. If test-clause$_1$ is false, execution proceeds to test-clause$_2$. Execution within the CASE structure continues until a true-clause is executed, or until all the test-clauses evaluate to false. Optionally, a default clause can be included. In this case, the default-clause is executed if all the test-clauses evaluate to false.

Conditional Commands

The IF...THEN...END and IF...THEN...ELSE structures are useful for situations where the true-clause and false-clause are *sequences* of commands and objects. Two commands, IFT (If...Then) and IFTE (If...Then...Else), let you easily execute the same decision-making process if the true- and false-clauses are each a *single* command or object.

The IFT (If-Then-End) Command

The IFT command takes two arguments: a test result in level 2 and an object in level 1 (the "true clause"). The object in level 1 is executed if the test result is true.

Example: The IFT Command. The following program removes a number from the stack and displays POSITIVE if the number is positive.

```
« 0 > "POSITIVE" IFT »
```

The IFTE Function

The IFTE function takes three arguments: a test result in level 3, and objects in levels 2 and 1. The level-2 object (the "true-clause") is executed if the test result is true. Otherwise, the level-1 object (the "false-clause") is executed.

Example: The IFTE Command. This program takes a value from level 1 and displays POSITIVE if it is positive or zero, and NEGATIVE otherwise:

```
« 0 ≥ "POSITIVE" "NEGATIVE" IFTE »
```

Using IFTE in Algebraics. The IFTE function can also be used as a function in algebraics. It has the syntax:

IFTE(*test*, *true-clause*, *false-clause*)

Example: The IFTE Function. This program is a user-defined function that takes a number (x) from the stack and calculates $\sin(x)/x$ if x is non-zero. If x is 0, the program returns 1:

```
« → x 'IFTE(x≠0,SIN(x)/x,1)' »
```

27

Loop Structures



Loop structures execute a part of a program repeatedly. There are two fundamental types of loops:

- For a *definite loop*, the program specifies in advance how many times the loop clause will be executed.
- In an *indefinite loop*, the program uses a test to determine whether to execute the loop-clause again.

Like the conditional structures described in chapter 26, looping structures are built with commands that work only when used in proper combination with each other. These commands are contained in the PRG BRCH menu ([PRG] BRCH).

Definite Loop Structures

There are two definite loop structures. Each has two variations:

- START...NEXT and START...STEP.
- FOR...NEXT and FOR...STEP.

The START...NEXT Structure

START...NEXT executes a portion of a program a specified number of times. The syntax is:

start finish START *loop-clause* NEXT

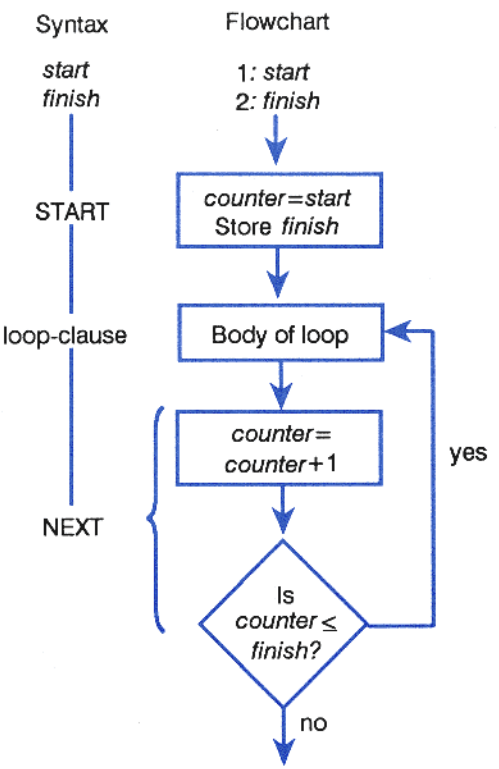
As a typing aid, press ◀START to key in:

```
START
NEXT
```

Example: A START...NEXT Loop. The following program creates a list containing ten copies of the string "ABC":

```
« 1 10 START "ABC" NEXT 10 →LIST »
```

How START...NEXT Works. START takes two numbers (*start* and *finish*) from the stack and stores them as the starting and ending values for a loop counter. Then, the loop-clause is executed. NEXT increments the counter by 1 and tests to see if its value is less than or equal to *finish*. If so, the loop-clause is executed again.



Notice that the loop-clause is always executed at least once.

The START...STEP Structure

START...STEP works just like START...NEXT, except that it lets you specify an increment value other than 1. The syntax is:

start finish START *loop-clause increment* STEP

As a typing aid, press → START to key in:

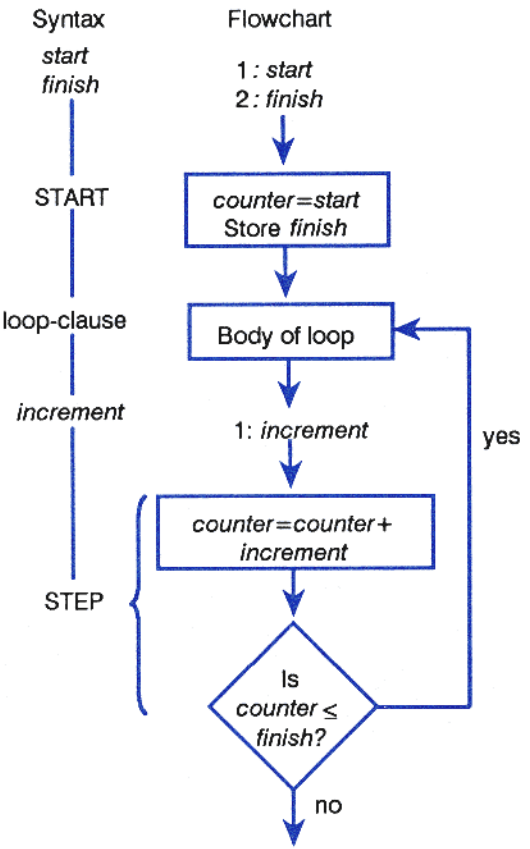
START
STEP

Example: A START...STEP Loop. The following program takes a number x from the stack and calculates the square of that number $x/3$ times:

« DUP → x « x 1 START x SQ -3 STEP »

How START...STEP Works. START takes two numbers (*start* and *finish*) from the stack and stores them as the starting and ending values of the loop counter. Then, the loop-clause is executed. STEP takes the increment value from the stack and increments the counter by that value. If the argument of STEP is an algebraic or a name, it is automatically evaluated to a number.

The increment value can be positive or negative. If it is positive, the loop is executed again when the counter is less than or equal to *final*. If the increment value is negative, the loop is executed when the counter is greater than or equal to *final*. In the following flowchart, the increment value is positive.


Syntax
Flowchart
start
finish
1 : start
2 : finish
START
counter=start
Store finish
loop-clause
Body of loop
increment
1: increment
yes
counter=counter+
increment
STEP
Is
counter ≤
finish?
no

The FOR...NEXT Structure

A FOR...NEXT loop executes a program segment a specified number of times using a local variable as the loop counter. You can use this variable within the loop. The syntax is:

start finish FOR *counter loop-clause* NEXT

As a typing aid, press ◀ FOR to key in:

```
FOR
NEXT
```

Example 1: A FOR...NEXT Loop. The following program places the squares of the integers 1 through 5 on the stack:

```
« 1 5 FOR j j SQ NEXT »
```

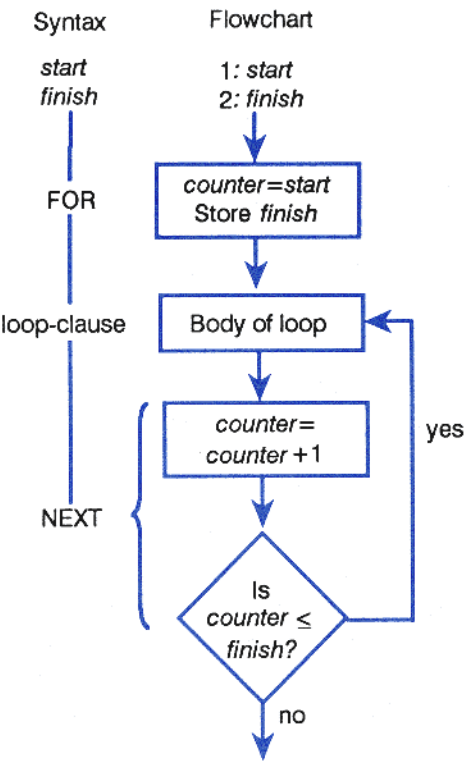
Example 2: A FOR...NEXT Loop. The following program takes the value x from the stack and computes the integer powers i of x. For example, when $x = 12$ and *start* and *finish* are 3 and 5 respectively, the program returns 12^3, 12^4, and 12^5. It requires as inputs *start* and *finish* in levels 3 and 2, and x in level 1:

```
« → x « FOR n 'x^n' EVAL NEXT » »
```

→ x removes x from the stack, leaving *start* and *finish* there as arguments for FOR.

How FOR...NEXT Works. FOR takes *start* and *finish* from the stack as the beginning and ending values for the loop counter, then creates the local variable *counter* as a loop counter. Then, the loop-clause is executed; *counter* can appear within the loop clause. NEXT increments *counter* by one, and then tests whether *counter* is less than or equal to *finish*. If so, the *loop-clause* is repeated (with the new value of *counter*).

When the loop is exited, *counter* is purged.


Syntax
Flowchart
start
finish
1: start
2: finish
FOR
counter=start
Store finish
loop-clause
Body of loop
counter=
counter+1
yes
NEXT
Is
counter ≤
finish?
no

The FOR...STEP Structure

FOR...STEP works just like FOR...NEXT, except that it lets you specify an increment value other than 1. The syntax is:

start finish FOR *counter loop-clause increment* STEP

As a typing aid, press [→] FOR to key in:

FOR
STEP

Example 1: A FOR...STEP Loop. The following program places the squares of the integers 1, 3, 5, 7, and 9 on the stack:

« 1 9 FOR x x SQ 2 STEP »

Example 2: A FOR...STEP Loop. The following program takes *n* from the stack, and returns the series of numbers 1, 2, 4, 8, 16, ... *n*. If *n* isn't in the series, the program stops at the last value less than *n*:

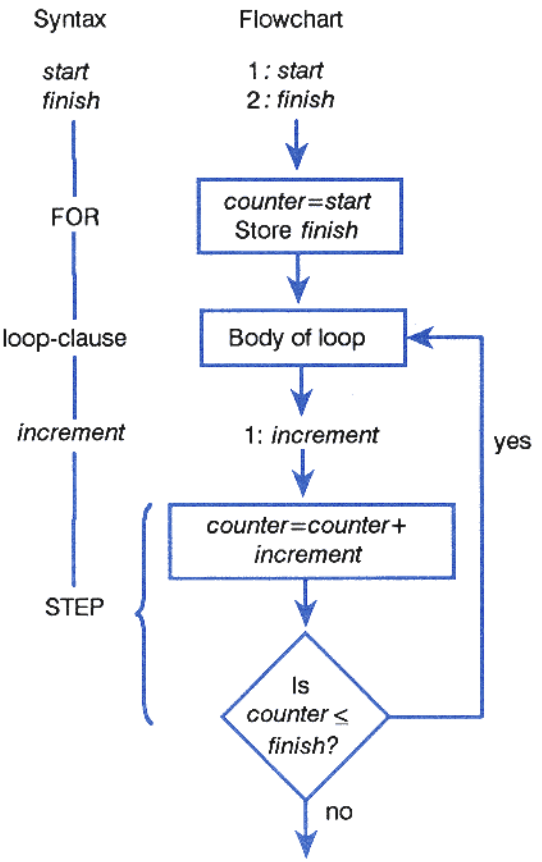
« 1 SWAP FOR n n n STEP »

How FOR...STEP Works. FOR takes *start* and *finish* from the stack as the beginning and ending values for the loop counter, then creates the local variable *counter* as a loop counter. Next, the loop-clause is executed; *counter* can appear within the loop clause. STEP takes the increment value from the stack and increments *counter* by that value.

The increment value can be positive or negative. If the increment is positive, the loop is executed again when *counter* is less than or equal to *final*. If the increment is negative, the loop is executed when *counter* is greater than or equal to *final*.

When the loop is exited, *counter* is purged.

(In the following flowchart, the increment value is positive.)


Syntax
Flowchart
start
finish
1: start
2: finish
FOR
counter=start
Store finish
loop-clause
Body of loop
increment
1: increment
yes
counter=counter+
increment
STEP
Is
counter ≤
finish?
no

Indefinite Loop Structures

The DO...UNTIL...END Structure

DO...UNTIL...END... executes a loop repeatedly until a test returns a true (non-zero) result. Since the test-clause is executed after the loop-clause, the loop is always executed at least once. The syntax is:

DO *loop-clause* UNTIL *test-clause* END

As a typing aid, press ◀ DO to key in:

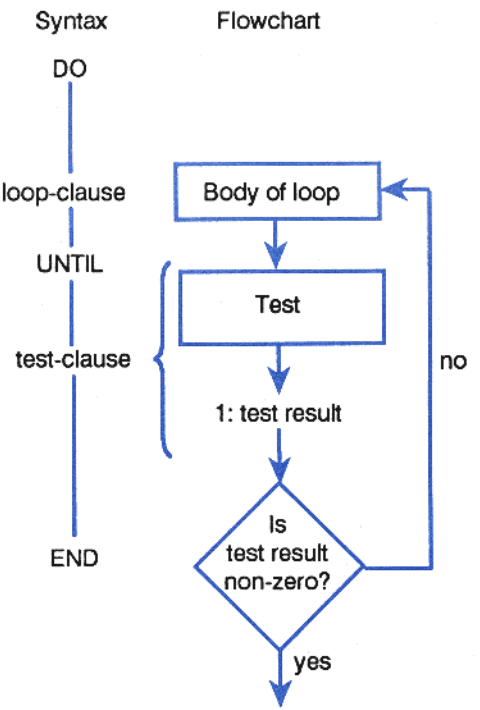
```
DO
UNTIL
END
```

Example: A DO...UNTIL...END Loop. The following program calculates $n + 2n + 3n + \ldots$ for a value of n. The program stops when the sum exceeds 1000, and returns the sum and the coefficient of n.

Program:	**Comments:**
«	
DUP 1 → n s c	Duplicates n and stores the value into n and s; initializes counter c to 1.
«	Starts the defining procedure, in this case a program, for the local variable structure.
DO	Starts the loop-clause.
'c' INCR	Increments the counter by 1. (INCR is discussed on page 513.)
n * 's' STO+	Calculates $c \times n$, and adds the product to s.

```
  UNTIL                    Starts the test clause.
    s 1000 >               Repeats loop until s>1000.
  END                      Ends the test-clause.
 s c                       Puts s and c on the stack.
 »                         Ends the defining procedure.
»
```

How DO...UNTIL...END Works. DO starts execution of the loop-clause. UNTIL ends the loop clause and begins the test-clause. The test-clause leaves a test result on the stack. END removes the test result from the stack. If its value is zero, the loop-clause is executed again; otherwise, execution resumes following END.



The WHILE...REPEAT...END Structure

WHILE...REPEAT...END repeatedly evaluates a test and executes a loop-clause if the test is true. Since the test-clause occurs before the loop-clause, the loop-clause is never executed if the test is initially false. The syntax is:

WHILE *test-clause* REPEAT *loop-clause* END

As a typing aid, press ◀WHILE to key in:

```
WHILE
REPEAT
END
```

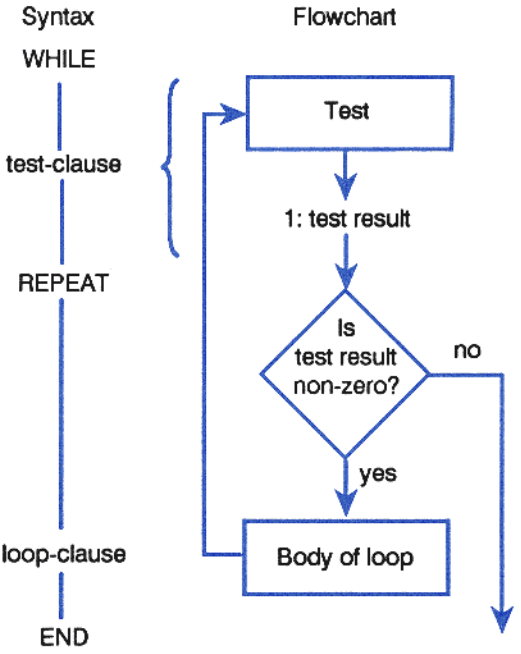
Example 1: A WHILE...REPEAT...END Loop. The following program starts with a number on the stack, and repeatedly performs a division by 2 as long as the result is evenly divisible. For example, starting with the number 24, the program computes 12, then 6, then 3:

```
« WHILE DUP 2 MOD 0 == REPEAT 2 / DUP END DROP »
```

Example 2: A WHILE...REPEAT...END Loop. The following program takes any number of vectors or arrays from the stack and adds them to the statistics matrix. (The vectors and arrays must have the same number of columns.) WHILE...REPEAT...END is used instead of DO...UNTIL...END because the test must be done *before* the addition. (If *only* vectors or arrays with the same number of columns are on the stack, the program errors after the last vector or array is added to the statistics matrix.)

```
« WHILE DUP TYPE 3 == REPEAT Σ+ END »
```

How WHILE...REPEAT...END Works. The test-clause is executed and returns a test result to the stack. REPEAT takes the value from the stack. If the value is non-zero, execution continues with the loop-clause; otherwise, execution resumes following END.



Loop Counters (INCR and DECR)

The INCR (increment) command ([→] [MEMORY] INCR) takes a global or local variable name as its argument. The variable must contain a real number. The command:

- Returns the new value of the variable.
- Increments by 1 the value stored in the variable.

For example, if *c* contains the value 5, `'c' INCR` returns 6 to the stack and stores 6 in *c*.

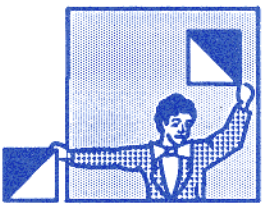
The DECR (decrement) command is analogous to INCR, except that it subtracts 1 from the specified variable.

Example: Using a Loop Counter with an Indefinite Loop. The following program takes a maximum of five vectors from the stack and adds them to the current statistics matrix.

Program:	**Comments:**
`«`	
`0 → c`	Stores 0 in local variable *c*.
`«`	Starts the defining procedure for the local variable structure.
`WHILE`	Starts the test clause.
`DUP TYPE 3 ==`	Returns true if level 1 contains a vector.
`'c' INCR`	Increments the value in *c* and puts the incremented value in level 1.
`5 ≤`	Returns true if the incremented value of $c \leq 5$.
`AND`	Returns true if the two previous test results are true.
`REPEAT`	
`Σ+`	Adds the vector to Σ*DAT*.
`END`	Ends the WHILE...REPEAT structure.
`»`	Ends the defining procedure.
`»`	

28

Flags



Flags are an important programming tool in the HP 48. You can think of a flag as a switch that is either on (*set*) or off (*clear*). A program can test a flag's state within a conditional or looping structure (described in the previous chapters) to make a decision. Since flags have unique meanings for the calculator, flag tests expand a program's decision-making capabilities beyond that available with comparison and logical functions.

Flag Types

There are two types of flags in the HP 48: *system* flags, numbered −1 through −64; and *user* flags, numbered 1 through 64. System flags have a predefined meaning for the calculator. For example, system flag −40 controls the clock display—when this flag is *clear* (the default state), the clock is displayed only when the TIME menu is selected; when this flag is *set*, the clock is displayed at all times. (Actually, when you press CLK in the MODES menu, you set or clear flag −40.) Appendix E lists the 64 system flags and their definitions.

User flags are not used by any built-in operations; what they mean depends entirely on how *you* define them. When you set a user flag 1 through 5, the corresponding annunciator is activated. (Note that plug-in cards, described in chapter 34, may affect the settings of user-flags 31—64.)

Setting, Clearing, and Testing Flags

The following commands take as their argument a flag number— an integer 1 through 64 (for user flags), or −1 through −64 (for system flags).

Flag Commands

Keys	Programmable Command	Description
[PRG] TEST (page 3) (or [→] [MODES] pages 2 and 3):		
SF	SF	Sets the flag.
CF	CF	Clears the flag.
FS?	FS?	Returns true (1) if the flag is set, or false (0) if the flag is clear.
FC?	FC?	Returns true (1) if the flag is clear, or false (0) if the flag is set.
FS?C	FS?C	Tests the flag (returns true if the flag is set), then clears the flag.
FC?C	FC?C	Tests the flag (returns true if the flag is clear), then clears the flag.

Example: Testing a System Flag. The following program sets an alarm for June 6, 1991 at 5:05 PM. It first tests the status of system flag −42 (the Date Format flag) in a conditional structure and then supplies the alarm date in the current date format, based on the test result.

Program:	Comments:
«	
IF -42 FC?	Tests the status of flag −42, the Date Format flag.
THEN 6.151991	If flag −42 is clear, supplies the date in *month/day/year* format.
ELSE 15.061991	If flag −42 is set, supplies the date in *day.month.year* format.
END	Ends the conditional.
17.05 "TEST COMPLETE" 3 →LIST STOALARM	Completes the set-alarm command sequence. (17.05 is the alarm time and "TEST COMPLETE" is the alarm message.)
»	

Example: User Flags in Programs. The following program returns either the fractional or integer part of the level 1 argument, depending on the state of user flag 10.

Program:	Comments:
«	
IF	Starts the conditional.
10 FS?	Tests the status of user flag 10.
THEN	If flag 10 is set ...
IP	... returns the integer part.
ELSE	If flag 10 is clear ...
FP	... returns the fractional part.
END	Ends the conditional.
»	

Before you execute this program, you set flag 10 if you want to return the integer part of the argument, or you clear flag 10 if you want to return the fractional part of the argument. Flag 10 is defined to have a unique meaning in the program; its status determines which part of the level 1 argument is returned to the stack.

Recalling and Storing the Flag States

The RCLF (recall flag status) and STOF (store flag status) commands let you recall and then store the status of the HP 48 flags. The commands let a program that alters the status of a flag or flags during execution preserve the pre-program-execution flag status.

Recalling the Flag States

RCLF returns a list containing two 64-bit binary integers that represent the current status of the system flags and user flags respectively:

$$\{ \ \#n_s \ \#n_u \ \}$$

The rightmost (least significant) bits of $\#n_s$ and $\#n_u$ represent the states of system flag −1 and user flag +1 respectively.

Storing the Flag States

STOF sets the current states of the system flags, or the states of both the system and user flags. It takes as its argument either:

- A single binary integer ($\#n_s$), in which case only the corresponding system flags are set or cleared.
- A list containing two binary integers ($\{ \ \#n_s \ \#n_u \ \}$), in which case the corresponding system and user flags are set or cleared.

A bit with value 1 sets the corresponding flag; a bit with value 0 clears the corresponding flag. The rightmost (least significant) bits of $\#n_s$ and $\#n_u$ set the states of system flag −1 and user flag +1 respectively.

The program *PRESERVE* on page 555 in chapter 31 uses RCLF and STOF.

29

Interactive Programs



Simple programs like those in chapter 25 use data that is supplied before program execution and return results as unlabeled numbers. Such programs may be difficult to use, particularly if you are not the program author. You must know what arguments to enter on the stack and in what order to enter them, and you must know how to interpret the results returned to the stack.

Interactive programs do any of the following:

- Stop during execution to prompt you for data.
- Display program results with explanatory messages or tags.
- Stop during execution so that you can make a choice about how you want the program to proceed.

Suspending Program Execution for Data Input

Data Input Commands

Keys	Programmable Command	Description
↰ CONT	CONT	Restarts a halted program.
PRG CTRL (pages 1, 2 and 3):		
HALT	HALT	Halts program execution.
INPUT	INPUT	Suspends program execution for data input. Prevents stack operations while the program is paused.
PROM	PROMPT	Halts program execution for data input.
DISP	DISP	Displays an object in the specified line of the display.
WAIT	WAIT	Suspends program execution for *x* seconds, where *x* is a number from level 1.
KEY	KEY	Returns a test result to level 1 and, if a key is pressed, the location of that key.
BEEP	BEEP	Sounds a beep at a specified frequency for a specified duration.
PRG DSPL (page 4):		
CLLCD	CLLCD	Blanks the display.
FREEZ	FREEZE	"Freezes" a specified area of the display so that it is not updated until a key press.

The PROMPT Command

PROMPT takes a string argument from level 1, displays the string (without the " delimiters) in the status area, and halts program execution. Calculator control is returned to the keyboard. Program execution is resumed by executing CONT. For example, when you execute the program segment:

```
« "ABC?" PROMPT »
```

the display looks like this:



The message is displayed until you press ENTER or ATTN or until you update the status area (for example, by pressing ◀ REVIEW).

The following program, *TPROMPT*, prompts you for the dimensions of a torus, then calls program *TORSA* (chapter 25, page 481) to calculate its surface area. You don't have to enter data on the stack prior to program execution.

Arguments	Results
1:	1: *area*

Program:

```
«
  "ENTER a, b IN ORDER:"
```

Comments:

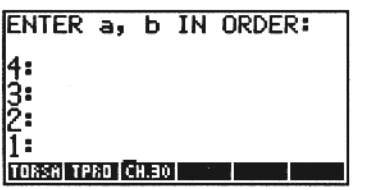
Puts the prompting string on the stack.

PROMPT	Displays the string in the status area, halts program execution, and returns calculator control to the keyboard.
TORSA	Executes *TORSA*, using the just-entered stack arguments.
»	
ENTER ' TPROMPT STO	Stores the program in *TPROMPT*.

Example: Prompting for Data Input in a Program. Execute *TPROMPT* to calculate the volume of a torus with inner radius $a = 8$ inches and outer radius $b = 10$ inches.

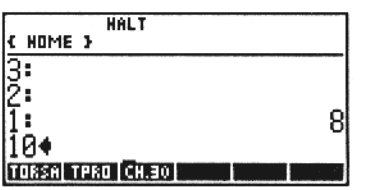
Select the VAR menu and start *TPROMPT*.

VAR TPRO



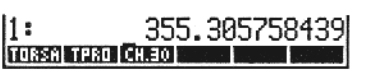
The program prompts you for data. Enter the inner and outer radii. Note that after you press ENTER, the prompt message is cleared from the status area.

8 ENTER 10



Continue the program.

← CONT



The answer is returned to level 1 of the stack.

Note that when program execution is suspended by PROMPT, you can execute calculator operations just as you did before you started the program. Suppose the outer radius b of the torus in the previous example is measured as 0.83 feet. You can convert that value to inches *while the program is suspended for data input* by pressing .83 ENTER 12 ×.

The BEEP Command

The BEEP command lets you enhance an interactive program with audible prompting. BEEP takes two arguments from the stack: the tone frequency from level 2 and the tone duration from level 1. The following edited version of *TPROMPT* sounds a 440-hertz, one-half-second tone at the prompt for data input.

Program:	**Comments:**
«	
"ENTER a, b IN ORDER:"	
440 .5 BEEP	Sounds a tone to audibly supplement the prompt for data input.
PROMPT	
TORSA	
»	

The DISP, HALT and FREEZE Commands

DISP, HALT, and FREEZE can be used together to prompt for data input:

- DISP displays an object in a specified line of the display. DISP takes two arguments from the stack: an object from level 2, and a display-line number 1 through 7 from level 1. To facilitate the display of messages, DISP displays *string* objects without the surrounding " delimiters.

  Note that the display created by DISP persists only as long as the program continues execution. When the program ends, or when it is suspended by the HALT command, the calculator returns to the normal stack environment, and the display is automatically updated.

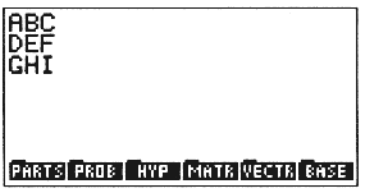
- FREEZE "freezes" one or more display areas so they are not updated until a *key press*. Argument *n* in level 1 is the sum of the value codes for the areas to be frozen. The value codes are: 1 for the status area; 2 for the stack/command line area; 4 for the menu area.

- HALT suspends program execution at the location of the HALT command and turns on the HALT annunciator. Calculator control is returned to the keyboard for normal operations. Program execution is resumed by executing CONT (or SST).

For example, when you execute the following program:

```
« "ABC▪DEF▪GHI" CLLCD 1 DISP 3 FREEZE HALT »
```

the display looks like this:



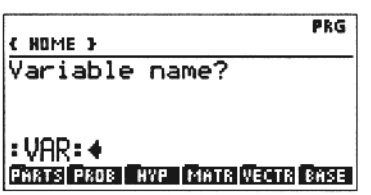
(The ▪ in the previous program is the calculator's representation for the ↵ (newline) character once a program has been entered on the stack.)

The INPUT Command

INPUT is used to prompt for data input when the programmer does not want the user to have access to stack operations. Consider the following program:

```
« "Variable name?" ":VAR:" INPUT »
```

When this program is executed, the display looks like:



1. The stack area is blanked, and the contents of the string from level 2, `Variable name?`, are displayed at the top of the stack area. The string from level 2 is called the *prompt string*.

2. The contents of the string from level 1, `:VAR:`, are displayed in the command line. The string from level 1 is called the *command-line string*. Program-entry mode is activated and the insert cursor is positioned after the string. The program is now suspended for data input.
3. Program execution is continued by pressing ENTER, which returns the contents of the command line to the stack as a string, called the *result string*.

The following program, *VSPH*, calculates the volume of a sphere. *VSPH* first calculates $^4/_3\,\pi$, then prompts for the radius of the sphere and completes the calculation. Because a partial calculation is already on the stack, *VSPH* protects the stack by executing INPUT to prompt for the radius. INPUT sets Program-entry mode when program execution pauses for data entry. Subsequent commands are not executed immediately—instead, they are listed in the command line until the user presses ENTER.

Arguments	Results
1:	1: *volume*

Program:	Comments:
«	
`4 3 / π * →NUM`	Starts the calculation.
`"Key in radius"`	Builds the prompt string, displayed at the top of the stack area.
`""`	Builds the command-line string. In this case, the string is empty, so the command line will be empty.
`INPUT`	Displays the stack-area prompt, positions the cursor at the start of the command line, and suspends the program for data input (the radius of the sphere).

OBJ→	Converts the result string into its component object — a real number.
3 ^ *	Cubes the radius and completes the calculation.

»

ENTER ' VSPH STO	Stores the program in *VSPH*.

Example: Prompting for Data with INPUT. Execute *VSPH* to calculate the volume of a sphere of radius 2.5 meters.

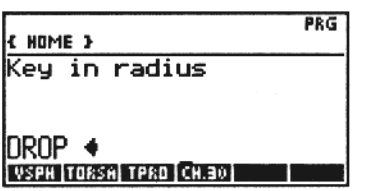
Select the VAR menu and start the program.

VAR VSPH



To show how INPUT protects the stack, press ◀ DROP.

◀ DROP



DROP is listed in the command line, but is not executed, so the partial calculation in level 1 is protected.

Press ATTN to restore the command line. Then key in the radius and continue program execution.

ATTN
2.5 ENTER



Options for the INPUT Command. In its general form, the level 1 argument for INPUT is a *list* that specifies the content and interpretation of the command line. The list can contain *one or more* of the following parameters, *in any order*:

- The *command-line string*, whose contents are placed in the command line for prompting when the program pauses.

- Either a *real number*, or a *list containing two real numbers*, that specifies the initial cursor position in the command line:
  - A real number *n* at the *n*th character from the left end of the first row (line) of the command line. A *positive n* specifies the insert cursor; a *negative n* specifies the replace cursor. 0 specifies the end of the command-line string.
  - A list that specifies the initial row and column position of the cursor: the first number in the list specifies a row in the command line (1 specifies the first row of the command line); the second number counts by characters from the left end of the specified line. 0 specifies the end of the command-line string in the specified row. A positive row number specifies the insert cursor; a negative row number specifies the replace cursor.
- One or more of the parameters ALG, α, or V, entered as unquoted names:
  - ALG activates Algebraic/Program-entry mode.
  - α ([α] [→][A]) specifies alpha lock.
  - V verifies if the characters in the result string, without the " delimiters, compose a valid object or objects. If the result-string characters do not compose a valid object or objects, INPUT displays the `Invalid Syntax` warning and prompts again for data.

The INPUT Default State. You can choose to specify as few as one of the level 1 list parameters. The default states for these parameters are:

- Blank command line.
- Insert cursor placed at the end of the initial command line string.
- Program-entry mode.
- Command-line string not checked for invalid syntax.

If you specify *only* a command-line string for the level 1 argument, you do not need to put it in a list. For example, the previous program, *VSPH*, specifies an empty command-line string for the level 1 argument.

Building the Command-Line String. After the user inputs data to the command line and presses ENTER to resume program execution, the contents of the command line are returned to level 1 as the result string. To process the input, the program may at some point execute OBJ→ to convert the result string to a *valid object or objects*. The program can accomplish this by specifying a command-line string of known form and then taking appropriate action after the result string is returned to level 1:

- The program can specify an *empty* command-line string. In this case, the result string consists *only* of the input. The program *VSPH* on page 525 uses this method.
- The program can specify a command-line string whose characters form the tag and delimiters for a *tagged object*. (See page 87 for a discussion of tagged objects.) In this case, the input completes the tagged object. The program *TINPUT* on page 529 uses this method.
- The program can specify a command-line string whose characters form a message. In this case, the program subtracts those characters from the result string to leave only the input in the string in string form. The program *SSEC* on page 531 uses this method.

In the first two cases, the V parameter can also be specified as part of the level 1 argument to specify that INPUT reprompt for data if the contents of the result string are not valid objects.

The following program, *TINPUT*, executes INPUT to prompt for the inner and outer radii of a torus, then calls *TORSA* (chapter 25, page 481) to calculate its surface area. *TINPUT* prompts for *a* and *b* in a two-row command line; the level 1 argument for INPUT is list that contains:

- The command-line string.
- An imbedded list specifying the initial cursor position.
- The V parameter to check for invalid syntax in the result string.

The command-line string forms the tags and delimiters for two tagged objects. The list does not specify the entry mode, so Program-entry mode is selected by default.

Arguments	Results
1:	1: *area*

Program:

Comments:

```
«
```

```
 "Key in a, b"
```

Builds the level 2 string, displayed at the top of the stack area.

```
 {
```

Starts the level 1 list argument.

```
  ":a:▪:b:" {1 0} V
```

The level 1 list contains a command-line string, a list, and the verify-syntax specification. (To key in the string, press [→] ["] [→] [:] a [▶] [→] [↵] [→] [:] b. After you press [ENTER] to put the finished program on the stack, the string will be shown on one line, with the ▪ character indicating the newline character.) The imbedded list positions the insert cursor in row 1 just after `:a:`. V specifies to check for invalid syntax in the result string.

```
 }
```

Ends the level 1 list argument.

```
 INPUT
```

Displays the stack string and command-line string, positions the cursor as specified by the list in the level 1 argument, and, by default, sets Program-entry mode. Then suspends program execution for data. Checks the resultant string for syntax errors.

```
 OBJ→
```

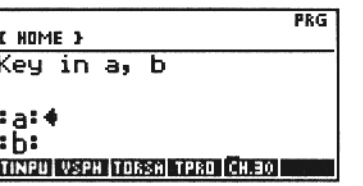
Converts the string into its component objects (in this case, two tagged objects).

TORSA	Calls *TORSA* to calculate the surface area.
»	
ENTER ' TINPUT STO	Stores the program in *TINPUT*.

Example: Prompting for Data with Input. Execute *TINPUT* to calculate the surface area of a torus of inner radius $a = 10$ cm and outer radius $b = 20$ cm.

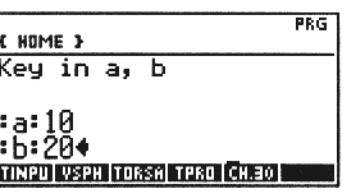
Select the VAR menu and start the program.

VAR TINPU



Key in the value for a and press ▼ to move the cursor to the next prompt in the command line. Then key in the value for b.

10 ▼ 20



Continue program execution.

ENTER



The following program executes INPUT to prompt for a social security number, then extracts in string form the first three digits and last four digits from the result string. The level-1 argument for INPUT specifies:

- A command-line string.
- The *replace* cursor positioned at the start of the prompt string (−1). The replace cursor lets the user "fill in" the command line string, using ▶ to skip over the dashes in the social-security number.
- By default, Program-entry mode.
- By default, no verification of object syntax—the dashes in the social-security number are not valid characters outside the string delimiters.

Arguments	Results
2: 1:	2: " *first three digits*" 1: "*last four digits*"

Program:	Comments:
«	
`"Key in S.S. #"`	Builds the level 2 string, displayed at the top of the stack area.
`{ "  -  -    " -1 }`	Builds the level 1 argument for INPUT. (Key in 3 spaces between the first " delimiter and the first -, two spaces between the two -'s, and 4 spaces between the last - and the ending " delimiter.)
`INPUT`	Suspends the program for data.
`DUP 1 3 SUB` `SWAP` `8 11 SUB`	Copies the result string, then extracts the first three and last four digits in string form.
»	
ENTER ' SSEC STO	Stores the program in *SSEC*.

Labeling Program Output

A descriptive tag or message can make program output more recognizable.

Using Tagged Objects as Data Output

You can label a program result using the →TAG command. →TAG ([PRG] OBJ →TAG) takes two arguments: any object from level 2, and a name, string, or real number (the tag) from level 1.

The following program *TTAG* is identical to *TINPUT*, except that it tags the result.

Program:	**Comments:**
«	
"Key in a, b"	
{ ":a:■:b:" {1 0} V }	
INPUT OBJ→	
TORSA	
'AREA'	Builds the tag, in this case a name.
→TAG	Joins the tag to the object in level 2, the program result, to create the tagged object.
»	
[ENTER] [ ] TTAG [STO]	Stores the program in *TTAG*.

Example: Using a Tagged Object for Data Output. Execute *TTAG* to calculate the area of a torus of inner radius $a = 1.5$ and $b = 1.85$.

Select the VAR menu and start the program. Supply the values for a and b and continue program execution. The answer is returned as a tagged object to the stack.

[VAR] TTAG
1.5 [▼] 1.85
[ENTER]



Using String Commands to Label Data Output

You can use string commands and DISP to label and display an object that has been returned to level 1 of the stack:

1. Convert the object to a string with →STR (PRG OBJ →STR).
2. Enter a labeling string on the stack.
3. Swap the two strings on the stack, then concatenate them (SWAP +).
4. Display the resultant string (*n* DISP).

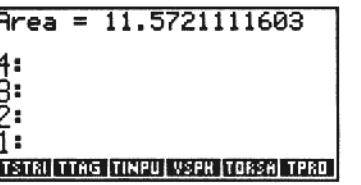
The following program *TSTRING* is identical to *TINPUT*, except that it converts the program result to a string and appends a labeling string to it.

Program:	**Comments:**
«	
"Key in a, b"	
{ ":a:■:b:" (1 0) V }	
INPUT OBJ→	
TORSA	
→STR	Converts the result to a string.
"Area = "	Enters the labeling string.
SWAP +	Swaps the positions of the two strings on the stack and adds them.
CLLCD 1 DISP 1 FREEZE	Displays the resultant string, without its delimiters, in line 1 of the display.
»	
ENTER ' TSTRING STO	Stores the program in *TSTRING*.

Example: Labeling Data Output. Execute *TSTRING* to calculate the area of the torus in the previous example ($a = 1.5, b = 1.85$).

Select the VAR menu and start the program. Supply the values for a and b and continue program execution. The labeled answer is displayed in the status area.

[VAR] TSTRI
1.5 [▼] 1.85
[ENTER]



Pausing to Display Data Output

The WAIT command ([PRG] CTRL [NXT] WAIT) suspends program execution for x seconds, where x is a positive real number from level 1. You can use WAIT with DISP to display messages during program execution—for example, to display intermediate program results.

WAIT interprets arguments 0 and −1 differently—see "Commands That Return a Key Location" on page 539.

Using Menus in Programs

Applications menus like the SOLVE and PLOT menus, as well as the VAR and CST menus, can be activated and used in a program as they are during normal keyboard operations.

Displaying a Built-In Menu

To display a built-in menu in a program, execute the MENU command ([PRG] CTRL [NXT] MENU) with the numeric argument that corresponds to that built-in menu. The table in Appendix D lists all the HP 48 menus and their corresponding menu numbers. For example, 20 MENU activates page 1 of the MODES menu. You can specify a particular page of a menu by supplying the argument in the form *xx.yy*, where *xx* is the menu number, and *yy* is the page number.

The following program activates the third page of the MODES menu and asks you to set the angle mode.

```
« 20.03 MENU "Select Angle Mode" PROMPT »
```

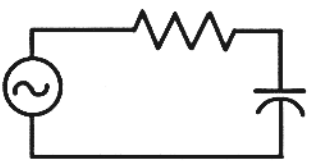
RCLMENU ([→] [MODES] [NXT] [RCLM]) returns the menu number of the currently displayed menu.

Custom Menus in Programs

In chapter 15 you learned how to build a custom menu by supplying a list argument for MENU. In programs, you can construct custom menus to:

- Emulate built-in applications like the HP Solve application.
- Prompt you to make decisions.

Emulating Built-In Applications. The following program, *EIZ*, constructs a custom menu to emulate the HP Solve application for capacitive electrical circuits.



Application of Ohm's law to this circuit results in the following expression:

$$E = IZ$$

where

E is the circuit voltage.
I is the circuit current.
Z is the circuit impedance.

Because the voltage, current, and impedance are complex numbers, you cannot use the HP Solve application to find solutions. The custom menu in *EIZ* assigns a *direct* solution to the left-shifted menu key for each variable, and assigns *store* and *recall* functionality to the unshifted and right-shifted keys — the key actions are analogous to the HP Solve application.

Program:	Comments:
`«`	
`DEG` `-15 SF -16 SF 2 FIX`	Sets Degrees mode. Sets flags −15 and −16 to display complex numbers in polar form. Sets the display mode to 2 Fix.
`{`	Starts the list for the custom menu.
`{ "E" { « 'E' STO »` `« I Z * DUP 'E' STO` `"E" →TAG` `CLLCD 1 DISP` `1 FREEZE »` `« E » } }`	Builds menu key 1, labeled E. When you press E, the object in level 1 is stored in variable *E*. When you press ↰ E, the product of *I* and *Z* is calculated, stored in variable *E*, and displayed as a tagged object. When you press ↱ E, the object stored in *E* is returned to level 1.
`{ "I" { « 'I' STO »` `« E Z / DUP 'I' STO` `"I" →TAG` `CLLCD 1 DISP` `1 FREEZE »` `« I » } }`	Builds menu key 2.
`{ "Z" { « 'Z' STO »` `« E I / DUP 'Z' STO` `"Z" →TAG` `CLLCD 1 DISP` `1 FREEZE »` `« Z » } }`	Builds menu key 3.
`}`	Ends the list.
`MENU`	Displays the custom menu.
`»`	
ENTER ' EIZ STO	Stores the program in *EIZ*.

Example: Emulating a Built-In Application. A 10-volt power supply at phase angle 0° drives an RC circuit. A current of .37 A at phase angle 68° is measured. What is the impedance of the circuit?

Select the VAR menu and start *EIZ*.

VAR EIZ



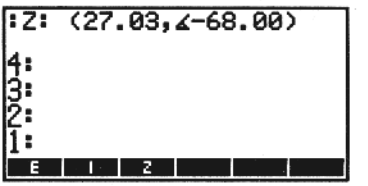
Key in the value for the voltage.

◀( ) 10 ▶∠ 0



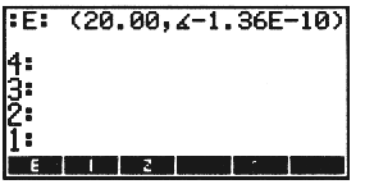
Store the value for the voltage. Then key in and store the value for the current. Solve for the impedance.

E
◀( ) .37 ▶∠ 68
I
◀ Z



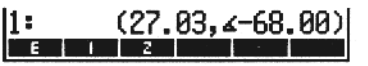
If the current amplitude is doubled and the impedance remains constant, what is the complex voltage?

◀( ) .74 ▶∠ 68
I
◀ E



Recall the value of *Z* to the stack.

▶ Z



Prompting for a Choice. A custom menu can prompt the user to make a decision during program execution.

The program *WGT* in this section calculates the weight of an object in either English or SI units. *WGT* builds a custom menu that prompts the user to select the desired unit system. Here is the defining list for the custom menu:

```
{
 { "ENGL" « "ENTER Mass
  in LB" PROMPT
  32.2 * » }
 { "SI" « "ENTER Mass
  in KG" PROMPT
  9.81 * » }
}
```

If you store this list in variable *LST*, program *WGT* is simply:

Program:	**Comments:**
«	
LST MENU	Displays the custom menu stored in *LIST*.
»	
ENTER ' WGT STO	Stores the program in *WGT*.

The custom menu defined by *WGT* remains active until you select a new menu, so you can do as many calculations as you want.

Note that the custom menu defined by *WGT* (and the custom menu defined by *EIZ*) is automatically stored in variable *CST*, *replacing* the previous custom menu—when you press CST after the program ends, the menu defined by *WGT* is displayed.

Example: Using a Custom Menu to Make a Choice. Use *WGT* to calculate the weight of an object of mass 12.5 kg.

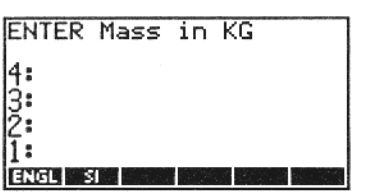
Select the VAR menu and start the program.

VAR WGT



Select the SI unit system.

SI



Key in the mass and continue program execution.

12.5 ◀ CONT



Building a Temporary Menu

The TMENU command (▶ MODES NXT TMEN) works just like MENU, except that list arguments do not replace the contents of *CST* and so leave the current custom menu unchanged. Note that the temporary menu remains active until a new menu is selected, even after the program ends. To programmatically restore the previous menu, execute `0 MENU`.

The program `« LIST TMENU »` is similar to *WGT*, except that it builds a temporary menu to prompt for the unit-system choice.

Commands That Return a Key Location

The WAIT Command with Argument 0

If you supply 0 as the argument for WAIT, the command suspends program execution until a valid keystroke is executed. It then returns the three-digit location number that defines where the key is on the keyboard and restarts program execution. (See section "Making User-Key Assignments" on page 217 in chapter 15.)

(Note that ◀, ▶, α, α◀, or α▶ do not by themselves constitute a valid keystroke.)

The WAIT Command with Argument −1

The WAIT command with argument −1 works just like it does with argument 0, except that the currently specified menu is also displayed. This lets you build and display a prompting menu while the program is paused. (Note that a menu built with MENU or TMENU is not normally displayed until the program ends or is halted with HALT.)

The KEY Command

A program can prompt for a simple "yes-no" decision using the KEY command in an indefinite loop, and a comparison test. (Indefinite looping structures are covered in chapter 27. Tests are covered in chapter 26.) When the loop begins, KEY simply returns a false result (0) to level 1 until a key is pressed. Once a key is pressed, KEY returns the two-digit location number that defines where the key is on the keyboard and returns a true result (1) to level 1. For example, when you use KEY in an indefinite loop and press ENTER, KEY returns 51 to level 2 and true result 1 to level 1.

The following program segment returns 1 to level 1 if + is pressed, or 0 to level 1 if any other key is pressed:

```
« ... DO UNTIL KEY END 95 SAME ... »
```

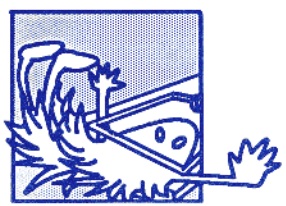
(Note that KEY returns only a two-digit location number RowColumn, unlike WAIT, which returns a three-digit location number that identifies shifted and alpha keys. Thus, if you press the ↰ key, KEY returns 71, while WAIT does not interpret ↰ itself as a valid keystroke.)

Turning the HP 48 Off from a Program

The OFF command turns the HP 48 off. If executed from a program, the program will resume when the calculator is turned back on.

30

Error Trapping



When you attempt an invalid operation from the keyboard, the operation is not executed and an error message is displayed. For example, if you execute + with a vector and a real number on the stack, the HP 48 returns the message:

```
+ Error:
Bad Argument Type
```

and, assuming that Last Arguments is enabled, returns the arguments to the stack. In a program, the same thing happens, but program execution is also aborted. Consider the following program:

```
« "KEY IN a AND b" "" INPUT OBJ→ + »
```

If you execute this program and supply a vector and a real number at the prompt, the program displays the `Bad Argument Type` error message and aborts execution at the + command. To supply new arguments, you must *restart* the program. For a short program like the one above, this method of error recovery presents little problem. However, when executing a program that performs time consuming calculations, or that has numerous stops for intermediate data entry, it may be inconvenient to restart the program at the beginning each time an error occurs.

You can enable a program to *continue* execution after an error has occurred by building an *error trap*. You can construct an error trap with one of the following conditional structures:

- IFERR...THEN...END.
- IFERR...THEN...ELSE...END.

The IFERR command is located on page 3 of the PRG BRCH menu.

The following commands enhance error-trap structures:

Error Trapping Commands

Keys	Programmable Command	Description
[PRG] CTRL (page 3):		
DOERR	DOERR	Executes a *user-specified* error. The calculator behaves just as if an ordinary error has occurred—if the error is not trapped in an IFFER structure, DOERR displays a message and abandons program execution.
ERRN	ERRN	Returns the error number, as a binary integer, of the most recent error. Returns #0 if the error number was cleared by ERR0.
ERRM	ERRM	Returns the error message (a string) for the most recent error. Returns empty string if the error number was cleared by ERR0.
ERR0	ERR0	Clears the last error number, so that a subsequent execution of ERRN returns #0. Also clears the last error message.

The IFERR...THEN...END Structure

The syntax of IFERR...THEN...END is

IFERR *trap-clause* THEN *error-clause* END

If an error occurs during execution of the trap-clause, the error is ignored, the remainder of the trap-clause is discarded and program execution jumps to the error-clause. The commands in the error-clause are executed only if an error is generated during execution of the trap-clause.

As a typing aid, press ↶ IFERR to key in:

```
IFERR
THEN
END
```

Example: An IFERR...THEN...END Structure. Recall the following program from chapter 27, page 512.

```
« WHILE DUP TYPE 3 == REPEAT Σ+ END »
```

The program takes any number of vectors or arrays from the stack and adds them to the statistics matrix. However, the program errors if a vector or array with a different number of columns is encountered. In addition, if *only* vectors or arrays with the same number of columns are on the stack, the program errors after the last vector or array has been removed from the stack.

In the following version, the program simply attempts to add the level 1 object to the statistics matrix until an error occurs. At that point, it "gracefully" ends by displaying the message DONE.

Program:	Comments:
«	
IFERR	Starts the trap-clause.
WHILE	Starts the test-clause of the nested loop.
1	1 is a true result, so executes the loop-clause until an error occurs.
REPEAT	Starts the loop clause.
Σ+	Adds the vector or array to the statistics matrix.
END	Ends the nested loop.
THEN	If an error does occur on execution of Σ+ ...
"DONE" 1 DISP 1 FREEZE	... displays the message DONE in the status area.
END	Ends the error trap.
»	

The IFERR...THEN...ELSE...END Structure

The syntax of IFERR...THEN...ELSE...END is:

IFERR *trap-clause* THEN *error-clause* ELSE *normal-clause* END

If an error occurs during execution of the trap-clause, the error is ignored, the remainder of the trap-clause is discarded and program execution jumps to the error-clause. If no error occurs, execution jumps to the normal-clause at the completion of the trap-clause.

As a typing aid, press → IFERR to key in:

```
IFERR
THEN
ELSE
END
```

Example: An IFERR...THEN...ELSE...END Structure. The following program prompts for two numbers, then adds them. If only one number is supplied, the program displays an error message and prompts again.

Program:	**Comments:**
«	
DO	Begins the outer loop.
"KEY IN a AND b" " " INPUT OBJ→	Prompts for two numbers.
UNTIL	Starts the test clause
IFERR	Starts the error trap.
+	Adds the contents of levels 1 and 2.
THEN	If an error occurs ...
ERRM 5 DISP 2 WAIT 0	... executes ERRM to display the Too Few Arguments error message for two seconds, then leaves 0 (false) on the stack for the outer-loop END.
ELSE	If an error does not occur ...
1	... leaves 1 (true) on the stack for the outer-loop END.
END	Ends the error trap.

`END`	Ends the outer loop. If the error trap left `0` on the stack, this END returns program execution to the prompt for numbers. Otherwise, the program ends.

`»`

User-Defined Errors

You may want to generate an error in a program when an error would not normally occur. For example, you might want an error to occur if the sum of the two numbers on the stack is greater than 10. You can do this with the DOERR command. DOERR causes a program to behave exactly as if a normal error has occurred during execution. The DOERR error can be trapped in an IFERR structure; if it is not, program execution is abandoned at the location of the DOERR command. DOERR takes *one* argument from the stack, either:

- A string, in which case the string is used as the message. (ERRM returns this string, and ERRN returns `#70000h`.)
- A real number or binary integer, in which case the corresponding built-in error message is displayed. (ERRM and ERRN return the corresponding error message and number, respectively.) `0 DOERR` is equivalent to ATTN; that is, program execution is aborted and no message is displayed. (In this case, the values returned by ERRM and ERRN are unchanged from their previous values.)

The following program aborts execution if there are three objects in the level 1 list.

```
«
 OBJ→
 IF 3 SAME
 THEN "3 OBJECTS IN LIST" DOERR
 END
»
```

In this program, DOERR abandons program execution. Alternatively, you can execute DOERR in the trap-clause of an error trap to enable program execution to continue.

31

More Programming Examples



The programs in this chapter demonstrate programming concepts introduced in the previous chapters. Some new concepts are also introduced. The programs are intended to both improve your programming skills and provide supplementary functions for your calculator.

At the end of each program, the *checksum* and the program *size* in bytes are listed. The checksum is a binary integer that uniquely identifies the program based on its contents. To verify that you've keyed the program in correctly, execute the BYTES command (←[MEMORY] BYTES) with the program *name* in level 1. The checksum for the program is returned to level 2, and its size in bytes is returned to level 1. (If you execute BYTES with the program *object* in level 1, before storing the program in its name, you'll get a different byte count returned to level 1.)

Fibonacci Numbers

This section includes three programs — two demonstrate an approach to the following problem:

Given an integer n, calculate the nth Fibonacci number F_n, where:

$$F_0 = 0,\ F_1 = 1,\ F_n = F_{n-1} + F_{n-2}$$

- *FIB1* is a user-defined function that is defined *recursively* — its defining procedure contains its own name. *FIB1* is short.
- *FIB2* is a user-defined function with a definite loop. It's longer and more complicated than *FIB1*, but it's faster.

The third program, *FIBT*, calls both *FIB1* and *FIB2*, and calculates the execution time of each subprogram.

FIB1 (Fibonacci Numbers, Recursive Version)

Arguments	Results
1: n	1: F_n

Techniques.

- IFTE (If-Then-Else function). The defining procedure for *FIB1* contains the conditional *function* IFTE, which can take its argument either from the stack or in algebraic syntax. (*FIB2* uses the conditional structure IF ... THEN ... ELSE ... END.)
- Recursion. The defining procedure for *FIB1* is written in terms of *FIB1*, just as F_n is defined in terms of F_{n-1} and F_{n-2}.

Program:	**Comments:**
«	
→ n	Defines local variable *n*.
'	Begins the defining procedure, an algebraic expression.
IFTE(n≤1,	If $n \leq 1$ ...
n,	... then $F_n = n$ ...
FIB1(n-1)+FIB1(n-2))	... else $F_n = F_{n-1} + F_{n-2}$.
'	Ends the defining procedure.
»	
ENTER ' FIB1 STO	Enters the program, then stores it in *FIB1*.

Checksum: # 41467d
Bytes: 113.5

Example. Calculate F_6. Calculate F_{10} using algebraic syntax.

First calculate F_6.

VAR
6 FIB1



Next calculate F_{10} using algebraic syntax.

' FIB1 ← ( ) 10 EVAL



FIB2 (Fibonacci Numbers, Loop Version)

Arguments	Results
1: n	1: F_n

Techniques.

- IF...THEN...ELSE...END. *FIB2* uses the program-structure form of the conditional. (*FIB1* uses IFTE.)
- START...NEXT (definite loop). To calculate F_n, *FIB2* starts with F_0 and F_1 and repeats a loop to calculate successive F_i's.

Program:	Comments:
«	
→ n	Creates a local variable.
«	Begins the defining procedure, a program.
IF n 1 ≤	If $n \leq 1$...
THEN n	... then $F_n = n$.
ELSE	Begins the ELSE clause.
0 1	Puts F_0 and F_1 on the stack.
2 n	From 2 to n ...
START	... does the following loop:
DUP	Makes a copy of the latest F (initially F_1).
ROT	Moves the previous F (initially F_0) to level 1.
+	Calculates the next F (initially F_2).

NEXT	Repeats the loop.
SWAP DROP	Drops F_{n-1}.
END	Ends the ELSE clause.
»	Ends the defining procedure.
»	Ends the program.
ENTER ' FIB2 STO	Enters the program, then stores it in *FIB2*.

Checksum: # 51820d
Bytes: 89

Example. Calculate F_6 and F_{10}. Note that *FIB2* is faster than *FIB1*.

Calculate F_6.

VAR
6 FIB2



Calculate F_{10}.

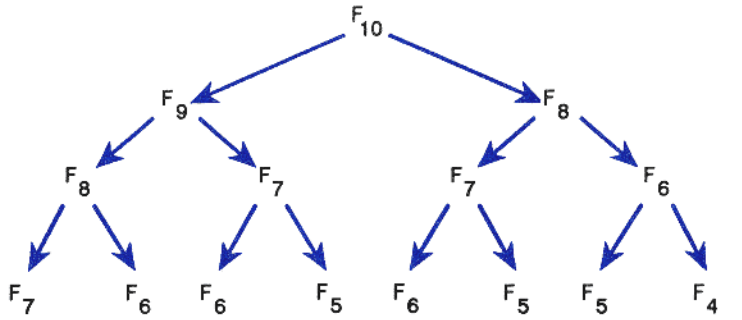
10 FIB2



FIBT (Comparing Program-Execution Time)

FIB1 calculates intermediate values F_i more than once, while *FIB2* calculates each intermediate F_i only once. Consequently, *FIB2* is faster. The difference in speed increases with the size of n because the time required for *FIB1* grows exponentially with n, while the time required for *FIB2* grows only linearly with n.

The diagram below shows the beginning steps of *FIB1* calculating F_{10}. Note the number of intermediate calculations: 1 in the first row, 2 in the second row, 4 in the third row, and 8 in the fourth row.



FIBT executes the TICKS command to record the execution time of *FIB1* and *FIB2* for a given value of *n*.

Arguments	Results
1: *n*	3: F_n 2: *FIB1 execution time*:z 1: *FIB2 execution time*:z

Techniques.

- Structured programming. *FIBT* calls both *FIB1* and *FIB2*.
- Programmatic use of calculator clock. *FIBT* executes the TICKS command to record the start and finish of each subprogram.
- Interactive programming. *FIBT* tags each execution time with a descriptive message.

Program:	Comments:
«	
DUP TICKS SWAP FIB1 SWAP TICKS SWAP	Copies *n*, then executes *FIB1*, recording the start and stop time.
- B→R 8192 /	Calculates the elapsed time, converts it to a real number, and converts that number to seconds. Leaves the

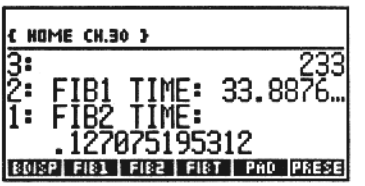
	answer returned by *FIB1* in level 2.
`"FIB1 TIME"` `→TAG`	Tags the execution time.
`ROT TICKS SWAP FIB2` `TICKS`	Executes *FIB2*, recording the start and stop time.
`SWAP DROP SWAP` `- B→R 8192 /`	Drops the answer returned by *FIB2* (*FIB1* returned the same answer). Calculates the elapsed time for *FIB2* and converts to seconds.
`"FIB2 TIME"` `→TAG`	Tags the execution time.
`»`	
ENTER ' FIBT STO	Stores the program in *FIBT*.

Checksum: # 22248d
Bytes: 135

Example. Calculate F_{13} and compare the execution time for the two methods.

Select the VAR menu and do the calculation.

VAR
13 FIBT



F_{13} is 233. *FIB2* takes 0.13 seconds to execute. *FIB1* takes 33.9 seconds. (Your results may differ depending on the contents of memory in your calculator.)

Displaying a Binary Integer

This section contains three programs:

- *PAD* is a utility program that converts an object to a string for right-justified display.
- *PRESERVE* is a utility program for use in programs that change the calculator's status (angle mode, binary base, and so on).
- *BDISP* displays a binary integer in HEX, DEC, OCT, and BIN bases. It calls *PAD* to show the displayed numbers right-justified, and it calls *PRESERVE* to preserve the binary base.

PAD (Pad with Leading Spaces)

PAD converts an object to a string and, if the string contains fewer than 23 characters, adds spaces to the beginning.

When a short string is displayed with DISP, it appears *left-justified*; its first character appears at the left end of the display. The position of the last character is determined by the length of the string. By adding spaces to the beginning of a short string, *PAD* moves the position of the last character to the right. When the string (including leading spaces) is 23 characters long, it appears *right-justified*; its last character appears at the right end of the display. *PAD* has no effect on strings that are longer than 22 characters.

Arguments	Results
1: *object*	1: "*object*"

Techniques.

- WHILE ... REPEAT ... END (indefinite loop). The WHILE clause contains a test that determines whether to execute the REPEAT clause and test again (if true) or to skip the REPEAT clause and exit (if false).
- String operations. *PAD* demonstrates how to convert an object to string form, count the number of characters, and concatenate two strings.

Program:	Comments:
«	
→STR	Makes sure the object is in string form. (Strings are unaffected by this command.)
WHILE	Begins WHILE clause.
DUP SIZE 22 <	Does the string contain fewer than 23 characters?
REPEAT	Begins REPEAT clause.
" " SWAP +	Adds a leading space.
END	Ends REPEAT clause.
»	
ENTER ' PAD STO	Enters the program, then stores it in *PAD*.

Checksum: # 38912d
Bytes: 61.5

PAD is demonstrated in the program *BDISP*.

PRESERVE (Save and Restore Previous Status)

Given a program on the stack, *PRESERVE* stores the current calculator (flag) status, executes the program, and then restores the previous status.

Arguments	Results
1: « *program* »	1: *(result of program)*
1: '*program name*'	1: *(result of program)*

Techniques.

- RCLF and STOF. *PRESERVE* uses RCLF (*recall flags*) to record the current status of the calculator in a binary integer and STOF (*store flags*) to restore the status from that binary integer.
- Local-variable structure. *PRESERVE* creates a local variable structure to remove the binary integer from the stack briefly; its defining procedure simply evaluates the program argument, then puts the binary integer back on the stack and executes STOF.

Program:	**Comments:**
«	
RCLF	Recalls the list of two 64-bit binary integers representing the status of the 64 system flags and 64 user flags.
→ f	Stores the list in local variable *f*.
«	Begins the defining procedure.
EVAL	Executes the program placed on the stack as the level 1 argument.
f STOF	Puts the list back on the stack, then restores the status of all flags.
»	Ends the defining procedure.
»	
ENTER ' PRESERVE STO	Enters the program, then stores it in *PRESERVE*.

Checksum: # 21528d
Bytes: 46.5

PRESERVE is demonstrated in the program *BDISP*.

BDISP (Binary Display)

BDISP displays a (real or binary) number in HEX, DEC, OCT, and BIN bases.

Arguments	Results
1: # *n*	1: # *n*
1: *n*	1: *n*

Techniques.

- IFERR ... THEN ... END (error trap). To accommodate real-number arguments, *BDISP* includes the command R→B (*real-to-binary*). However, this command causes an error if the argument is *already* a binary integer. To maintain execution if an error occurs, the R→B command is placed inside an IFERR clause. No action is required when an error occurs (since a binary number is an acceptable argument), so the THEN clause contains no commands.
- Enabling LASTARG. In case an error occurs, LASTARG must be enabled to return the argument (the binary number) to the stack. *BDISP* clears flag −55 to enable the LASTARG recovery feature.
- FOR ... NEXT loop (definite loop with counter). *BDISP* executes a loop from 1 to 4, each time displaying *n* (the number) in a different base on a different line. The loop counter (named *j* in this program) is a local variable. It is created by the FOR ... NEXT program structure (rather than by a → command) and it is automatically incremented by NEXT.
- Unnamed programs as arguments. A program defined only by its « and » delimiters (not stored in a variable) is not automatically evaluated; it is simply placed on the stack and may be used as an argument for a subroutine. *BDISP* demonstrates two uses for unnamed program arguments.

  1. *BDISP* contains a main program argument and a call to *PRESERVE*. This program argument goes on the stack and is executed by *PRESERVE*.

2. There are four program arguments that "customize" the action of the loop. Each program argument contains a command to change the binary base, and each iteration of the loop evaluates one of these arguments.

When *BDISP* creates a local variable for *n*, the defining procedure is an unnamed program. However, since this program is a defining procedure for a local variable structure, it *is* automatically executed.

Required Programs.

- *PAD* (page 555) expands a string to 23 characters so that DISP shows it right-justified.
- *PRESERVE* (page 556) stores the current status, executes the main nested program and restores the status.

Program:	**Comments:**
`«`	
`« DUP`	Begins the main nested program. Makes a copy of *n*.
`-55 CF`	Clears flag −55 to enable LASTARG.
`IFERR`	Begins error trap.
`R→B`	Converts *n* to a binary integer.
`THEN`	If an error occurred ...
`END`	... do nothing (there are no commands in the THEN clause).
`→ n`	Creates a local variable *n*.
`«`	Begins the defining program for the local variable structure.
`CLLCD`	Clears the display.
`« BIN »`	Writes the nested program for BIN.

« OCT »	Writes the nested program for OCT.
« DEC »	Writes the nested program for DEC.
« HEX »	Writes the nested program for HEX.
1 4	Sets the first and last counter values.
FOR j	Starts the loop with counter *j*.
EVAL	Executes one of the nested base programs (initially the one for HEX).
n →STR	Makes a string showing *n* in the current base.
PAD	Pads the string to 23 characters.
j DISP	Displays the string in the *j*th line.
NEXT	Increments *j* and repeats the loop.
»	Ends the defining procedure.
3 FREEZE	Freezes the status and stack areas.
»	Ends the main nested program.
PRESERVE	Stores the current status, executes the main nested program, and restores the status.
»	
ENTER ' BDISP STO	Enters the program, then stores it in *BDISP*.

Checksum: # 18055d
Bytes: 191

Example. Switch to DEC base, display # 100 in all bases, and check that *BDISP* restored the base to DEC.

Clear the stack and select the MTH BASE menu. Make sure the current base is DEC and enter # 100.

```
↷ CLR
MTH BASE
DEC
↷ # 100 ENTER
```

```
1:                    # 100d
HEX DEC ■ OCT BIN STWS RCWS
```

Execute *BDISP*.

```
VAR BDISP
```

```
                      # 64h
                     # 100d
                     # 144o
               # 1100100b

BDISP FIB1 FIB2 FIBT PAD PRESE
```

Return to the normal stack display and check the current base.

```
ATTN
MTH BASE
```

```
HEX DEC ■ OCT BIN STWS RCWS
```

Although the main nested program left the calculator in BIN base, *PRESERVE* restored DEC base.

To check that *BDISP* also works for real numbers, try 144.

```
VAR
144 BDISP
```

```
                      # 90h
                     # 144d
                     # 220o
              # 10010000b

BDISP FIB1 FIB2 FIBT PAD PRESE
```

Median of Statistics Data

This section contains three programs:

- *SORT* orders the elements of a list.
- *LMED* calculates the median of a sorted list.
- *MEDIAN* uses *SORT* and *LMED* to calculate the median of the current statistics data.

SORT (Sort a List)

SORT sorts a list of real numbers into ascending order.

Arguments	Results
1: ⟨ *list* ⟩	1: ⟨ *sorted list* ⟩

Techniques.

- Bubble sort. Starting with the first and second numbers in the list, *SORT* compares adjacent numbers and moves the larger number toward the end of the list. This process is done once to move the largest number to the last position in list, then again to move the next largest to the next-to-last position, and so on.
- Nested definite loops. The outer loop controls the stopping position each time the process is done; the inner loop runs from 1 to the stopping position each time the process is done.
- Nested local-variable structures. *SORT* contains two local-variable structures, the second inside the defining procedure (a program) of the first. This nesting is done for convenience; it's easier to create the first local variable as soon as its value is computed, thereby removing its value from the stack, rather than computing both values and creating both local variables at once.
- FOR ... STEP and FOR ... NEXT (definite loops). *SORT* uses two counters: − 1 STEP decrements the counter for the outer loop each iteration; NEXT increments the counter for the inner loop by 1 each iteration.

Program:	Comments:
«	
DUP SIZE 1 - 1	From the next-to-last position to the first position ...
FOR j	... begins the outer loop with counter *j*.
1 j	From the first position to the *j*th position ...
FOR k	... begins the inner loop with counter *k*.
k GETI → n1	Gets the *k*th number in the list and stores it in a local variable n_1.
«	Begins the defining procedure (a program) for the outer local variable structure.
GETI → n2	Gets the next number in the list and stores it in a local variable n_2.
«	Begins the defining procedure (a program) for the inner local variable structure.
DROP	Drops the index returned by GETI.
IF n1 n2 >	If the two numbers are in the wrong order ...
THEN	... then does the following:
k n2 PUTI	... puts the second one back in the *k*th position;
n1 PUT	... puts the *k*th one back in the next position.
END	Ends THEN clause.

»	Ends inner defining procedure.
»	Ends outer defining procedure.
NEXT	Increments *k* and repeats the inner loop.
−1 STEP	Decrements *j* and repeats the outer loop.

»

ENTER ' SORT STO	Enters the program, then stores it in *SORT*.

Checksum: # 15011d
Bytes: 144

Example. Sort the list { 8 3 1 2 5 }.

Select the VAR menu, key in the list, and execute *SORT*.

VAR
◀ { } 8 SPC 3 SPC
1 SPC 2 SPC 5 ENTER
SORT



LMED (Median of a List)

Given a sorted list, *LMED* returns the median. If the list contains an odd number of elements, the median is the value of the center element. If the list contains an even number of elements, the median is the average value of the elements just above and below the center.

Arguments	Results
1: { *sorted list* }	1: *median of sorted list*

Techniques.

- FLOOR and CEIL. For an integer, FLOOR and CEIL both return that integer; for a noninteger, FLOOR and CEIL return successive integers that bracket the non- integer.

Program:	**Comments:**
«	
DUP SIZE	Copies the list, then finds its size.
1 + 2 /	Calculates the center position in the list (fractional for even-sized lists).
→ p	Stores the center position in local variable *p*.
«	Begins the defining procedure (a program) for the local variable structure.
DUP	Makes a copy of the list.
p FLOOR GET	Gets the number at or below the center position.
SWAP	Moves the list to level 1.
p CEIL GET	Gets the number at or above the center position.
+ 2 /	Calculates the average of the two numbers at or near the center position.
»	Ends the defining procedure.
»	
ENTER ' LMED STO	Enters the program, then stores it in *LMED*.

Checksum: # 3682d
Bytes: 77

Example. Calculate the median of the list you sorted using *SORT*.

Put the list on the stack if necessary, select the VAR menu, and execute *LMED*.

[←] [{ }] 1 2 3 5 8 [ENTER]
[VAR] LMED



MEDIAN (Median of Statistics Data)

MEDIAN returns a vector representing the medians of the columns of the statistics data.

Arguments	Results
1:	1: [x_1 x_2 ... x_m]

Techniques.

- Arrays, lists, and stack elements. *MEDIAN* extracts a column of data from Σ*DAT* in vector form. To convert the vector to a list, *MEDIAN* puts the vector elements on the stack and then combines them into a list. From this list the median is calculated using *SORT* and *LMED*.

  The median for the *m*th column is calculated first, and the median for the first column is calculated last, so as each median is calculated, it is moved to the stack level above the previously calculated medians.

  After all medians are calculated and positioned correctly on the stack, they're combined into a vector.
- FOR ... NEXT (definite loop with counter). *MEDIAN* uses a loop to calculate the median of each column. Because the medians are calculated in reverse order (last column first), the counter is used to reverse the order of the medians.

Required Programs.

- *SORT* (page 562) arranges a list in ascending order.
- *LMED* (page 564) calculates the median of a sorted list.

Program:	Comments:
«	
RCLΣ	Puts a copy of the current statistics matrix Σ*DAT* on the stack for safekeeping.
DUP SIZE	Puts the list { *n m* } on the stack, where *n* is the number of rows in Σ*DAT* and *m* is the number of columns.
OBJ→ DROP	Puts *n* and *m* on the stack. Drops the list size.
→ n m	Creates local variables for *n* and *m*.
«	Begins the defining procedure (a program) for the local variable structure.
'ΣDAT' TRN	Transposes Σ*DAT*. Now *n* is the number of columns in Σ*DAT* and *m* is the number of rows. (To key in the Σ character, press [→][Σ], then delete the parentheses.)
1 m	Specifies the first and last rows.
FOR j	For each row, does the following:
Σ-	Extracts the last row in Σ*DAT*. Initially this is the *m*th row, which corresponds to the *m*th column in the original Σ*DAT*. (To key in the Σ- command, press [←][STAT] [←] [Σ+].)

`OBJ→ DROP`	Puts the row elements on the stack. Drops the index list { *n* }, since *n* is already stored in a local variable.
`n →LIST`	Makes an *n*-element list.
`SORT`	Sorts the list.
`LMED`	Calculates the median of the list.
`j ROLLD`	Moves the median to the proper stack level.
`NEXT`	Increments *j* and repeats the loop.
`m →ARRY`	Combines all the medians into an *m*-element vector.
`≫`	Ends the defining procedure.
`SWAP`	Moves the original Σ*DAT* to level 1.
`STOΣ`	Restores Σ*DAT* to its previous value.
`≫`	
ENTER ' MEDIAN STO	Enters the program, then stores it in *MEDIAN*.

Checksum: # 19502d
Bytes: 129.5

Example. Calculate the median of the following data.

$$\begin{bmatrix} 18 & 12 \\ 4 & 7 \\ 3 & 2 \\ 11 & 1 \\ 31 & 48 \\ 20 & 17 \end{bmatrix}$$

There are two columns of data, so *MEDIAN* will return a two-element vector.

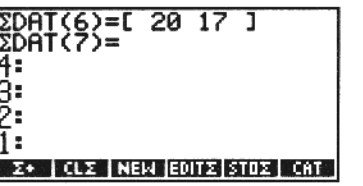
Enter the matrix.

[→] [MATRIX]
18 [ENTER] 12 [ENTER] [▼]
4 [ENTER] 7 [ENTER]
3 [ENTER] 2 [ENTER]
11 [ENTER] 1 [ENTER]
31 [ENTER] 48 [ENTER]
20 [ENTER] 17 [ENTER]
[ENTER]



Store the matrix in Σ*DAT*.

[←] [STAT] Σ+



Calculate the median.

[VAR] MEDIA



The medians are 14.5 for the first column and 9.5 for the second column.

Expanding and Collecting Completely

This section contains two programs:

- *MULTI* repeats a program until the program has no effect on its argument.
- *EXCO* calls *MULTI* to completely expand and collect an algebraic.

MULTI (Multiple Execution)

Given an object and a program that acts on the object, *MULTI* applies the program to the object repeatedly until the object is unchanged.

Arguments	Results
2: *object* 1: « *program* »	2: 1: *resulting object*

Techniques.

- DO ... UNTIL ... END (indefinite loop). The DO clause contains the steps to be repeated; the UNTIL clause contains the test that determines whether to repeat both clauses again (if false) or to exit (if true).
- Programs as arguments. Although programs are commonly named and then executed by calling their names, programs can also be put on the stack and used as arguments to other programs.
- Evaluation of local variables. The program argument to be executed repeatedly is stored in a local variable. It's convenient to store an object in a local variable when you don't know beforehand how many copies you'll need.

  Recall from page 98 that an object stored in a local variable is simply put on the stack when the local variable is evaluated. *MULTI* uses the local variable name to put the program argument on the stack and then executes EVAL to execute the program.

Program:	Comments:
«	
→ p	Creates a local variable *p* containing the program from level 1.
«	Begins the defining procedure (a program) for the local variable structure.

DO	Begins the DO clause.
DUP	Makes a copy of the object, now in level 1.
▷ EVAL	Applies the program to the object, returning a new version.
DUP	Makes a copy of the new version of the object.
ROT	Moves the old version to level 1.
UNTIL	Begins the UNTIL clause.
SAME	Tests whether the old version and the new version are the same.
END	Ends the UNTIL clause.
»	Ends the defining program.
»	Ends the program.
ENTER ' MULTI STO	Puts the program on the stack, then stores it in *MULTI*.

Checksum: # 34314d
Bytes: 56

MULTI is demonstrated in the next programming example.

EXCO (Expand and Collect Completely)

Given an algebraic object, *EXCO* executes EXPAN repeatedly until the algebraic doesn't change, then executes COLCT repeatedly until the algebraic doesn't change. In some cases the result will be a number.

Arguments	Results
1: *'algebraic'*	1: *'algebraic'*
1: *'algebraic'*	1: z

Techniques.

- Subroutines. *EXCO* calls the program *MULTI* twice. It is more efficient to create program *MULTI* and simply call its name twice than write each step in *MULTI* two times.

Required Programs.

- *MULTI* (page 569) repeatedly executes the programs that *EXCO* provides as arguments.

Program:	Comments:
«	
« EXPAN »	Puts a program on the stack as the level 1 argument for *MULTI*. The program executes the EXPAN command.
MULTI	Executes EXPAN until the algebraic object doesn't change.
« COLCT »	Puts another program on the stack for *MULTI*. The program executes the COLCT command.
MULTI	Executes COLCT until the algebraic object doesn't change.
»	
ENTER ' EXCO STO	Puts the program on the stack, then stores it in *EXCO*.

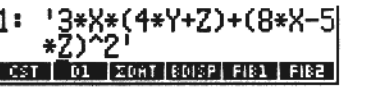
Checksum: # 48008d
Bytes: 65.5

Example. Expand and collect completely the expression:

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

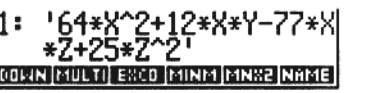
Enter the expression.

[']3 [×] X [×]
[◀][( )] 4 [×] Y [+] Z [▶] [+]
[◀][( )] 8 [×] X [−] 5 [×] Z
[▶] [y^x] 2
[ENTER]



Select the VAR menu and start the program.

[VAR] EXCO



Expressions with many products of sums or with powers can take many iterations of EXPAN to expand completely, resulting in a long execution time for *EXCO*.

Finding the Minimum or Maximum Element of an Array

This section contains two programs that find the minimum or maximum element of an array:

- *MNX* uses a DO ... UNTIL ... END (indefinite) loop.
- *MNX2* uses a FOR ... NEXT (definite) loop.

MNX (Finding the Minimum or Maximum Element of an Array—Technique 1)

Given an array on the stack, *MNX* finds the minimum or maximum element in the array.

Arguments	Results
1: [[*array*]]	2: [[*array*]] 1: *z* (*maximum element of array*)
1: [[*array*]]	2: [[*array*]] 1: *z* (*minimum element of array*)

Techniques.

- DO ... UNTIL ... END (indefinite loop). The DO clause contains the sort instructions. The UNTIL clause contains the system-flag test that determines whether to repeat the sort instructions.
- User and system flags for logic control:
  - *User* flag 10 defines the sort: When flag 10 is set, *MNX* finds the maximum element; when flag 10 is clear, it finds the minimum element. *You* determine the status of flag 10 at the beginning of the program.
  - *System* flag −64, the Index Wrap Indicator flag, determines when to end the sort. While flag −64 is clear, the sort loop continues. When the index invoked by GETI wraps back to the first array element, flag −64 is *automatically* set, and the sort loop ends.
- Nested conditional. An IF ... THEN ... END conditional is nested in the DO ... UNTIL ... END conditional—it determines:
  - Whether to maintain the current minimum or maximum element, or make the current element the new minimum or maximum.
  - The sense of the comparison of elements (either < or >) based on the status of flag 10.
- Custom menu for making a choice. *MNX* builds a custom menu that lets you choose whether to sort for the minimum or maximum element. Key 1, labeled MAX, sets flag 10. Key 2, labeled MIN, clears flag 10.

- Logical function. *MNX* executes XOR (*exclusive OR*) to test the combined state of the relative value of the two elements and the status of flag 10.

Program:	**Comments:**
`«`	
`{`	Begins the defining list for the option menu.
`{ "MAX" « 10 SF CONT » }` `{ "MIN" « 10 CF CONT » }`	Builds menu keys MAX to set flag 10 and continue program execution, and MIN to clear flag 10 and continue program execution.
`}`	Ends the defining list for the temporary option menu.
`TMENU` `"Sort for MAX or MIN?"` `PROMPT`	Displays the temporary menu and a prompt message.
`1 GETI`	Gets the first element of the array.
`DO`	Begins the DO loop.
`ROT ROT`	Puts the index and the array in levels 1 and 2.
`GETI 4 ROLL DUP2`	Gets the new array element, moves the current minimum or maximum array element from level 4 to level 1. Then copies both elements.
`IF`	Begins the conditional.
`> 10 FS? XOR`	Tests the combined state of the relative value of the two elements and the status of flag 10.
`THEN`	If the new element is either less than the current maximum or greater than the current minimum ...

SWAP	... swaps the new element into level 1.
END	Ends the conditional.
DROP	Saves the current minimum or maximum and drops the other element off the stack.
UNTIL	Begins the UNTIL clause.
-64 FS?	Tests if flag −64 is set. If flag −64 is clear, executes the DO clause again.
END	If flag −64 is set, ends the loop.
SWAP DROP 0 MENU	Swaps the index to level 1, then drops it off the stack. Restores the last menu.

»

ENTER ' MNX STO	Enters the program, then stores it in *MNX*.

Checksum: # 57179d
Bytes: 210.5

Example. Find the maximum element of the following matrix:

$$\begin{bmatrix} 12 & 56 \\ 45 & 1 \\ 9 & 14 \end{bmatrix}$$

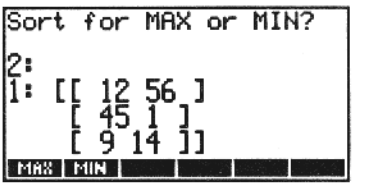
Enter the matrix.

→ MATRIX
12 ENTER 56 ENTER ▼
45 ENTER 1 ENTER
9 ENTER 14 ENTER
ENTER



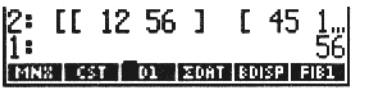
Select the VAR menu and execute *MNX*.

VAR MNX



Find the maximum element.

MAX



MNX2 (Finding the Minimum or Maximum Element of an Array—Technique 2)

Given an array on the stack, *MNX2* finds the minimum or maximum element in the array. *MNX2* uses a different approach than *MNX*; it executes OBJ→ to break up the array into individual elements on the stack for testing, rather than executing GETI to index through the array.

Arguments	Results
1: [[*array*]]	2: [[*array*]] 1: *z* (*maximum element of array*)
1: [[*array*]]	2: [[*array*]] 1: *z* (*minimum element of array*)

Techniques.

- FOR ... NEXT (definite loop). The initial counter value is 1. The final counter value is *nm* - 1 where *nm* is the number of elements in the array. The loop-clause contains the sort instructions.
- User flag for logic control. *User* flag 10 defines the sort: When flag 10 is set, *MNX2* finds the maximum element; when flag 10 is clear, it finds the minimum element. *You* determine the status of flag 10 at the beginning of the program.
- Nested conditional. An IF ... THEN ... END conditional is nested in the FOR ... NEXT loop—it determines:

- Whether to maintain the current minimum or maximum element, or make the current element the new minimum or maximum.
- The sense of the comparison of elements (either < or >) based on the status of flag 10.

- Logical function. *MNX2* executes XOR (*exclusive OR*) to test the combined state of the relative value of the two elements and the status of flag 10.
- Custom menu for making a choice. *MNX2* builds a custom menu that lets you choose whether to sort for the minimum or maximum element. Key 1, labeled MAX, sets flag 10. Key 2, labeled MIN, clears flag 10.

Program:	**Comments:**
`«`	
`{`	Begins the defining list for the temporary option menu.
`{ "MAX" « 10 SF CONT » }` `{ "MIN" « 10 CF CONT » }`	Builds menu keys MAX to set flag 10 and continue program execution, and MIN to clear flag 10 and continue program execution.
`}`	Ends the defining list for the option menu.
`TMENU` `"Sort for MAX or MIN?"` `PROMPT`	Displays the temporary menu and a prompting message.
`DUP`	Copies the array.
`OBJ→`	Returns the individual array elements to levels 2 through $nm+1$, and returns the list containing n and m to level 1.
`1`	Sets the initial counter value.
`SWAP OBJ→`	Converts the list to individual elements on the stack.

`DROP * 1 -`	Drops the list size, then calculates the final counter value (*nm* - 1).
`FOR n`	Starts the FOR ... NEXT loop.
`DUP2`	Saves the array elements to be tested (initially the last two elements). Establishes the last array element as the current minimum or maximum.
`IF`	Begins the conditional.
`> 10 FS? XOR`	Tests the combined state of the relative value of the two elements and the status of flag 10.
`THEN`	If the new element is either less than the current maximum or greater than the current minimum ...
`SWAP`	... swaps the new element into level 1.
`END`	Ends the conditional.
`DROP`	Saves the current minimum or maximum (and drops the other element off the stack).
`NEXT`	Ends the FOR ... NEXT loop.
`0 MENU`	Restores the last menu.

```
»
```

ENTER ' MNX2 STO	Enters the program, then stores it in *MNX2*.

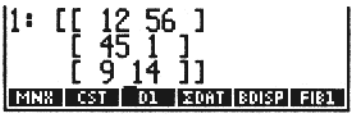
Checksum: # 12277d
Bytes: 200.5

Example. Use *MNX2* to find the minimum element of the matrix from the previous example:

$$\begin{bmatrix} 12 & 56 \\ 45 & 1 \\ 9 & 14 \end{bmatrix}$$

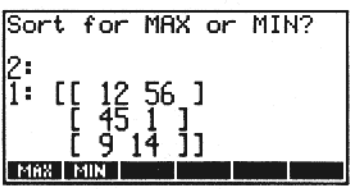
Enter the matrix.

[↱] [MATRIX]
12 [ENTER] 56 [ENTER] [▼]
45 [ENTER] 1 [ENTER]
9 [ENTER] 14 [ENTER]
[ENTER]



Select the VAR menu and execute *MNX2*.

[VAR] MNX2



Find the minimum element.

MIN



Verification of Program Arguments

The two utility programs in this section verify that the argument to a program is the correct object type.

- *NAMES* verifies that a list argument contains exactly two names.
- *VFY* verifies that the argument is either a name or a list containing exactly two names. It calls *NAMES* if the argument is a list.

You can modify these utilities to verify other object types and object content.

NAMES (Does the List Contain Exactly Two Names?)

If the argument for a program is a list (as determined by *VFY*), *NAMES* verifies that the list contains exactly two names. If the list does not contain exactly two names, an error message is displayed in the status area and program execution is aborted.

Arguments	Results
1: « *valid list* »	1:
1: « *invalid list* »	status-area error message 1:

Techniques.

- Nested conditionals. The outer conditional verifies that there are two objects in the list. If there are two objects, the inner loop verifies that they are both names.
- Logical functions. *NAMES* uses the AND command in the inner conditional to determine if *both* objects are names and the NOT command to display the error message if they are not both names.

Program:	Comments:
«	
IF	Starts the outer IF...THEN...ELSE...END structure.
OBJ→	Returns the n objects in the list to levels 2 through (n + 1), and returns the list size n to level 1.
DUP	Copies the list size.
2 SAME	Tests if the list size is 2.

`THEN`	If the list size *is* 2 . . .
`DROP`	. . . moves the objects to levels 1 and 2.
`IF`	Begins the inner IF. . .THEN. . .END structure.
`TYPE 6 SAME`	Tests if the first object is a name. If so, returns a true result (1). If not, returns a false result (0).
`SWAP TYPE 6 SAME`	Moves the second object to level 1, then tests if it is a name.
`AND`	If both results are true, returns a true result (1). If either or both results are false, returns a false result (0).
`NOT`	Returns the opposite result.
`THEN`	If the opposite result is true (if the objects are not both names) . . .
`"List needs two names"` `DOERR`	. . . displays an error message and aborts program execution.
`END`	Ends the inner conditional.
`ELSE`	If the list size is not 2 . . .
`DROPN` `"Illegal list size"` `DOERR`	. . . drops the list size, displays an error message, and aborts program execution.
`END`	Ends the outer conditional.
`»`	
ENTER ' NAMES STO	Enters the program and stores it in *NAMES*.

Checksum: # 40666d
Bytes: 141.5

NAMES is demonstrated in program *VFY*.

VFY (Verify Program Argument)

Given an argument on the stack, *VFY* verifies that the argument is either a name or a list that contains exactly two names.

Arguments	Results
1: *'name'*	1: *'name'*
1: *{ valid list }*	1: *{ valid list }*
1: *{ invalid list }*	status-area error message 1: *{ invalid list }*
1: *invalid object*	status-area error message 1: *invalid object*

Techniques.

- Utility programs. *VFY* by itself has little use. However, it can be used (with minor modifications) by other programs to verify that specific object types are valid arguments.
- CASE ... END (case structure). *VFY* uses a case structure to determine if the argument is a list or a name.
- Structured programming. If the argument is a list, *VFY* calls *NAMES* to verify that the list is valid.
- Local variable structure. *VFY* stores its argument in a local variable so that it may be passed to *NAMES* if necessary.
- Logical operator. *VFY* uses NOT to display an error message.

Required Programs.

- *NAMES* (page 580) verifies that a list argument contains exactly two names.

Program:	Comments:
«	
DUP	Saves the original argument.
DTAG	Removes any tags from the argument for subsequent testing.
→ arg	Stores the argument in local variable *arg*.
«	Begins the defining procedure (a program) for the local variable structure.
CASE	Begins the case structure.
arg TYPE 5 SAME	Tests if the argument is a list.
THEN	If the argument is a list ...
arg NAMES	... puts the argument back on the stack, and calls *NAMES* to verify that the list is valid.
END	Ends the first case. (If the first case was true, leaves the case structure. If the first case was false, goes to the next case.)
arg TYPE 6 SAME NOT	Tests if the argument is a name, then inverts the test result.
THEN	If the argument is *not* a name (and not a list) ...
"Not name or list" DOERR	... displays an error message and aborts program execution.
END	Ends the second case.
END	Ends the case structure.

»	Ends the defining procedure.
»	
ENTER ' VFY STO	Enters the program, then stores it in *VFY*.

Checksum: # 14621d
Bytes: 135.5

Example. Part 1. Execute *VFY* to test the validity of the name argument *PAT*.

Put the name *PAT* on the stack. Select the VAR menu and execute *VFY*.

' PAT ENTER
VAR VFY



The argument is valid and is simply returned to the stack.

Part 2. Execute *VFY* to test the validity of the list argument { *PAT DIANA TED* }.

Put the names *DIANA* and *TED* on the stack. Convert the three names now on the stack to a list.

' DIANA ENTER
' TED ENTER
3 PRG OBJ →LIST



Execute *VFY*. Since the list contains too many names, the error message is displayed and program execution is aborted.

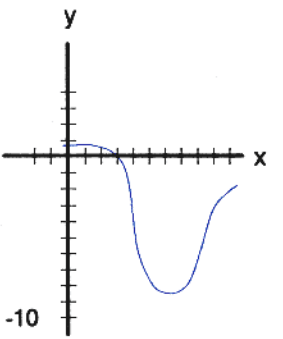
VAR VFY



Bessel Functions

The real and imaginary parts of the Bessel function $J_n(xe^{\frac{3\pi i}{4}})$ are denoted $\mathrm{Ber}_n(x)$ and $\mathrm{Bei}_n(x)$. When $n = 0$,

$$\mathrm{Ber}(x) = 1 - \frac{(x/2)^4}{2!^2} + \frac{(x/2)^8}{4!^2} - \cdots$$



User-defined function *BER* calculates Ber(*x*) to 12 significant digits.

Arguments	Results
1: z	1: *Ber(z)*

Techniques.

- Local variable structure. *BER* consists solely of a local variable structure and so has two properties of a user-defined function; it takes numeric or symbolic arguments from the stack or in algebraic syntax. Because *BER* uses a FOR ... STEP loop, its defining procedure is a *program*. (Loop structures are not allowed in algebraic expressions.) Therefore, unlike a user-defined function, *BER* is not differentiable.

- FOR ... STEP loop (definite loop with counter). Successive terms in the series are calculated with a counter-controlled loop. When the new term does not change the series value within the 12-digit precision of the calculator, the loop ends. The final counter value (9.0×10^{499}) ensures that enough terms will be calculated.
- Nested conditional. The IF ... THEN ... ELSE ... END conditional within the definite loop sets the step value *n* for the loop counter. As long as the newly calculated series value does not equal the old series value, the step value *n* is set to 2. When the new series value *does* equal the old series value, the step value is set to a number larger than the final value of the counter, ending the definite loop. In essence, the nested conditional makes the outer loop work like a DO ... UNTIL ... END (indefinite) loop.

Program:	**Comments:**
`«`	
`→ x`	Creates local variable *x*.
`«`	Begins the defining procedure (a program) for the local variable structure.
`1`	Writes the first term of the series.
`2 9.E499`	Sets the counter for the FOR ... STEP loop.
`FOR j`	Begins the loop.
`DUP`	Saves the current value of the series (initially 1).
`'(-1)^(j/2)* (x/2)^(2*j) /SQ(j!)' EVAL`	Calculates the next term of the series.
`+`	Adds the next term to the current value of the series to calculate the new value of the series.

`IF`	Begins the conditional.
`DUP ROT ≠`	Tests if the new series value is not equal to the old series value.
`THEN`	If the new and old values are not equal ...
`2`	... specifies $n = 2$.
`ELSE`	If the new and old terms are equal (to 12-digit precision) ...
`9.1E499`	... specifies $n = 9.1E499$
`END`	Ends the conditional.
`STEP`	Specifies the step value based on the conditional.
`»`	Ends the defining procedure.

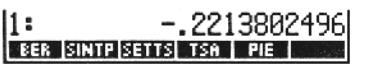
`»`

ENTER ' BER STO	Enters the program, then stores it in *BER*.

Checksum: # 872d
Bytes: 148

Example. Calculate Ber(3).

VAR
3 BER



Calculate Ber(2) in algebraic syntax.

' BER ◀ ( ) 2
EVAL



Animation of Successive Taylor's Polynomials

This section contains three programs that manipulate graphics objects to display a sequence of Taylor's polynomials for the sine function.

- *SINTP* draws a sine curve, and saves the plot in a variable.
- *SETTS* superimposes plots of successive Taylor's polynomials on the sine curve plot from *SINTP*, and saves each graphics object in a list.
- *TSA* displays in succession each graphics object from the list built in *SETTS*.

Drawing a Sine Curve and Converting It to a Graphics Object

SINTP draws a sine curve, returns the plot to the stack as a graphics object, and stores that graphics object in a variable.

Arguments	Results
1:	1:

Techniques.

- Programmatic use of PLOT commands to build and display a graphics object.

Program:	Comments:
«	
'X' PURGE 'SIN(X)' STEQ	Makes *X* a formal variable, then stores the expression for sin *x* in *EQ*.
-2 2 YRNG	Sets the *y*-axis display range.
ERASE DRAW	Erases *PICT*, then plots the expression.

`PICT RCL 'SINT' STO`	Returns the resultant graphics object to the stack and stores it in *SINT*.
»	
ENTER ' SINTP STO	Stores the program in *SINTP*.

Checksum: # 61373d
Bytes: 78.5

Superposition of Successive Taylor's Polynomials

SETTS superimposes successive Taylor's polynomials on a sine curve and stores each graphics object in a list.

Arguments	Results
1:	1:

Techniques.

- Structured programming. *SETTS* calls *SINTP* to build a sine curve and convert it to a graphics object.
- FOR ... STEP (definite) loop. *SETTS* calculates successive Taylor's polynomials for the sine function in a definite loop. The loop counter serves as the value of the order of each polynomial.
- Programmatic use of PLOT commands. *SETTS* draws a plot of each Taylor's polynomial.
- Manipulation of graphics objects. *SETTS* converts each Taylor's polynomial plot into a graphics object. Then it executes + to combine each graphics object with the sine curve stored in *SINT*, creating nine new graphics objects, each the superposition of a Taylor's polynomial on a sine curve. *SETTS* then puts the nine new graphics objects, and the sine curve graphics object itself, in a list.

Program:	Comments:
«	
SINTP	Plots a sine curve and stores the graphics object in *SINT*.
17 1 FOR x	For each value of local variable *x* ...
x 'X' DUP SIN SWAP ROT TAYLR STEQ ERASE DRAW	... plots the Taylor's polynomial for the sine curve (where *x* is the order of the polynomial).
PICT RCL SINT +	Returns the plot to the stack as a graphics object and executes + to superimpose the Taylor series on the sine curve stored in *SINT*.
-2 STEP	Decrements the loop counter (the order of the Taylor's polynomial) by 2 and repeats the loop.
SINT 10 →LIST 'TSL' STO	Puts the sine curve graphics object on the stack, then builds a list that contains that graphics object and the nine graphics objects created in the FOR ... STEP loop. Stores the list in *TSL*.
»	
ENTER ' SETTS STO	Stores the program in *SETTS*.

Checksum: # 5841d
Bytes: 136.5

Animation of Taylor's Polynomials

TSA displays in succession each graphics object created in *SETTS*.

Arguments	Results
1:	1:

Techniques.

- Passing a global variable. Because *SETTS* takes a long time to execute (approximately six minutes), *TSA* does not call *SETTS*. Instead, you must first execute *SETTS* to create the global variable *TSL* containing the list of graphics objects. *TSA* simply executes that global variable to put the list on the stack.
- FOR ... NEXT (definite loop). *TSA* executes a definite loop to display in succession each graphics object from the list.

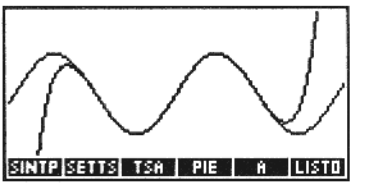
Program:	Comments:
«	
TSL	Puts the list *TSL* on the stack.
OBJ→	Puts the 10 graphics objects from the list and the list count on the stack.
1 SWAP FOR s	For *s* from 1 to 10 ...
ERASE →LCD 1 WAIT	... clears the display, converts the level-1 graphics object to a display image, and shows it for one second.
NEXT	
»	
ENTER ' TSA STO	Stores the program in *TSA*.

Checksum: # 39562d
Bytes: 51

Example. Execute *SETTS* and *TSA* to build and display in succession a series of Taylor's polynomial approximations of the sin function.

Set Radians mode. Execute *SETTS* to build the list of graphics objects. *SETTS* takes about six minutes to execute. Execute *TSA* to display each plot in succession. The display shows *TSA* in progress.

◀ RAD (if necessary)
VAR SETTS
TSA



Programmatic Use of Statistics and Plotting

Program *PIE* prompts for single variable data, stores that data in the statistics matrix Σ*DAT*, then draws a labeled pie chart that shows each data point as a percentage of the total.

Arguments	Results
1:	1:

Techniques.

- Programmatic use of PLOT commands. *PIE* executes XRNG and YRNG to define *x*- and *y*-axis display ranges in user units, executes ARC to draw the circle, and LINE to draw individual slices.
- Programmatic use of matrices and statistics commands.
- Manipulation of graphics objects. *PIE* recalls *PICT* to the stack and executes GOR to merge the label for each slice with the plot.
- FOR ... NEXT (definite) loop. Each slice is calculated, drawn and labeled in a definite loop.

- CASE ... END structure. To avoid overwriting the circle, each label is offset from the midpoint of the arc of the slice. The offset for each label depends on the position of the slice in the circle. The CASE ... END structure assigns an offset to the label based on the position of the slice.
- Preservation of current calculator flag status. Before specifying Radians mode, *PIE* saves the current flag status in a local variable, then restores that status at the end of the program.
- Temporary menu for data input.

Program:	**Comments:**
`«`	
`RCLF → flags`	Recalls the current flag status and stores it in variable *flags*.
`«`	
`RAD`	Sets Radians mode.
`{`	Begins the defining list for the input menu.
`{ "SLICE" Σ+ }`	Defines key 1. Key 1 executes Σ+ to store each data point in Σ*DAT*.
`{ }` `{ "CLEAR" CLΣ }`	Defines keys 2 and 3. Key 3 clears Σ*DAT*.
`{ } { }` `{ "DRAW" CONT }`	Defines keys 4, 5, and 6. Key 6, labeled DRAW continues program execution after data entry.
`}`	Ends the defining list.
`TMENU`	Displays the temporary menu.
`"Key values into SLICE,▪DRAW restarts program." PROMPT`	Prompts for inputs. The ▪ is the calculator's representation of the ↵ character (→ ENTER) after the program has been entered on the stack.

```
ERASE 1 131 XRNG
1 64 YRNG CLLCD
```
Erases the current *PICT* and sets plot parameters.

```
"Please wait.....■
Drawing Pie Chart"
1 DISP
```
Displays "drawing" message.

```
(66,32) 20 0 6.28
ARC
```
Executes ARC to draw the circle.

```
PICT RCL →LCD
```
Displays the empty circle.

```
RCLΣ TOT /
```
Recalls the statistics data matrix, computes totals, and calculates the proportions.

```
DUP 100 *
```
Converts the proportions to percentages.

```
→ prcnts
```
Stores the percentage matrix in *prcnts*.

```
«
 2 π →NUM * * 0
```
Multiplies the proportion matrix by 2π.

```
 → prop angle
```
Stores the proportions in *prop* and initializes *angle* to 0.

```
 «
  prop SIZE OBJ→
  DROP SWAP
```
Sets up *start* and *finish* for FOR...NEXT loop.

```
  FOR x
```
Begin FOR clause.

```
   (66,32) prop x GET
   'angle' STO+
```
Puts the center of the circle on the stack and gets the *x*th value from the proportion matrix.

```
   angle COS LASTARG
   SIN R→C 20 * OVER +
   LINE
```
Computes the endpoint and draws the line for the *x*th slice.

```
PICT RCL
```
Recalls *PICT* to the stack.

```
angle prop x GET
2 / - DUP
COS LASTARG SIN R→C
26 * (66,32) +
```
For labeling the slice, computes the midpoint of the arc of the slice.

```
SWAP DUP
CASE
```
Starts the CASE...END structure to determine the offset value for the label.

```
  1.5 ≤
 THEN
```
From 0 to 1.5 radians ...

```
  DROP
```
... doesn't offset the label.

```
 END
  DUP 4.4 ≤
 THEN
```
From 1.5 to 4.4 radians ...

```
  DROP 15 -
```
... offsets the label 15 user units left.

```
 END
  5 <
 THEN
```
From 4.4 to 5 radians ...

```
  (3,2) +
```
... offsets the label 3 units right and 2 units up.

```
 END
END
```

```
prcnts x GET
```
Gets the *x*th value from the percentage matrix.

```
1 RND
```
Rounds the percentage to one decimal place.

```
→STR "%" +
```
Converts the percentage to a string and adds % to the string.

`1 →GROB`	Converts the string to a graphics object.
`GOR DUP PICT STO`	Adds the label to the plot and stores the new plot.
`→LCD`	Displays the plot with the new slice and label.
`NEXT`	
`« » PVIEW`	Displays the finished plot.
`»`	
`»`	
`flags STOF`	Restores the original flag status.
`» 2 MENU`	Displays the VAR menu. (Note that the user must first press [ATTN] to clear the plot.)
`»`	
[ENTER] ['] PIE [STO]	Enters the program and stores it in *PIE*.

Checksum: # 8706d
Bytes: 758.5

Example. The fruit inventory at Joe's grocery includes 983 oranges, 416 apples, and 85 bananas. Draw a pie chart to show each fruit's percentage of total inventory.

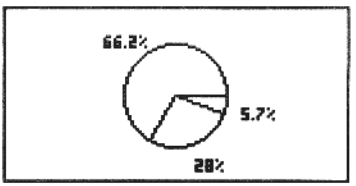
Start *PIE*.

[VAR] PIE



Clear the current statistics data. (The prompt is removed from the display.) Key in the new data and draw the pie chart.

```
CLEAR
983 SLICE
416 SLICE
85 SLICE
DRAW
```



Animation of a Graphical Image

Program *WALK* shows a man walking across the display. It animates this custom graphical image by incrementing the image position in a loop structure.

Arguments	Results
1:	1:

Techniques.

- Use of a custom graphical image in a program. (Note that the programmer derives the full information content of the graphical image before writing the program by building the image *interactively* in the Graphics environment and then returning it to the command line.)
- FOR...STEP definite loop to animate the graphical image. The ending value for the loop is MAXR. Since the counter value cannot exceed MAXR, the loop executes indefinitely.

Program:	Comments:
«	
GROB 9 15 E300 14001500 1C001400E300 8000C110AA0094009000 4100220014102800	Puts the graphical image of the man in the command line. (Note that the hexadecimal portion of the graphics object is a continuous integer E300. . .2800. The linebreaks do *not* represent spaces.)
→ man	Creates local variable *man* containing the graphics object.
«	
ERASE (# 0d # 0d) PVIEW	Clears *PICT*, then displays it.
(# 0d # 25d) PICT OVER man GXOR	Puts the first position on the stack and turns on the first image. This readies the stack and *PICT* for the loop.
5 MAXR FOR i	Starts FOR. . .STEP loop to generate horizontal coordinates indefinitely.
i 131 MOD R→B	Computes the horizontal coordinate for the next image.
# 25d 2 →LIST	Specifies a fixed vertical coordinate. Puts the two coordinates in a list.
PICT OVER man GXOR	Displays the new image, leaving its coordinates on the stack.
PICT ROT man GXOR	Turns off the old image, removing its coordinates from the stack.

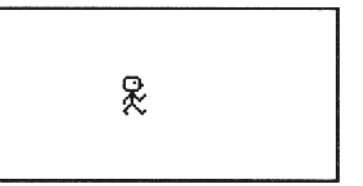
5 STEP	Increments the horizontal coordinate by 5.
»	
»	
ENTER ' WALK STO	Stores the program in *WALK*.

Checksum: # 4342d
Bytes: 236.5

Example. Send the man out for a long walk.

Select the VAR menu and execute *WALK*.

VAR WALK



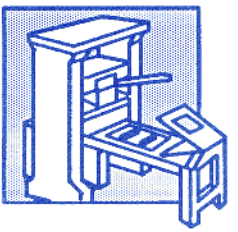
When he tires, press ATTN to take him home (and end the program).

Part 5

Printing, Data Transfer, and Plug-Ins

32

Printing



This chapter describes how to use your HP 48 with an HP 82240B Infrared Printer, with an HP 82240A infrared printer, and with printers that connect to the serial port.

Printing with an HP 82240B Printer

You can send information from your HP 48 to an HP 82240B Infrared Printer via the infrared port. Refer to the printer manual for instructions about how to operate the printer and how to position the printer relative to the HP 48.

PRINT Commands

Keys	Programmable Command	Description
ON MTH		When ON and MTH are pressed simultaneously and then released, the current display is printed.
→ PRINT	PR1	Prints the object in level 1.
← PRINT:		
PR1	PR1	Prints the object in level 1.
PRST	PRST	Prints all objects on the stack starting with the object in the highest level.
PRSTC	PRSTC	Prints all objects on the stack in compact form, starting with the object in the highest level.
PRLCD	PRLCD	Prints the current display.
PRVAR	PRVAR	Searches the current path for the specified variables, and prints the name and contents of each variable. The variables are specified either by name or in a list in level 1.
CR	CR	Causes printer to do a carriage-return/line-feed, printing the contents, if any, of the printer buffer.
DELAY	DELAY	Sets the delay time, $\leq$ 6.9 seconds, between sending lines of information to the printer.
OLDPR	OLDPRT	Remaps the HP 48 character set to the HP 82240A Infrared Printer.

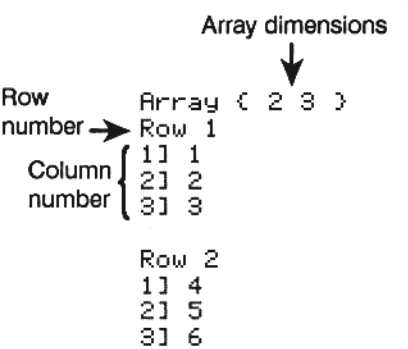
Print Formats

Multiline objects can be printed in *multiline* format or *compact* format. Multiline printer format is similar to multiline display format, with the following exceptions:

- Strings and names that are more than 24 characters long are continued on the next printer line.
- The real and imaginary parts of complex numbers are printed on separate lines if they don't fit on the same line.
- Arrays are printed with a numbered heading for each row and with a column number before each element. For example, the 2 × 3 array

$$\begin{bmatrix} 1 & 2 & 3 \\ 4 & 5 & 6 \end{bmatrix}$$

would be printed like this:



Compact printer format is the same as compact display format: Multiline objects are truncated and appear on one line only.

The PRSTC command prints the stack in compact form. All other print commands print in multiline format.

Basic Printing Commands

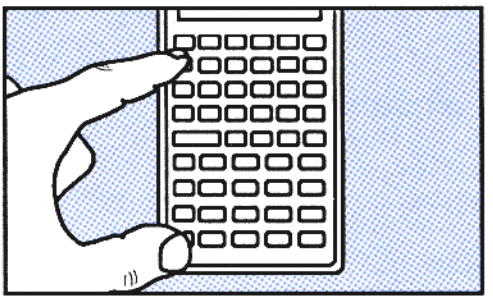
Printing the Display. To print an image of the display under any condition without using the PRINT menu: *

1. Press and hold [ON].
2. Press and release [MTH] (the key with "PRINT" written above it).
3. Release [ON].



Note

A low-battery condition may result in consistent failure of the [ON][MTH] printing procedure. If you notice consistent failure, replace your calculator batteries to remedy the situation.



The PRLCD command ([↰][PRINT] PRLCD) also prints an image of the display.

* These keystrokes use the current DELAY setting. Also, if you are printing to the serial port to capture graphics data on your printer, the serial port must be open (the OPENIO command) before these keystrokes are executed.

Printing the Contents of Level 1 of the Stack. PR1 (◀ PRINT PR1) prints the contents of level 1 in multiline printer format. All objects except strings are printed with their identifying delimiters. Strings are printed without their " delimiters. PR1 can be executed also by pressing ▶ PRINT.

Printing the Stack. PRST (◀ PRINT PRST) prints all objects on the stack, starting with the object in the highest level, in multiline printer format (except for graphics objects, which print the same as they are displayed).

PRSTC (◀ PRINT PRSTC) prints all objects on the stack, starting with the object in the highest level, in compact printer format.

Printing Variables. PRVAR (◀ PRINT PRVAR) searches the current path for the variables that you have specified, and prints the name and contents of each variable in multiline printer format. PRVAR takes one argument from the stack: either one name or a list containing one or more names. (PRVAR also prints backup objects.)

Printing a Text String

You can print any sequence of characters by entering a string object that contains the characters and executing PR1. The printer prints the characters without the quotation marks and leaves the print head at the end of the print line. Subsequent printing begins on the next line.

Printing a Graphics Object

Like other objects, you can print a graphics object either by putting the graphics object in level 1 and executing PR1, or, if the graphics object is stored in a variable, by entering the variable name and executing PRVAR. Graphics objects wider than 166 dot columns are printed in 166-column wide segments down the paper, separated by a dashed line. For example, a 350-column wide graphics object would be printed in two 166-column segments and one 18-column segment.

Double Space Printing

To select double-space printing (one blank line between lines), set flag −37. To return to single-space printing, clear flag −37.

Setting the Delay

The DELAY command lets you specify how long the HP 48 waits between sending lines of information to the HP 82240B Infrared Printer. DELAY takes a real number from level 1 that specifies the delay time in seconds. If you do not specify a delay, it is automatically set to 1.8 seconds. The maximum delay is 6.9 seconds.

A shorter delay setting can be useful when the HP 48 sends multiple lines of information to your printer (for example, when printing a program). To optimize printing efficiency, set the delay just longer than the time the printhead requires to print one line of information.

If you set the delay *shorter* than the time to print one line, you may lose information. Also, as the batteries in the printer lose their charge, the printhead slows down, and, if you have previously decreased the delay, you may have to increase it to avoid losing information. (Battery discharge will not cause the printhead to slow to more than the 1.8 second default delay setting.)

The HP 48 Character Set

The table in appendix C lists each HP 48 character and its corresponding *character code*. Most of the characters in the table can be directly typed into the display from the Alpha keyboard. For example, to display ‡, type [α] [←] [4]. (The Alpha keyboard is presented in chapter 2.) Any character in the table can be displayed by typing its corresponding character code and then executing the CHR command. The syntax is *char#* CHR. Certain characters in the table in appendix C are *not* on the Alpha keyboard. To display one of these characters, you *must* type its character code and execute CHR.

The HP 82240B Infrared Printer can print any character from the HP 48 character set.

Sending Escape Sequences and Control Codes

You can select various printer modes by sending *escape sequences* to the printer. An escape sequence consists of the escape character — character 27 — followed by additional characters. When the printer receives an escape sequence, it switches into the selected mode. The escape sequence itself isn't printed.

Printer owner's manuals generally describe the escape sequences and control codes recognized by the printer.

Use CHR and + to create escape sequences and use PR1 to send them to the printer.

Example. These characters send information to the HP 82240B printer to turn on Underline mode, underline the string HELLO, and then turn off Underline mode:

```
27 CHR 251 CHR + "HELLO" +
  27 CHR + 250 CHR + PR1
```

Accumulating Data in the Printer Buffer

You can print any combination of text, graphics, and objects on a single print line by accumulating data in the printer's *buffer*.

Normally, each print command completes data transmission by *automatically* executing the CR (*carriage right*) command, which tells the printer to do a carriage-return/line-feed. Then the printer prints the data currently in its buffer and leaves the print head at the right end of the print line.

You can disable the automatic execution of the CR command by setting flag −38, the Line-feed flag. Data from subsequent print commands is accumulated in the printer buffer and is printed only when you manually execute CR. When flag −38 is set, follow these three rules:

- Execute CR ([←][PRINT] CR) to print the accumulated data. (Alternately, send character 4 or character 10.)
- Print the data in the buffer before you accumulate more than 200 characters. Otherwise, the buffer fills up and subsequent characters are lost.

- Allow time for the printer to print a line before sending more data. The printer requires about 1.8 seconds per line.

Clear flag −38 to restore normal operation of the print commands.

Printing with an HP 82240A Infrared Printer

You can use your HP 48 calculator with an HP 82240A Infrared Printer, executing the same print commands that you would use for an HP 82240B. However, the character set in the HP 82240A Infrared Printer does not match the HP 48 character set:

- 24 characters in the HP 48 character set are not available in the HP 82240A Infrared Printer. (From the table in appendix C, these characters are numbers 129, 130, 143-157, 159, 166, 169, 172, 174, 184, and 185.) The HP 82240A prints a ▒ in substitution.
- Many characters in the extended character table (character codes 128 through 255) do not have the same character code. For example, the « character has code 171 in the HP 48 and code 146 in the HP 82240A Infrared Printer. If you want to use the CHR command to print extended characters with an HP 82240A Infrared Printer, first execute OLDPRT. OLDPRT adds a remap string to the *PRTPAR* variable, which changes the character code of each byte to match the codes in the HP 82240A Infrared Printer character table. (If you want to print a string containing graphics data, OLDPRT must *not* be in effect.)

If you executed OLDPRT to print with an HP 82240A Infrared Printer, and then want to print to an HP 82240B Infrared Printer, you should first purge the reserved variable *PRTPAR*. (You can first copy its contents to another variable if you want to save the settings for later use.) This resets the print parameters so that the character set matches the HP 82240B. (*PRTPAR* is described on page 611.)

Printing to the Serial Port

You can print to a serial printer via the HP 48 serial port. Once the HP 48 is connected to the printer:

1. Set flag −34, the Printing Device flag.
2. Check that flag −33, the I/O Device flag is clear. (The default is clear.)*
3. Set the HP 48 baud rate, parity, and translation code appropriately for your printer. These can be set using the I/O SETUP menu, described on page 617.
4. If your printer uses XON/XOFF handshaking, edit (or create) *IOPAR* to set transmit pacing ≠ 0. The reserved variable *IOPAR* is described on page 618.
5. If the number of characters that fit on one line on your printer is not 80, edit *PRTPAR* to contain the correct number as the third element in its list. (See the next section for information on *PRTPAR*.)
6. If your printer requires a line termination sequence other than carriage-return/line-feed, edit *PRTPAR* to contain that sequence as the fourth element in its list. The reserved variable *PRTPAR* is described in the following section.

You can execute any of the print commands described in this chapter with a serial printer. However, note that:

- The maximum line length to print is specified in the reserved variable *PRTPAR* (described next).
- You cannot print a graphics object.

* Setting both flags -33 and -34 would enable infrared serial data transmission. Printing with an HP 82240B Infrared Printer when these flags are set will not work—the HP 82240B would likely print blots.

The PRTPAR Variable

When you first print information with a command from the PRINT menu, the HP 48 automatically creates the *PRTPAR* variable. *PRTPAR* is a reserved variable containing a list that specifies how the HP 48 works with the printer. The list contains, in order, the following objects:

- A real number that specifies the delay time, in seconds. If you have not previously executed DELAY, the delay time is automatically set to 1.8 seconds in *PRTPAR*.
- A string that represents the current remapping of the HP 48 extended character set. The string can contain as many characters as you want to remap, with the first character in the string being the new character 128, the second being the new character 129, and so on. (Any characters outside the string length will not be remapped.) If you have not previously executed OLDPRT, the string is empty; if you have executed OLDPRT, the string contains the character remapping for the HP 82240A Infrared Printer.
- A real number that specifies the line length, in number of characters, for serial printing. This parameter does *not* affect infrared printing. The default is 80 characters.
- A string that represents the line termination method for serial printing. This parameter does *not* affect infrared printing. The default is *carriage-return/line-feed* (control characters 13 and 10).

You can edit any parameter in the list. The delay time, however, can be set more easily using the DELAY command: Enter the delay number (6.9 or less) on the stack and execute DELAY ([←] [PRINT] [NXT] DELAY).

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Transferring Data to and from the HP 48



This chapter covers:

- Transferring data from one HP 48 to another using the infrared port.
- Transferring data between the HP 48 and a computer using the serial port. (For this operation, you need the Serial Interface Kit appropriate for your computer. For more information, see your Hewlett-Packard dealer.)
- Other serial I/O operations.

The HP 48 uses *Kermit* file transfer protocol to transfer data and to correct transmission errors between two HP 48 calculators, or between an HP 48 and a computer. Kermit protocol was developed at the Columbia University Center for Computing Activities.

The calculator commands needed to accomplish Kermit data transfer are built into the HP 48. Therefore, you can transfer data from one HP 48 to another by simply lining up the two infrared ports and executing the proper commands, which are described in this chapter.

To transfer data to and from a computer, the computer must be running a program that implements Kermit protocol. Also, there must be a cable connecting the HP 48 and the computer. Details about the cable connection are covered later in this chapter. (Kermit protocol and a

special serial cable are required for this operation and are available from your Hewlett-Packard dealer as part of a Serial Interface Kit to match your computer.)

If you want additional information on Kermit protocol, a book by Frank da Cruz, *KERMIT, A File Transfer Protocol*, is available in many bookstores or can be ordered. *

The HP 48 provides additional serial I/O commands for non-Kermit data transfers. These commands are for specialized I/O operations—for example, printing directly from the HP 48 to a serial printer.

Types of Data You Can Transfer

The unit of information that is transferred using Kermit protocol is called a *file*. In the HP 48 world, a file can consist of:

- A named object (variable, backup object, etc.).
- An entire directory. When you transfer a directory, the contents of all the subdirectories under that directory are also transferred.
- All of user memory—all the variables you've created, the user-key assignments, and the Alarm Catalog.

In all cases, a *copy* of the data is sent to the receiving device and stored as a file (variable) in the current directory.

When you transfer a directory or all of user memory between an HP 48 and a computer, the data is sent as a single file, and you cannot conveniently access the contents of the individual variables in that file. For this reason, a directory transfer to a computer should be done mainly for archiving purposes. When the purpose of a file transfer is to use the file at its destination (for example, to edit a program on your computer), you should transfer the contents of the individual variable. If you put the variable names in a list and use the SEND command to transfer the data, the variables can then be accessed individually.

* da Cruz, Frank. 1987. *KERMIT, A File Transfer Protocol*. Bedford, MA: Digital Press.

When you transfer a directory from one HP 48 to another, it is installed in the destination machine as a normal directory. This means that it can be manipulated just like other directories and its variables are all accessible. Transferring a directory from one HP 48 to another is a good way to transfer a set of related objects — for instance, a set of programs, variables, printer configurations, etc. — all ready to be used together by the destination HP 48.

The I/O Menu

The commands for Kermit protocol and serial operations are contained in the I/O menu. The serial commands are covered at the end of the chapter.

Kermit Protocol Commands

Keys	Programmable Command	Description
◀ I/O (pages 1 and 2):		
SEND	SEND	Sends the contents of one or more variables to another device. SEND takes an argument from level 1 — the variable name, or a list of names { $name_1$ $name_2$ . . . }. (See the paragraph immediately following this table for more information.)
RECV	RECV	Tells the HP 48 to wait to receive a variable from another Kermit protocol device.
SERVE	SERVER	Puts the HP 48 into Kermit Server mode. (Also executed by pressing ▶ I/O.)

Kermit Protocol Commands (continued)

Keys	Programmable Command	Description
KGET	KGET	Gets one or more variables from a server device. KGET takes an argument from level 1 — the name of the requested variable, or a list of names { *name*$_1$ *name*$_2$ ... }. (See the paragraph immediately following this table for more information.)
FINIS	FINISH	Issues the Kermit FINISH command to a server device to terminate Server mode.
SETUP		Displays the SETUP menu for setting I/O parameters.
RECN	RECN	Same as RECV, except that it takes a name argument. The received file is stored using that name.
PKT	PKT	Provides the ability to send a Kermit command "packet" to a server. It takes the packet data field as a string in level 2 and the packet type as a string in level 1. For example, "D" "G" PKT sends a "generic directory" command.
KERR	KERRM	Returns the text of the most recent Kermit error.
OPENI	OPENIO	Opens the serial port using the I/O parameters in *IOPAR*.
CLOSE	CLOSEIO	Closes the serial port, clears KERRM, and clears the input buffer.

You can also use SEND and KGET to rename a variable when it's transferred by including a sublist for that variable in the main list. The first element in the sublist is the existing variable name and the second element is the new name. For example, executing the SEND command with the list { {$name_1$ $name_2$} $name_3$ $name_4$ } as an argument would result in $name_3$ and $name_4$ being sent under their own names and $name_1$ being sent under the new name of $name_2$.

Local and Server Modes

There are two Kermit protocol configurations for transferring data from an HP 48 to another HP 48 or computer:

- **Local/Local.** Both machines are controlled *locally* from their own keyboards, and Kermit commands can be issued by either machine. Data is transmitted by issuing a SEND command from the sender's keyboard and a RECV or RECN command from the receiver's keyboard.
- **Local/Server.** One machine is controlled *locally* and the other machine is a *server*. The server passively waits for instructions or data from the sender. A server:
  - Receives data when a sender executes a SEND command.
  - Transmits data when it receives a KGET command.
  - Ceases to be a server when it receives a FINISH command.

Local/Server mode is most useful when you wish to transfer a number of variables from different directories; the local device can issue repeated "send" or "get" commands to which the server responds.

Setting the I/O Parameters

The SETUP Menu

Pressing SETUP displays the current I/O parameter settings and a menu for changing them. If the displayed settings are overwritten by the stack or other information, press ↰ REVIEW to redisplay them.

SETUP Menu

Keys	Programmable Command	Description
↰ I/O SETUP:		
IR/W		Switches between IR (infrared) and Wire (serial) modes. In IR mode, I/O output is directed to the infrared port. In Wire mode, I/O output goes to the serial port.
ASCII		Switches between ASCII and binary transmission modes (see page 629).
BAUD	BAUD	Steps through 1200, 2400, 4800, and 9600 baud. The default transfer rate is 9600 baud.
PARIT	PARITY	Steps through odd (1), even (2), mark (3), space (4), and no (0) parity. The default is no parity.

SETUP Menu (continued)

Keys	Programmable Command	Description
CKSM	CKSM	Steps through checksum (error detection) options. The CKSM set is the type of checksum requested when initiating a SEND. Choices are 1 (1-digit arithmetic checksum), 2 (2-digit arithmetic checksum), and 3 (3-digit cyclic redundancy check, or CRC). The default is 3; IR transmissions should use 3.
TRAN	TRANSIO	Steps through the character translate code options. Choices are 0 (no translation), 1 (translate character 10 to characters 13 and 10), 2 (translate characters 128 through 159), or 3 (translate characters 128 through 255). The default is 1. (See page 626 for more information.)

The BAUD, PARITY, CKSM, and TRANSIO commands can be used in programs by preceding the command with the number representing the appropriate choice.

The IOPAR Variable

The reserved variable *IOPAR* stores the I/O parameters needed to establish a communications link with a computer. *IOPAR* contains a list consisting of these elements:

{ baud parity receive-pacing transmit-pacing checksum translate-code }

IOPAR is created in the HOME directory the first time you transfer data or open the serial port (OPENI). It is automatically updated whenever you change the settings using the commands in the I/O SETUP menu.

The Parity Setting. If the parity setting is positive, it is used on both transmit and receive. If it is negative, it is used only on transmit, and parity is not checked during receive. The menu key PARIT steps through only positive choices, but you can make the parity negative by putting the negative parity number on the stack, keying in the command PARITY, and pressing ENTER. You can also edit *IOPAR*, which contains the current I/O parameter settings, to make the parity element negative.

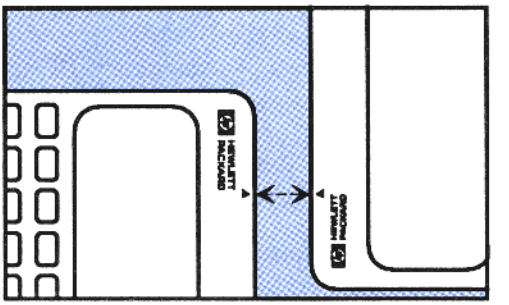
Receive Pacing and Transmit Pacing. Receive pacing and transmit pacing are not used by Kermit protocol. They can, however, be used in other serial I/O transfers — for instance, printing with a serial printer. A non-zero value for receive pacing causes the HP 48 to send an XOFF signal when its receive buffer is getting full, and then an XON signal when it can take more data. A non-zero value for transmit pacing causes the HP 48 to stop transmitting if it receives an XOFF signal and wait for an XON signal to continue. The default settings for both these *IOPAR* elements is 0, which means "don't send XON/XOFF signals, and ignore any that are received."

Transferring Data between Two HP 48's

Before beginning the transfer:

1. On the sender, switch to the directory where the variables are located. Use the IO SETUP menu to set IR and binary transfer modes and to set the CKSM to 3.
2. On the receiver, use the IO SETUP menu to set IR transfer mode. Then, switch to the directory to which you want the data sent.

3. Line up the infrared ports by lining up the ▲ marks (near the Hewlett-Packard logo just above the display). The calculators should be no farther apart than 2 inches.



To transfer data using the local/local configuration:

1. On the receiver, do either of the following:
   - Execute RECV ([←][I/O] RECV) to store the variable under the name given by the sender.
   - If you want to change the variable name, enter a new name and execute RECN ([←][I/O] [NXT] RECN). When the object is received, it will be stored using that name.
2. On the sender, enter the name of the variable or directory to be sent and execute SEND ([←][I/O] SEND). (For variables in the same directory, you can enter a list of variables and SEND them all at once.)
3. To transfer additional variables or lists of variables, repeat the previous two steps.

To transfer data using the local/server configuration:

1. On the HP 48 that will be the server, execute SERVER ([→][I/O] *or* [←][I/O] SERVE).

2. On the other, "locally controlled" HP 48:
   - To send a file to the server, enter the variable name and execute SEND ([←][I/O] SEND). (To send the variable using a different name, or to send several variables from the same directory, use a list argument as described on page 616.)
   - To receive a file from the server, enter the variable name and execute KGET ([←][I/O] KGET). (To have the variable stored locally using a different name, or to receive several variables together, use a list argument as described on page 616.)
3. To transfer additional variables or lists of variables, repeat step 2.
4. To end the session, execute FINISH ([←][I/O] FINIS) on the locally controlled machine.

Transferring Data between a Computer and the HP 48

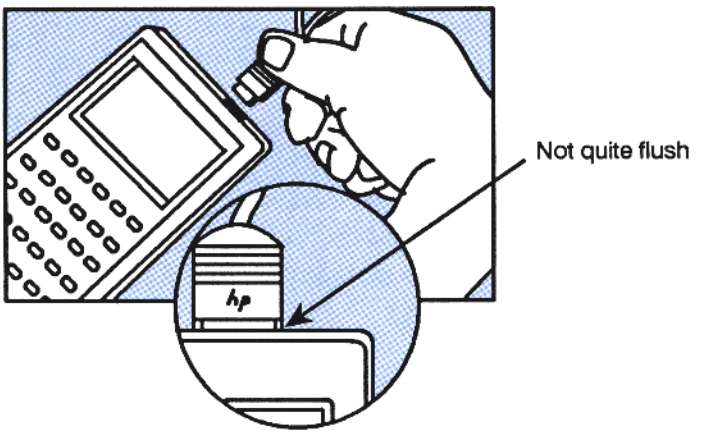
There are many reasons to transfer information between a computer and your HP 48—you might want to back up all of your calculator's user memory; you might want to edit a calculator program on your computer; or you might want to write a program on your computer and then run it on your calculator. Whatever the reason, the first step involves making a physical connection.

Cable Connection

Before transferring data between a computer and your calculator, you must connect the HP 48 to the computer via the serial cable in the Serial Interface Kit for your computer. (If you need information on what Serial Interface Kit is right for your computer, or if you don't have an Interface Kit, see your HP dealer.)

1. Connect the computer end of the serial cable to the serial port on the computer. (If you need instructions for this, consult your computer documentation.)

2. With the calculator right-side up and the HP logo on the cable connector facing up, connect the cable to your calculator. You should feel the connector lightly snap into place.



Note that when the cable is fully connected, the case around the connector is not quite flush with the calculator case.

Transferring Data

Before beginning the transfer:

1. On the HP 48, display the I/O SETUP menu ([←] [I/O] SETUP) and read the status message. If necessary:
   - Set Wire transmission mode by pressing IR/W.
   - Select ASCII or Binary transmission mode by pressing ASCII. (See page 629 for guidelines on selecting the mode to use.)
   - Set the HP 48 transfer rate by pressing BAUD until it matches the rate expected by the Kermit program running on the computer.
   - Set the HP 48 parity by pressing PARIT until it matches the parity expected by the Kermit program running on the computer.
   - Set the checksum (CKSM)—type 1 is the fastest—and set the character translate code (TRAN). (See page 618 for guidelines on what translate code settings to use.)

2. On both the HP 48 and the computer, switch to the directory where the variables (files) are located and to the directory to which you want the variables (files) sent.
3. Open the HP 48 serial port by executing OPENIO ([←][I/O] [NXT] OPENI). This step is not necessary for most connections, but it will prevent difficulties caused by the inability of certain devices to communicate with a closed port.
4. Run the program on the computer that implements Kermit protocol. If you are transferring data in binary mode, and if the Kermit program on the computer has a binary mode setting command, you should execute it on the computer.

To transfer data using the local/local configuration:

1. On the receiver, issue the "receive" command:
   - If the HP 48 is the receiver, execute RECV ([←][I/O] RECV), or enter a variable name and execute RECN ([←][I/O] [NXT] RECN).
   - If the computer is the receiver, issue the command on the computer to receive a file.
2. On the sender, issue the "send" command:
   - If the HP 48 is the sender, key in the argument (variable name or variable list as described on page 616) and execute SEND ([←][I/O] SEND).
   - If the computer is the sender, issue the command on the computer to send a file.
3. To transfer additional variables or variable lists, repeat steps 1 and 2.
4. Optional: To conserve battery power, execute CLOSEIO ([←][I/O] CLOSE) when finished.

To transfer data using local/server configuration:

1. If your computer will be the server, make sure it is able to execute the Kermit "server" command.
2. Set server operation on the device that will act as server:
   - If the HP 48 is to act as server, execute SERVER (→ I/O *or* ← I/O SERV).
   - If the computer is to act as server, execute the command on the computer to make it the server.
3. On the locally controlled device:
   - To send a file to the server, issue the appropriate "send" command. (See SEND on page 614 if the HP 48 is the sender.)
   - To receive a file from the server, issue the appropriate "get" command. (See KGET on page 615 if the HP 48 is the receiver.)
4. To transfer additional variables, repeat step 3.
5. To end the session, execute the "finish" command on the locally controlled machine. (If the HP 48 is locally controlled, press ← I/O FINIS.)
6. Optional: To conserve battery power, execute CLOSEIO (← I/O CLOSE) on the HP 48 when finished.

Backing Up All of HP 48 Memory

The ARCHIVE and RESTORE commands provide the ability to back up all variables, user key assignments, and alarms in calculator memory onto your computer.

To backup all of user memory:

1. Follow the instructions in "Before Beginning the Transfer" on page 622.
2. Enter the object `:IO:`*name*, where *name* is the file name that will contain backed up memory. For example, `:IO:AUG1` will back up memory into a file named *AUG1*.
3. Issue the Kermit RECEIVE command on the computer.
4. Execute ARCHIVE ([←] MEMORY NXT NXT ARCHI) to send the data to the PC. (Regardless of the ASCII/binary setting, ARCHIVE uses binary transmission.)

To copy backed up user memory into the HP 48:



Caution

Use the RESTORE command with care; restoring backed up user memory completely erases current user memory and replaces it with the backup copy.

1. Follow the instructions in "Before Beginning the Transfer" on page 622.
2. Transfer the computer file to the HP 48 the same way you transfer any other file.
3. Place the name of the file on the stack (for example, `'AUG1'`) and press [→] RCL. This recalls `Backup HOMEDIR` to level 1.
4. Execute RESTORE ([←] MEMORY NXT NXT RESTO).

If you want your current flag settings archived when you back up all of memory, execute RCLF and store the result in a variable before you archive memory. Then, after you archive and restore memory, you can recall the contents of the variable and execute STOF to make the flag settings active again.

Character Translations (TRANSIO)

The HP 48 character set contains certain characters that cannot be displayed using most computer software packages. These characters fall into two groups:

- Characters with "character numbers" in the range 128 through 159 cannot be displayed without special software designed to support the HP 48.
- Characters with character numbers in the range 160 through 255 can be displayed by computer software that supports the ISO 8859 character set.

The translate code lets you choose what happens to these characters when they are transmitted from the HP 48 to a computer. You set the translate code using the TRANSIO command. (See TRHH in the table on page 618 for a description of the four translate codes.)

The following table shows the conversions for many of the characters with numbers above 127. For characters not in the table, the conversion is to *xxx*, where *xxx* is the three-digit character number.* This conversion makes it possible for you to use your computer editor to type and display these characters.

---

* You can also use this conversion for characters in the table and for characters 0 through 127, making it easier to edit in control characters or in an escape sequence on your computer. The HP 48 will not generate the xxx sequences, but it will recognize them.

I/O Character Translations

Char. Number	HP 48 Char.	PC Char.	Char. Number	HP 48 Char.	PC Char.
128	∡	\<)	147	ε	\Ge
129	$\overline{x}$	\x-	148	η	\Gn
130	▽	\.V	149	θ	\Gh
131	√	\v/	150	λ	\Gl
132	∫	\.S	151	ρ	\Gr
133	Σ	\GS	152	σ	\Gs
134	▶	\\|>	153	τ	\Gt
135	π	\pi	154	ω	\Gw
136	∂	\.d	155	Δ	\GD
137	≤	\<=	156	Π	\PI
138	≥	\>=	157	Ω	\GW
139	≠	\=/	158	■	\[]
140	α	\Ga	159	∞	\oo
141	→	\->	171	«	\<<
142	←	\<-	176	°	\^o
143	↓	\\|v	181	μ	\Gm
144	↑	\\|^	187	»	\>>
145	γ	\Gg	215	×	\.x
146	δ	\Gd	216	Ø	\O/
			247	÷	\:-

To avoid any ambiguity during translation and reverse translation:

- When data is transferred *from* the HP 48 with a translate code of 2 or 3, any occurrence of the \ character is replaced by \\. For example, A\->B is translated to A\\->B. This prevents the reverse translation to A→B when the data is transmitted back to the HP 48.

- When data is transferred *to* the HP 48 with a translate code of 2 or 3, character sequences beginning with `\` are unchanged unless any of the following:
  - They match a sequence in the table.
  - The `\` is followed by three decimal digits in the range 000 through 159 for translate code 2.
  - The `\` is followed by three decimal digits in the range 000 through 255 for translate code 3.

  For example, `\Ga` and `\215` are translated to α and ×, respectively, but `\Gx` and `\267` are not translated.

More About File Names

In general, the file naming conventions for computers are different than the name requirements for HP 48 variables. When a file is transferred from a computer to the HP 48, the following difficulties may arise due to the computer file name:

- The file name contains characters not allowed in a variable name—for example, `AB#` or `{ABC}`. In this case, the HP 48 terminates the transfer and sends an error message to the computer.
- The file name matches a built-in command—for example, `SIN` or `DUP`. In this case, the HP 48 appends a number extension to the name—for example, `SIN.1`.
- The name matches a variable name in the current directory. In this case, to avoid overwriting your variable a number extension is added to the name. (However, if flag −36 is set, the variable will be overwritten.)

Also, an HP 48 file can have a name that is incompatible with the name requirements of the computer software. Transferring such a file can result in a transfer error.

Always check the filenames before a transfer to make sure they are compatible with the receiving system's requirements. If they are not compatible, change the names appropriately.

Errors

Executing the KERRM command (◀ I/O NXT KERR) displays the text of the most recent Kermit error packet.

ASCII and Binary Transmission Modes

The HP 48 Kermit protocol provides two transfer modes — ASCII and Binary. To get the fastest transfers, you generally should use Binary mode to transfer data from one HP 48 to another, and ASCII mode to transfer data between the HP 48 and a computer.

A receiving HP 48 treats all files as ASCII unless they match the special encoding generated for HP 48 binary files. The calculator will automatically switch to binary receive mode for files with this encoding.

ASCII Mode. You *must* use ASCII mode if you want to display, edit, or print your HP 48 file using a computer.

When data is sent from the HP 48 to a computer in ASCII mode:

- The data is converted from its internal HP 48 format to a sequence of characters.
- If the translate code is set to 1, 2, or 3, all line-feed (LF) characters are converted to carriage-return/line feed sequences (CR/LF).
- If the translate code is set to 2 or 3, some or all of the characters with character numbers greater than 127 are translated into displayable character sequences.
- The character sequence %%HP: *modes* ; is added at the beginning of the data, where *modes* is a series of characters that describes certain calculator mode settings — the translate, angle, and fraction-mark settings — when the transfer occurred. When this sequence is present, you don't have to set the corresponding modes on the receiving HP 48 when you send the data back.

When data is received by the HP 48 using ASCII mode:

- The data is translated (compiled) into the HP 48 internal format.
- If the translate code is set to 1, 2, or 3, all CR/LFs are converted to LFs.

- So that the receiving calculator can accurately reconstruct the object being sent by the computer, any modes specified at the beginning of the data are set temporarily in the calculator for the duration of the transfer. If a mode is not specified, the receiving calculator uses its current mode setting.

  If you created data (a program, for instance) on your computer, or if you substantially changed data that originally came from your calculator, you may need to include at the beginning of the data the characters %%HP: *modes* ;, where *modes* is a series of characters—T( ), A( ), and/or F( )—representing the translate code, angle mode, and/or fraction mark. Inside the parentheses are the characters you choose:

  - T (translate code) can be followed by 0 (no translation), 1 (translate CR/LF to LF and vice versa), 2 (translate CR/LFs and character numbers 128 through 159), or 3 (translate CR/LFs and character numbers 128 through 255).
  - A (angle mode) can be followed by D (degrees), R (radians), or G (grads). If the data contains an angle in degrees, radians, or grads, you should include A(D), A(R), or A(G), respectively.
  - F (fraction mark) can be followed by . (period) or , (comma). If it differs from your calculator's setting, the fraction mark used in the data being sent should be included by F(.) or F(,).

  For example, at the beginning of the data the sequence %%HP:A(D) will cause the angle mode to be set to degrees during the transfer; %%HP:T(2)A(G)F(,) will cause the translate code to be set to 2, the angle mode to be set to grads, and the fraction mark to be set to comma.

  A translate code of T(1) is the normal requirement (and also the system default). You should use T(2) or T(3) only when characters in their respective ranges are being translated according to the table on page 618. You should use T(0) only for string objects, or objects containing string objects, where the string contains binary data.

Binary Mode. In Binary mode, no character conversions are performed. Therefore, the files received from the HP 48 cannot be displayed by the computer. However, if data is being transferred for backup purposes only, Binary mode may be preferable because it is faster, since the data does not require as much processing.

The HP 48 automatically uses Binary mode when transferring libraries, transferring backup objects, or archiving all of user memory.

Sending Commands to a Server (PKT)

The PKT command (◀ I/O NXT PKT) provides the ability to send and receive data other than HP 48 objects to a remote server. It is particularly useful for sending Kermit commands—for example, Directory (D) or Erase (E).

The PKT command takes two string arguments from the stack—the data field of the packet in level 2, and the packet type in level 1. For example, executing the sequence `"D" "G" PKT` sends a request for a directory listing.

A server issues one of the following responses to the PKT command:

- An acknowledging message, which is returned to stack level 1.
- An error packet. The HP 48 briefly displays the contents of the error packet. It can be retrieved by executing KERRM (◀ I/O NXT KERR).

Serial Commands



Caution When using the commands described below to transfer data to or from an HP 48 at 9600 baud, make sure the ticking clock is not in the display. If the clock is in the display, it may interrupt a transfer or corrupt the data being transferred. The clock display is described on page 439 in chapter 24, "Time, Alarms, and Date Arithmetic."

Serial I/O Commands

Keys	Programmable Command	Description
↰ I/O (page 3):		
XMIT	XMIT	Sends a string in level 1 without Kermit protocol. Once the entire string is sent, a 1 is returned to level 1; if the entire string failed to transmit, a 0 is returned to level 1 and the unsent part of the input string is returned to level 2. Execute ERRM to see the error message.

Serial I/O Commands (continued)

Keys	Programmable Command	Description
SRECV	SRECV	Receives *x* characters (argument *x* is taken from level 1). The characters are returned as a string to level 2, along with a 1 (successful receive) or 0 (unsuccessful receive) to level 1. If the input buffer contains fewer than *x* characters, the HP 48 will wait the number of seconds specified by the STIME command (the default is 10 seconds). (If the level 2 number returned by the BUFLEN command (see BUFLE below) is used as the argument for SRECV, no waiting will occur because *x* will exactly match the number of characters in the input buffer.) In the event of an unsuccessful receive, executing ERRM returns the error message associated with the failure.
STIME	STIME	Sets the serial transmit/receive timeout to *x* seconds (argument *x* is taken from level 1). The value for *x* can range from 0 to 25.4 seconds. If 0 is used, no timeout will occur (which could result in excessive battery drain).
SBRK	SBRK	Sends a serial BREAK.

Serial I/O Commands (continued)

Keys	Programmable Command	Description
BUFLE	BUFLEN	Returns the number of characters in the HP 48 input buffer to level 2, along with a 1 (no framing error or UART overrun) or a 0 (framing error or UART overrun) to level 1. If a 0 is returned, the number of characters returned to level 2 represents the part of the data received *before* the error. Therefore, that number can be used to determine where the error occurred.



Note

Even though XMIT, SRECV, and BUFLEN check the send and receive mechanisms, the integrity of the data is not checked. One method to insure that the data sent is the same as the data received involves appending a checksum to the end of the data being sent, and then verifying that checksum at the receiving end.

XMIT, SRECV, and SBRK automatically open the IR/serial port using the current values of the first four *IOPAR* parameters (baud, parity, receive pacing, and transmit pacing) and the current IR/wire setting (set using IR/W in the I/O SETUP menu).

34

Using Plug-in Cards and Libraries



This chapter covers:

- The types of memory and plug-in cards.
- Installing and removing plug-in cards.
- Using RAM cards to expand user memory or to back up data.
- Using application cards and libraries.

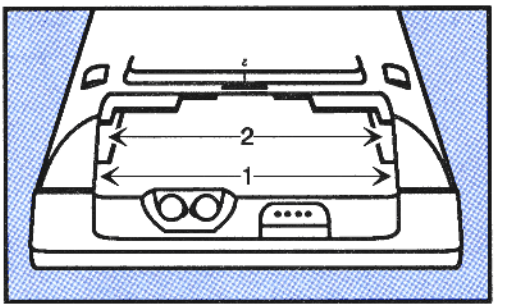
Types of Memory

Plug-in cards increase the amount of HP 48 memory. The HP 48 has two types of memory:

- *Read-only memory*, or ROM, is memory that cannot be altered. The HP 48 has 256K bytes of built-in ROM that contains its command set. You can expand the amount of ROM by installing plug-in application cards.
- *Random-access memory*, or RAM, is memory you can change. You can store data into RAM, modify its contents, and purge data. The HP 48 contains 32K bytes of built-in RAM. You can increase the amount of RAM by adding plug-in RAM cards.

Installing and Removing Plug-In Cards

The HP 48 has two *ports* for installing plug-in cards, designated port 1 and port 2. Port 1 is closest to the front of the calculator; port 2 is closest to the back. Cards can be installed in either port.



Caution

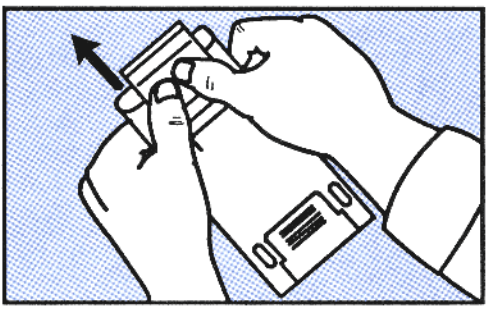
The calculator must be turned off while you are installing or removing plug-in cards. Otherwise, all of user memory could be erased.

Also, whenever a card is installed or removed, the HP 48 executes a system halt, causing the contents of the stack to be lost.

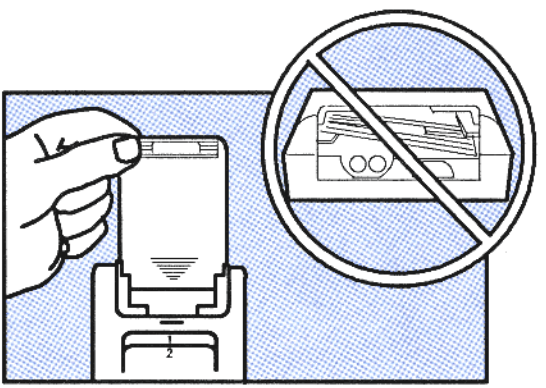
To install a plug-in card:

1. If you are installing a new RAM card, first install its battery (see "Installing the Battery in a New RAM Card," page 639) and set the write-protect switch to the desired position (see "Setting the Write-Protect Switch" on page 641).
2. Turn off the calculator. *Do not press* ON *until you've completed the installation procedures.*

3. Remove the port cover at the top of the calculator by pressing down against the grip area and then pushing in the direction shown. Removing the cover exposes the two plug-in ports.



4. Select an empty port for the card—either port may be used.
5. Position the plug-in card as shown. The triangular arrow on the card must point down, toward the calculator. Make sure the card is lined up properly with a port opening and not positioned half in one port and half in the other.



6. Slide the card firmly into the port until it stops. When you first feel resistance, the card has about $^1/_4$″ to go to be fully seated.
7. If desired, repeat steps 4 through 6 for another card.
8. Replace the port cover by sliding it on until the latch engages.

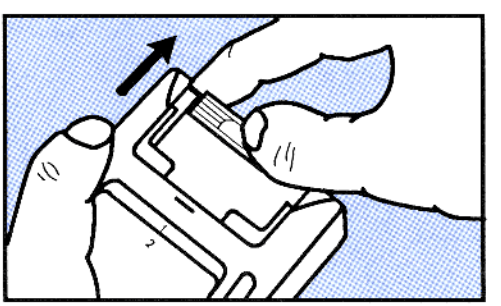
9. If the card is a RAM card, you must decide how you want to use it (see page 642):
   - If you want to use the RAM card to increase user memory, execute the MERGE command as described on page 643.
   - If you want to use the RAM card as independent memory, execute the MERGE command as described on page 643 and then the FREE command as described on page 649.

To remove a plug-in card:

Caution If the plug-in card you want to remove is a RAM card that contains merged memory, you must *free* the merged memory before removal. Failure to do so would probably result in loss of data stored in user memory. See "Freeing Merged Memory" on page 649 for instructions.

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1. Turn off the calculator. *Do not press* [ON] *until you've completed the removal process.*
2. Remove the port cover.
3. To remove a card, press against the grip as shown and slide the card out of the port.



4. Replace the port cover.

RAM Cards

RAM cards let you increase the amount of RAM in your HP 48. Each card contains a battery that preserves its contents when the calculator is off or when the card has been properly removed from the calculator.

RAM cards are good tools for:

- Expanding user memory.
- Backing up or hiding important data.
- Exchanging data between two HP 48 calculators.
- Storing prototype application programs that will eventually be made into ROMs.

"Uses for RAM Cards" on page 642 covers these tasks.

Preparing the Card for Installation

Installing the Battery in a New RAM Card. Before a new RAM card is installed, the battery that came with it must be installed in the card.

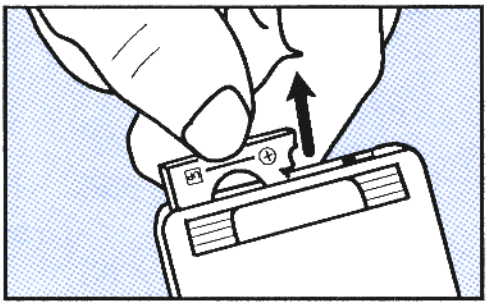


Caution

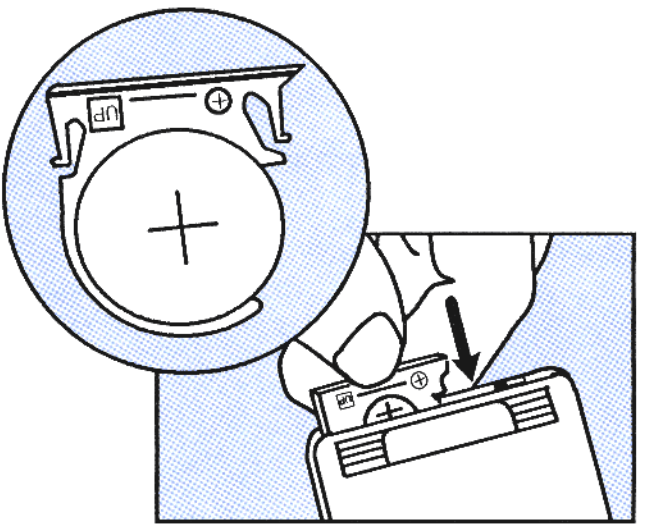
Do not use this procedure for *replacing* a battery in a RAM card—it could cause loss of memory in the RAM card. Appendix A contains instructions for replacing RAM card batteries on page 663.

To install the battery in a new RAM card:

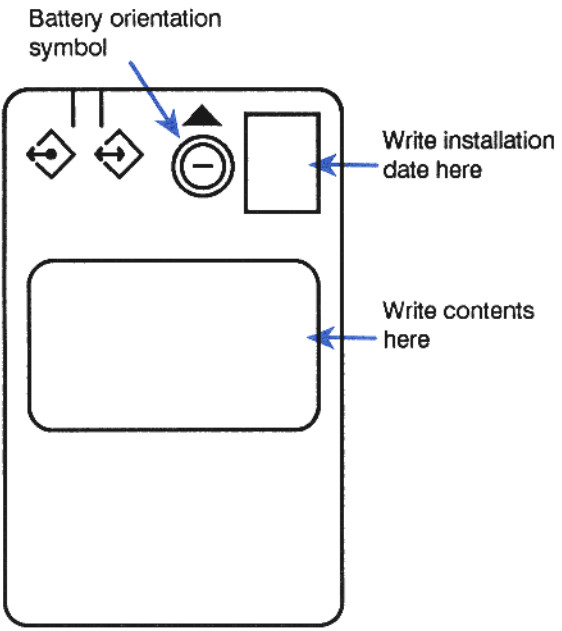
1. Remove the battery holder from the card by inserting a thumbnail or small screwdriver into the groove and pulling in the direction shown.



2. The grooved side of the battery holder is marked with the + symbol and the word UP. Insert the battery into the holder with its + side up, and then slide the holder into the card.



3. Write the date of installation on the card using a fine-point, permanent marker. The date is important for determining when to replace the battery.



4. Set an alarm in the calculator for 1 year from the date of installation to remind you to replace the battery. (Depending on the use, the battery should last between 1 and 3 years. When the battery needs replacing, a display message will appear *if the card is in the calculator.* You are setting this alarm in case the card is not in the calculator when the battery gets low.) Setting alarms is covered in chapter 24, and replacing RAM-card batteries is covered in appendix A.

Setting the Write-Protect Switch. The write-protect switch lets you protect the contents of the RAM card from being accidentally overwritten or erased. The switch has two positions:

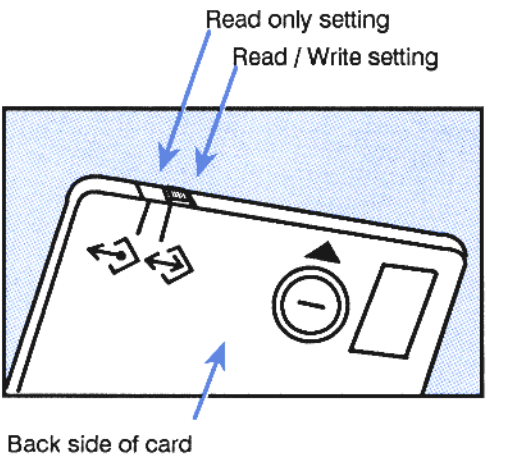
- Read-only. The contents of the RAM card can be read, but cannot be changed or erased.
- Read/write. You can write information to the RAM card and erase its contents.

Caution

To avoid loss of user memory:

- Always turn off the calculator before changing the write-protect switch on an installed card.
- Do not write protect a RAM card containing merged memory; the memory should be freed first (see page 649).

You can operate the write-protect switch while the card is installed; however, the switch labels are not visible.



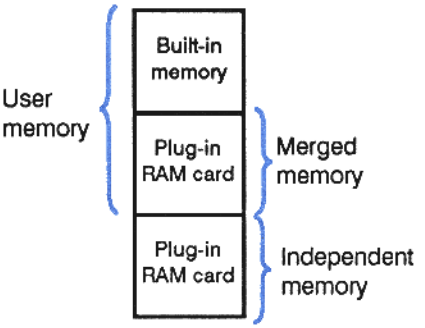
Uses for RAM Cards

A RAM card can be used in one of two ways:

- It can be *merged* with built-in memory. This enables you to expand the amount of user memory available (up to 288K bytes) for creating variables and directories, putting objects on the stack, etc.
- It can provide a place *independent* of user memory in which to back up important data. You can copy individual objects or entire directories to a RAM card in much the same way as you would back up computer files to a disk. After you've copied the data, you can remove the card and store it in a safe place, or, as a way of transferring data, install the card in another HP 48.

You can install one or two RAM cards, and you can use either or both of them for either purpose. However, you cannot use a single card for both merged and independent memory at the same time.

The following diagram illustrates a system containing two RAM cards — one containing merged memory and the other containing independent memory.

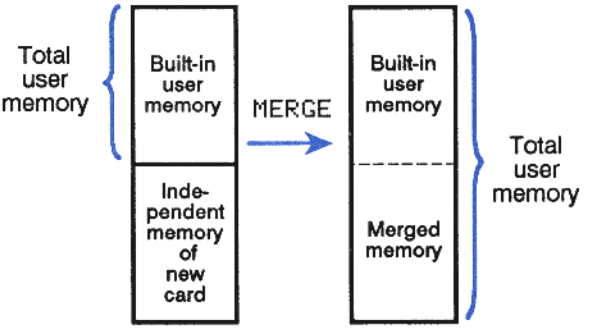


Using RAM Cards to Expand User Memory (Merged Memory)

Before you can use an installed RAM card to expand user memory, you must execute the MERGE command to *merge* its memory with built-in memory.

Before you execute the MERGE command, the write-protect switch on the RAM card must be in the read/write position. (See page 641 for how to set the write-protect switch.)

MERGE takes a port number as its argument. For example, the keystrokes 1 ← MEMORY NXT NXT MERG merge the plug-in memory installed in port 1 with built-in memory.



When you merge a RAM card that contains backup objects, those objects are moved to a special port, called port 0. (See page 647 for a description of port 0.)

Caution

You should never remove a RAM card that contains merged memory. Doing so will cause loss of data stored in user memory. Before you can remove the RAM card, you must *free* the merged memory. (See "Freeing Merged Memory" on page 649 for instructions.) If you accidentally remove a card with merged memory and see the message `Replace RAM, Press ON`, you can minimize memory loss by *leaving the calculator on*, reinserting the card in the same port, and then pressing ON.

Using RAM Cards for Backup (Independent Memory)

The HP 48 uses a special object type, the *backup object*, to store backed-up data. A backup object contains another object, its name, and its checksum. Simply put, a backup object contains a variable or directory and its checksum.

An independent-memory RAM card that contains the backup objects can be removed from the HP 48 and either stored for later use or transferred to another HP 48.

Backing Up Objects into Independent Memory

Backup objects can exist:

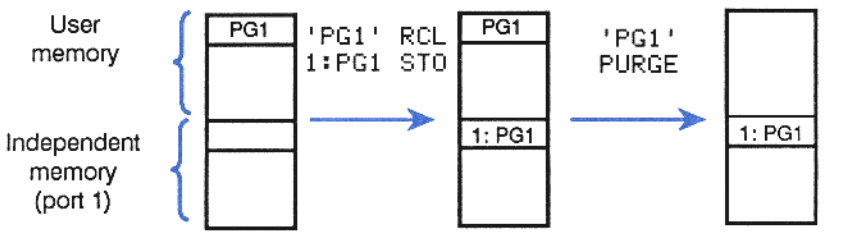
- In independent memory (port 1 and/or port 2).
- In a portion of user memory called port 0 (see page 647).

To create a backup object, execute the STO command with two arguments—the object to be backed up in level 2, and a *backup identifier* in level 1. A backup identifier has this form:

:port#:name

where *port#* is the port number (0, 1, or 2) and *name* is the name under which the backup copy will be stored.

Example: Backing Up a Program. To back up a program named *PG1* into independent memory in port 1, recall the program to the stack by evaluating the sequence `'PG1' RCL`, and then store the object as a backup object in port 1 by evaluating `:1:PG1 STO`.



The backup object in the previous example happens to have the same name as the original object, but the two names could be different.

Note that a directory and its subdirectories can be backed up in a single backup object.

Example: Backing Up a Directory and Its Subdirectories. Suppose your *HOME* directory contains a subdirectory named *CHEM*, which in turn contains several subdirectories. To back up the entire directory structure of *CHEM* in a backup object named *BCHEM*, recall the directory to the stack by evaluating the sequence `'CHEM' RCL`, and then store it in the backup object by evaluating `:1:BCHEM STO`.

Accessing Backup Objects

You can recall, evaluate, and purge the contents of backup objects. You can also obtain a listing of all the backup objects in a given port.

Recalling Backup Objects. The LIBRARY menu can be used to recall the contents of backup objects. Pressing ◀ LIBRARY followed by `PORT0`, `PORT1`, or `PORT2` displays a menu of backup objects and libraries in that port. To recall the contents of a backup object to the stack, simply press ▶ and then the menu key for the desired backup object.

The RCL command can also be used to recall the contents of a backup object to the stack. For example, evaluating the sequence `:1:BPG1 RCL` recalls the object stored in 1:*BPG1*.

Evaluating Backup Objects. To use the LIBRARY menu to evaluate the contents of a backup object, press ◀ LIBRARY followed by `PORT0`, `PORT1`, or `PORT2`. Then, simply press the menu key for the desired backup object.

Also, when the argument of EVAL is a backup name, the contents of the backup object is evaluated. For example, executing the sequence `:1:BPG1 EVAL` evaluates the program stored in backup object 1:*BPG1*. (EVAL also takes a list of backup objects as its argument to evaluate more than one at a time.)

Purging Backup Objects. To purge a backup object, use the backup name as the argument of PURGE. For example, executing the sequence `:1:BPG1 PURGE` purges the backup object. (PURGE can take a list of backup objects as its argument to purge more than one at a time.)

Using Wildcards to RCL, EVAL, and PURGE. The character & can be used as a wildcard to replace the port number in the arguments used by RCL, EVAL, and PURGE. (& is the left-shifted alpha key above ENTER.) When the HP 48 encounters the wildcard with these commands, it searches port 2, 1, 0, and then main memory for the accompanying backup object (the first occurrence of the name is used). For example, evaluating the sequence `:&:BPG1 PURGE` causes the HP 48 to search port 2, 1, 0, and then main memory for the first occurrence of *BPG1* and then delete it.

Listing Backup Objects. The PVARS command (↰ MEMORY NXT `PVARS`) can be used to display a list of objects in the specified port. It takes as its argument a port number 0, 1, or 2. It returns to level 1 the type of memory contained in the port (`"ROM"`, `"SYSRAM"`, or a number representing the amount of free independent RAM); and to level 2 it returns a list of backup objects and library identification numbers (both tagged with the port number).

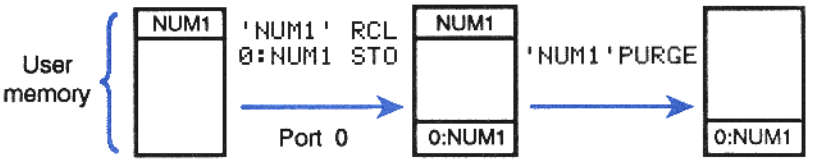
Also, you can use the LIBRARY menu to display a menu of backup objects and libraries in a given port. Simply press ↰ LIBRARY followed by `PORT0`, `PORT1`, or `PORT2` to see the desired menu.

Backing Up Objects into User Memory (Port 0)

The HP 48 lets you create backup objects in user memory. The portion of user memory used for backup objects and libraries is called "port 0." There are several reasons you might want to back up data into user memory:

- You want to "hide" data; that is, you want certain data to be in user memory, but you don't want the variable(s) to appear in *any* directory.
- You want to "free" a RAM card being used for merged memory, and instead use it for independent memory. (See "Freeing Merged Memory" on page 649).

You create a backup object in user memory the same way you create other backup objects, except you specify port 0 as the port number.



The size of port 0 is dynamic—it grows and shrinks to accommodate its contents.

Backing Up All of Memory

The ARCHIVE command ([◀] MEMORY NXT NXT ARCHI) creates a backup object named *:port#:name* in independent memory containing a copy of:

- The entire *HOME* directory.
- User key assignments.
- The alarm catalog.

It takes a name tagged by a port number (0, 1, or 2) as its argument. For example, executing the sequence `:2:JUN12 ARCHIVE` creates backup object `:2:JUN12`.

The RESTORE command ([◀] MEMORY NXT NXT RESTO) retrieves the data backed up by the ARCHIVE command. It, too, takes a name (where the corresponding object is a directory) tagged by a port number as its argument. For example, executing the sequence `:2:JUN12 RESTORE` retrieves the *HOME* directory backed up above.



Caution

Executing RESTORE *overwrites* the entire contents of user memory with the contents of the backup object.

If you want your flag settings to be saved when you back up all of memory, recall them to the stack (using RCLF) and store them in a variable before executing ARCHIVE. After you RESTORE memory, you can reactivate the flag settings by recalling the contents of that variable to the stack and executing STOF (store flags).

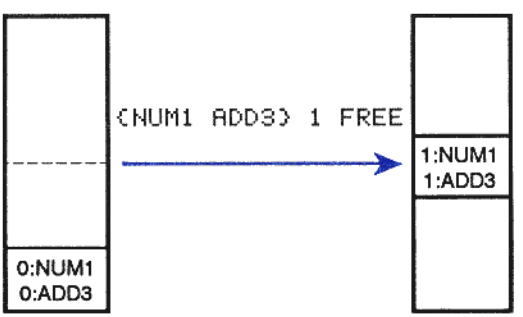
Freeing Merged Memory

Freeing merged memory converts it to independent memory. Merged memory must be freed if:

- You want to remove the RAM card from its port.
- You want to use the RAM card as independent memory, rather than user memory.

The FREE command (◀ MEMORY NXT NXT FREE) frees the merged memory in a specified port. It takes two arguments — a list in level 2, and the port number in level 1.

The list can be empty, in which case the merged memory is simply freed, or it can contain one or more names or library identifiers. If the list is not empty, FREE moves the named backup objects and libraries from port 0 into the newly-freed card. For example, executing the sequence `{ NUM1 ADD3 } 1 FREE` frees the merged memory in port 1 and makes it independent memory. At the same time, the backup objects *NUM1* and *ADD3* in port 0 are moved to port 1.



To free merged memory, first execute MEM to determine the amount of available memory (press ↰ MEMORY MEM). If the amount of available memory is greater than or equal to the amount of memory on the card you are going to free, you are ready to execute the FREE command.

If MEM returns a value less than the amount of memory on the card, executing FREE without any preparation would return an error, since your stored data would not fit into the amount of user memory remaining after the merged memory was freed. To avoid an error, you can do any of the following:

- Purge unneeded variables from user memory.
- Back up data into another RAM card installed in the other port and then purge the original variables.
- Back up data into port 0 (built-in memory) and then use the level-2 argument of the FREE command to move that data into the freed memory. Here's a step-wise procedure for doing this:
  1. Determine the amount of data that must be moved into the memory that you'll be freeing. For example, if you'll be removing a 128K RAM card, and the amount of user memory available is 126K, you must move at least 2K of variables.
  2. Back up the variable in port 0. For example, to back up *CALC1* into port 0, recall its contents to the stack and execute `:0:CALC1 STO`.
  3. Purge the variable from user memory (for example, `'CALC' PURGE`).
  4. If necessary, back up and purge additional variables and directories.
  5. When you've backed up enough data, you are ready to execute the FREE command. The level-2 argument must be a list containing the names of the variables and directories you've backed up into port 0.

Using Application Cards and Libraries

A *library* is an object that contains named objects that can act as an extension to the built-in command set. You cannot view or change the contents of a library. Libraries can exist in application cards, or they may be copied into RAM. However, libraries cannot be created by the HP 48.

Libraries are identified by:

- A *library identifier*, which has the form :*port#*:*library#*. The *library#* (*library number*) is a unique number associated with the library. The library identifier is used as the argument of commands that work with library objects.
- The *library name*, which is a sequence of characters. The library name appears in the LIBRARY menu when the library is attached to a directory on the current path.

Attaching a Library to a Directory

To use a library, it must be *attached* to a directory in user memory. The attachment may happen automatically when you install an application card, or you may have to do it yourself. Consult the owner's documentation accompanying your application card (or RAM-based library) for information about attaching the library.

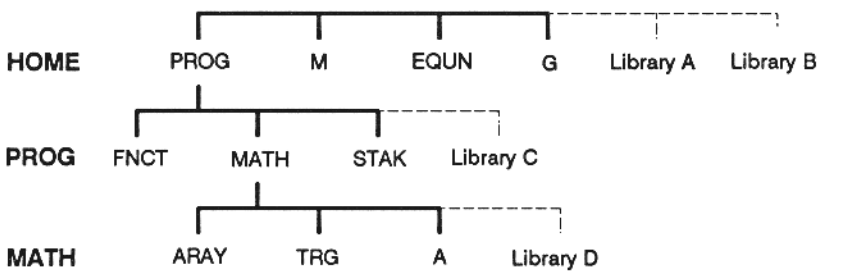
If the library is not attached automatically, you must use the ATTACH command (↰ MEMORY NXT ATTAC) to attach it. ATTACH requires a library number as its argument.

This is no limit on the number of libraries that can be attached to the HOME directory. Only one library at a time can be attached to a particular subdirectory.

Accessing Library Operations (The LIBRARY Menu)

The LIBRARY Menu. Pressing ◀ LIBRARY displays the LIBRARY menu, which contains the names of the libraries on the current directory path. To display a menu of the operations in a library, press the appropriate key. For example, if you have the HP Solve Equation Library installed in your calculator, pressing ◀ LIBRARY EQLIB displays a menu of all the operations in that library.

Accessing Libraries Attached to Subdirectories. The rules for accessing libraries attached to various subdirectories are the same as the rules for accessing variables in those directories. For example, suppose your HP 48 has the following directory structure and attached libraries:



When *HOME* is the current directory, pressing ◀ LIBRARY displays the menu of its attached libraries— A B. When PROG is the current directory, pressing ◀ LIBRARY displays a menu of its attached library, C, as well as the other libraries on the current path, A and B.

Like variables, library operations can be accessed if the library is attached to the current directory or to a directory in the current path. For example, since libraries A and B are attached to *HOME*, their operations can be accessed from any directory. You can access the operations in library C when PROG or MATH are the current directory. However, you cannot access the operations in library D when PROG is the current directory.

Additional Commands That Access Libraries

Library Commands

Keys	Programmable Command	Description
[STO]	STO	Stores a library object from level 2 into independent memory in the port specified in level 1.
[→][RCL]	RCL	Takes a library identifier (:*port#*:*library#*) as its argument and recalls the specified library to the stack.
[←][PURGE]	PURGE	Takes a library identifier (:*port#*:*library#*) as its argument and purges the specified RAM-based library.
[←][MEMORY] (page 2):		
PVARS	PVARS	Takes a port number as its argument and displays a list of the backup identifiers and library identifiers in the specified port.
LIBS	LIBS	Displays a list containing the names, library number, and port number of all the libraries attached to the current directory.
ATTAC	ATTACH	Takes a library number as its argument and attaches the specified library to the current directory.
DETAC	DETACH	Takes a library number as its argument and detaches the specified library from the current directory.

Appendixes and Indexes

A

Support, Batteries, and Service

Calculator Support

You can obtain answers to questions about using your calculator from our Calculator Support department. Our experience has shown that many customers have similar questions about our products, so we have provided the following section, "Answers to Common Questions." If you don't find the answer to your question there, contact us at the address or phone number on the inside back cover.

Answers to Common Questions

Q: *The calculator doesn't turn on when I press* [ON]. *What's wrong?*

A: There may be a simple problem that you can solve immediately, or the calculator may require service. See "Testing Calculator Operation" on page 665.

Q: *I'm not sure whether the calculator is malfunctioning or if I'm doing something incorrectly. How can I verify that the calculator is operating properly?*

A: Refer to "Testing Calculator Operation" on page 665 in this appendix.

Q: *The* (•)) *annunciator stays on even when the calculator is turned off. Is anything wrong?*

A: This indicates a low-battery condition in the calculator or a RAM card, or an alarm that is past due. To determine what is causing the (•)) annunciator to stay on, turn the calculator off and then on. A message in the display will identify the problem. Refer to "Changing Batteries" in this appendix (page 661) or to "Setting Alarms" in chapter 24 (page 443).

Q: *How can I determine how much memory is left in the calculator?*

A: Press ↰ MEMORY MEM. The number of bytes of available memory will appear at the lower right corner of the display. An empty memory should show approximately 30000 (bytes of internal RAM).

Q: *How do I clear everything from the calculator's memory?*

A: Perform the following steps:

1. Press and hold ON.
2. Simultaneously press and release *both of the outer keys* in the top row (the menu keys with A and F next to them).
3. Release ON.

The calculator will beep and the Try To Recover Memory? prompt will be displayed. Press NO to clear user memory; the Memory Clear message will appear in the display.



Note

This procedure will not clear the contents of a plug-in RAM card unless that RAM is merged with the calculator's main memory.

Q: *How do I change the number of decimal places the HP 48 displays?*

A: Perform the following steps:

1. Go to page 1 of the MODES menu: press ↰ MODES.
2. Press the number of decimal places you want (0 — 11).
3. Press the menu key for the display format you desire (FIX, SCI, or ENG).

Refer to "Display Modes" in chapter 2 (page 57).

Q: *My numbers contain commas as decimal points. How do I restore periods?*

A: Perform the following steps:

1. Go to page 4 of the MODES menu (press ◀ MODES NXT NXT NXT).
2. Press the FM,■ radix toggle menu key. (The ■ should disappear from the menu key.)

Q: *What does an "E" in a number (for example, 2.51E−13) mean?*

A: Exponent of 10 (for example, 2.51×10^{-13}). Refer to "Display Modes" (page 57) in chapter 2.

Q: *When I take the sine of π in Degrees mode, why do I get* `'SIN(π)'` *instead of a number?*

A: The calculator is in Symbolic Result mode; `'SIN(π)'` is the symbolic answer. Press ▶ →NUM to convert `'SIN(π)'` to its numerical equivalent of .0548... up to 11 decimal places. You can also press SYM■ on page 1 of the MODES menu to change to Numerical Results mode and prevent symbolic evaluation.

Q: *What does "object" mean?*

A: "Object" is the general term for all elements of data the HP 48 works with. Numbers, expressions, arrays, programs, and so on, are all types of objects. Refer to chapter 4, "Objects," for a description of the object types accepted by the calculator.

Q: *What do three dots (...) mean at either end of a display line?*

A: The three dots (called an *ellipsis*) indicate that the displayed object is too long to display on one line. To view undisplayed portions of the object, use the ◀ or ▶ cursor keys.

Q: *The calculator beeps and displays* `Bad Argument Type`. *What's wrong?*

A: The objects on the stack aren't the correct type for the command you are attempting. For example, executing →UNIT (in page 2 of the PRG OBJ menu) with a number in stack levels 1 and 2 causes this error.

Q: *The calculator beeps and displays* `Too Few Arguments`. *What's wrong?*

A: There are fewer arguments on the stack than required by the command you are attempting. For example, executing + with only one argument or number on the stack causes this error.

Q: *The calculator beeps and displays a message different from the two listed above. How do I find out what's wrong?*

A: Refer to "Messages" in appendix B.

Q: *I can't find some variables that I used earlier. Where did they go?*

A: You may have been using the variables in a different directory. If you can't remember which directory you were using, you'll need to check all the directories in your calculator.

Q: *Sometimes my HP 48 seems to pause for a few seconds during a calculation. Is anything wrong?*

A: Nothing is wrong. The calculator does some system cleanup from time to time to eliminate temporary objects created from normal operation. This cleanup process frees memory for current operations.

Q: *During normal operation, the printer prints several lines quickly, then slows down. Why?*

A: The calculator quickly transmits a certain amount of data to the printer, then slows its transmission rate to ensure that the printer can keep up.

Q: *How can I increase the printing speed of my HP 82240B Infrared Thermal Printer?*

A: Use an agc adapter with your HP 82240B printer so that the printer can print faster. Also, set the calculator delay to match the print speed (see "Setting the Delay" on page 607).

Environmental Limits

Calculator. To maintain product reliability, avoid getting the calculator wet and observe the following temperature and humidity limits:

- Operating temperature: 0° to 45°C (32° to 113°F).
- Storage temperature: −20° to 65°C (−4° to 149°F).
- Operating and storage humidity: 90% relative humidity at 40°C (104°F) maximum.

Plug-In Cards. The environmental limits for Hewlett Packard plug-in cards are:

- Operating temperature: 0° to 45°C (32° to 113°F).
- Storage temperature: −20° to 60°C (−4° to 140°F).
- Storage temperature for RAM card data retention: 0° to 60°C (32° to 140°F).
- Operating and storage humidity: 90% relative humidity at 40°C (104°F) maximum.

When to Replace Batteries

When a low-battery condition exists, the (•)) annunciator remains on, even when the calculator is turned off. When the calculator is turned on during a low-battery condition, `Warning: LowBat( )` is displayed for approximately 3 seconds. `LowBat(P1)` refers to port 1, `LowBat(P2)` refers to port 2, and `LowBat(S)` refers to the calculator (system) batteries.

Replace the RAM card battery or the calculator batteries as soon as possible after the (•)) low-battery annunciator and warning message appear. If you continue to use the calculator while the (•)) annunciator is on, the display will eventually dim and you may lose calculator and RAM card data.

Under typical use, a RAM card's battery should last between 1 and 3 years. Be sure to mark the card with the battery-installation date, and, in case the RAM card is not in the calculator when the battery needs replacement, set an alarm for 1 year from that date to remind you to install a fresh battery. RAM cards do not come with a battery installed.

Changing Batteries

Battery Types

Calculator Batteries. Any brand of size AAA batteries. *Be sure that all three batteries are of the same brand and type.*

The use of rechargeable batteries is not recommended because of their lower capacity.

Plug-In RAM Card Batteries. 3-Volt 2016 coin cell.

Changing Calculator Batteries

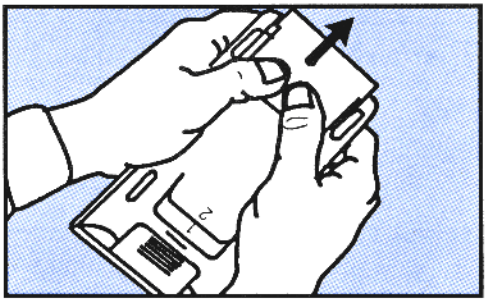
These instructions are for changing *calculator* batteries. The instructions for replacing RAM card batteries start on page 663.



Caution Whenever you remove batteries from the calculator, be sure the calculator is off and *do not press the* [ON] *key until the new batteries are installed.* If you press [ON] when batteries are not in the calculator, you may lose all of calculator memory.

1. Turn the calculator off. You may lose memory in the calculator and plug-in RAM cards if the calculator batteries are removed when the calculator is on.

2. Have three, fresh batteries (of the same brand and type) at hand. Wipe off both ends of each battery with a clean, dry cloth.
3. Remove the calculator battery-compartment door by pressing down and sliding it off away from the calculator. Be careful not to press the calculator's [ON] key. Refer to the following illustration:



4. Turn the calculator over and shake the batteries out. Once the batteries are out, you should replace them with fresh batteries within 2 minutes to protect against memory loss.



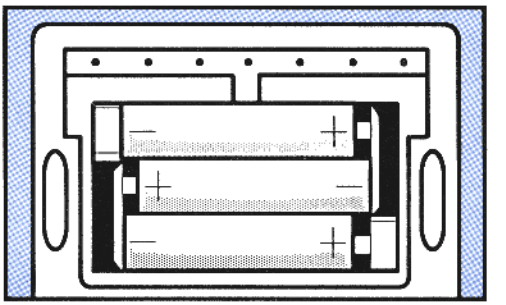
Warning

Do not mutilate, puncture, or dispose of batteries in fire. The batteries can burst or explode, releasing hazardous chemicals. Discard used batteries according to the manufacturer's instructions.

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5. *Avoid touching the battery terminals*. Batteries are easier to install if the negative (plain) ends are inserted first, and if the center battery is installed last.

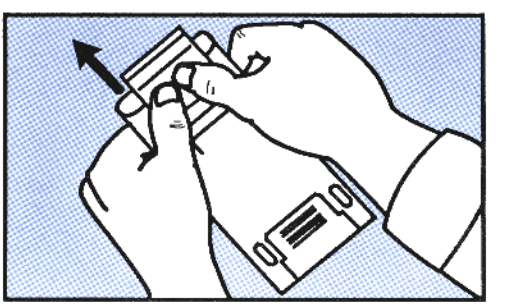
   Position the batteries according to the outlines in the bottom of the battery compartment. Refer to the following illustration:



6. Replace the battery-compartment door by sliding the tabs on the door into the slots in the calculator case.
7. Press [ON] to turn the calculator on.

Changing a RAM Card Battery

1. Turn the calculator over and remove the plastic cover over the plug-in card ports (on the display-end of the calculator).



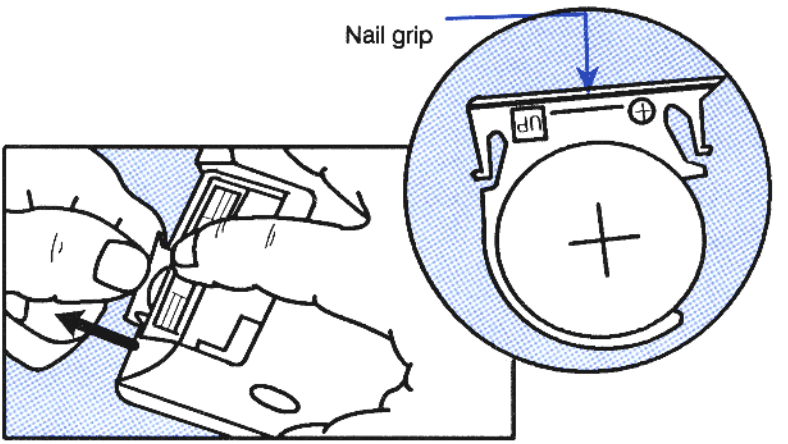
2. With the RAM card in port 1 or 2, turn the calculator on.



Caution Since RAM cards run off the calculator batteries when the calculator is [ON], you should replace a card's battery only when the card is in the calculator and the calculator is turned on. RAM memory may be lost if you remove a RAM card battery when the calculator is off, or when the card is not installed in the calculator.

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3. Place your index finger in the recess near the exposed end of the RAM card—this prevents removal of the card from the calculator when you remove the card's battery holder. Now insert the thumbnail of your free hand into the nail grip in the black plastic at the left side of the end of the card and pull the battery holder out of the card.



4. Remove the old battery from the plastic battery holder.



Warning

Do not mutilate, puncture, or dispose of batteries in fire. The batteries can burst or explode, releasing hazardous chemicals. Discard used batteries according to the manufacturer's instructions.

5. Install a fresh, 3-Volt 2016 coin cell in the plastic battery holder and reinsert the battery holder (with battery) into the RAM card. *Be sure to install the battery with the side marked "+" toward the front of the card.*
6. Mark the card with the battery-installation date, and, in case the RAM card is not in the calculator when its battery needs replacing, set an alarm for 1 year from that date to remind you to change it.
7. Replace the plug-in port cover.

Testing Calculator Operation

Use the following guidelines to determine whether the calculator is functioning properly. Test the calculator after every step to see if operation has been restored. If your calculator requires service, refer to page 674.

The calculator won't turn on or doesn't respond when you press the keys.

1. Make sure that three fresh batteries are correctly installed in the calculator.
2. If the display is blank, press and hold [ON]; press and release [+] several times until characters become visible; then release [ON]. If no characters appear in the display, the calculator requires service.
3. If a halted program won't respond when you press [ATTN], try pressing [ATTN] again.

4. If the keyboard is "locked," perform a system halt as follows:
   a. Press and hold [ON].
   b. Press and release the third key from the left in the top row (the menu key with C next to it).
   c. Release [ON].

   The empty stack display should appear.
5. If the display appears garbled, perform a memory reset as follows:
   a. Press and hold [ON].
   b. Press and hold both of the outer keys in the top row (the menu keys with A and F next to them).
   c. Release all three keys.

   The calculator will beep and display the message `Try To Recover Memory?` at the top of the display. Press `YES` to recover as much memory as possible.

If these steps fail to restore operation, the calculator requires service.

The calculator responds to keystrokes, but you suspect it's malfunctioning.

1. Run the self-test described in the next section. If the calculator fails the self-test, it requires service.
2. If the calculator passes the self-test, you may have made a mistake operating the calculator. Reread appropriate portions of the manual and check "Answers to Common Questions" (page 656).
3. Contact the Calculator Support department. The address and phone number are listed on the inside back cover.

Self-Test

If the display turns on, but the calculator does not seem to be operating properly, run the diagnostic self-test :

1. Press and hold [ON].
2. Press and release the second key from the right in the top row (the menu key with E next to it).
3. Release [ON].

   The diagnostic self-test tests the internal ROM and RAM, and generates various patterns in the display. The test repeats continuously until it is halted.
4. To halt the self-test, perform a system halt as follows:
   a. Press and hold [ON].
   b. Press and release the third key from the left in the top row (the menu key with C next to it).
   c. Release [ON].

   The empty stack display should appear.

The diagnostic self-test should be successfully completed before running any of the tests described in the following sections.

If the self-test indicates an internal ROM or RAM failure (if `IROM OK` and `IRAM OK` are not displayed), the calculator requires service.

Keyboard Test

This test checks all of the calculator's keys for proper operation.

To run the interactive keyboard test:

1. Press and hold [ON].
2. Press and release the third key from the right in the top row (the menu key with D next to it).
3. Release [ON].

4. Press and release the second key from the right in the top row (the menu key with E next to it). KBD1 will appear in the upper left corner of the display.
5. Starting at the upper left corner and moving left to right, press each of the 49 keys on the keyboard. If you press the keys in the proper order and they are functioning properly, the calculator emits a high-pitch beep at each press of a key. When the 49th key ([+]) has been pressed, the displayed message should change to KBD1 OK.

   If you press a key out of sequence, a five-digit hexadecimal number will appear next to KBD1. Reset the keyboard test (do steps 1 through 3 above), and rerun the test.

   If a key isn't functioning properly, the next keystroke displays the hex location of the expected and the received location. If you pressed the keys in order and got this message, the calculator requires service. Be sure to include a copy of the error message when you ship the calculator for service.
6. To exit the keyboard test, perform a system halt as follows:
   a. Press and hold [ON].
   b. Press and release the third key from the left in the top row (the menu key with C next to it).
   c. Release [ON].

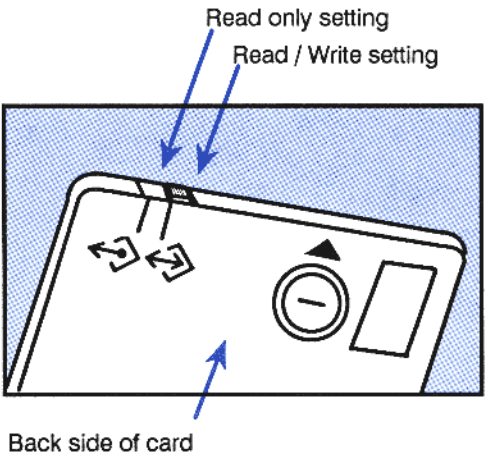
   The empty stack display should appear.

Port RAM Test

The port RAM test non-destructively tests the ports and the installed plug-in RAM cards. (Plug-in RAM-card memory is preserved.)

To run the port RAM test:

1. Check that a plug-in RAM card is properly installed in port 1 and/or port 2.
2. Verify that the switch on each card is set to the "read/write" position:



3. Turn the calculator on.
4. Press and hold [ON].
5. Press and release the fourth key from the left in the top row (the menu key with D next to it).
6. Release [ON].

   A vertical line will appear at both sides and at the center of the display.

7. Press and release [▲].

   RAM1 and/or RAM2 will appear at the top left corner of the display and the size of the corresponding plug-in RAM card (32K or 128K) will appear at the top right corner of the display. OK will appear to the right of RAM1 and/or RAM2 when the port RAM test has been successfully completed. A failure message (for example, RAM1 00002) will be displayed for each port that does not contain a plug-in RAM card or if a card's read/write switch is in the "write-protect" position. This message should be ignored.

   If OK does not appear for a RAM card set to read/write, the card should be moved to the other port and the test rerun. IF OK still doesn't appear, the RAM card should be replaced with a new one.

8. To return to normal calculator operation, perform a system halt as follows:

   a. Press and hold [ON].

   b. Press and release the third key from the left in the top row (the menu key with C next to it).

   c. Release [ON].

   The empty stack display should appear.

IR Loop-Back Test

This test checks the operation of the send and receive infrared sensors and their associated circuits.

To run the IR Loop-Back test:

1. Press and hold [ON].
2. Press and release the fourth key from the left in the top row (the menu key with D next to it).
3. Release [ON]; a vertical line will appear at both sides, and at the center of the display.
4. Be sure that the plastic plug-in card cover is in place and that it covers the clear lamp bulbs in the top end of the calculator.

5. Press [EVAL].

   IRLB will appear at the top left corner of the display.

   OK will appear to the right of IRLB if the calculator passes this test.

   If OK does not appear, the calculator requires service.

6. To return to normal calculator operation, perform a system halt as follows:
   a. Press and hold [ON].
   b. Press and release the third key from the left in the top row (the menu key with C next to it).
   c. Release [ON].

   The empty stack display should appear.

Serial Loop-Back Test

This test checks the operation of the send and receive circuits of the serial interface at the top of the calculator.

To run the Serial Loop-Back test:

1. Press and hold [ON].
2. Press and release the fourth key from the left in the top row (the menu key with D next to it).
3. Release [ON]; a vertical line will appear at both sides, and at the center of the display.
4. Temporarily connect (short) the middle two pins (pins 2 and 3) of the 4-pin serial connector at the top end of the calculator. Be careful not to bend or severely jar the pins.

5. Press [PRG].

   U_LB will appear at the top left corner of the display.

   OK will appear to the right of U_LB if the calculator passes this test.

   If OK does not appear, the calculator requires service.



Note

If you inadvertently short pins 1 and 2 or pins 3 and 4 of the serial connector, the loop-back test will return U_LB 00001 or U_LB 00002 (test-failed message), but you will not damage the calculator.

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6. To return to normal calculator operation, perform a system halt as follows:
   a. Press and hold [ON].
   b. Press and release the third key from the left in the top row (the menu key with C next to it).
   c. Release [ON].

   The empty stack display should appear.

Limited One-Year Warranty

What Is Covered. *The calculator* (except for the batteries, or damage caused by the batteries) *and calculator accessories are warranted by Hewlett-Packard against defects in materials and workmanship for one year from the date of original purchase.* If you sell your unit or give it as a gift, the warranty is automatically transferred to the new owner and remains in effect for the original one-year period. During the warranty period, we will repair or, at our option, replace at no charge a product that proves to be defective, provided you return the product, shipping prepaid, to a Hewlett-Packard service center. (Replacement may be made with a newer model of equal or better functionality.)

This warranty gives you specific legal rights, and you may also have other rights that vary from state to state, province to province, or country to country.

What Is Not Covered. *Batteries, and damage caused by the batteries, are not covered by the Hewlett-Packard warranty. Check with the battery manufacturer about battery and battery leakage warranties.*

This warranty does not apply if the product has been damaged by accident or misuse or as the result of service or modification by other than an authorized Hewlett-Packard service center.

No other express warranty is given. The repair or replacement of a product is your exclusive remedy. **ANY OTHER IMPLIED WARRANTY OF MERCHANTABILITY OR FITNESS IS LIMITED TO THE ONE-YEAR DURATION OF THIS WRITTEN WARRANTY.** Some states, provinces, or countries do not allow limitations on how long an implied warranty lasts, so the above limitation may not apply to you. **IN NO EVENT SHALL HEWLETT-PACKARD COMPANY BE LIABLE FOR CONSEQUENTIAL DAMAGES.** Some states, provinces, or countries do not allow the exclusion or limitation of incidental or consequential damages, so the above limitation or exclusion may not apply to you.

Products are sold on the basis of specifications applicable at the time of manufacture. Hewlett-Packard shall have no obligation to modify or update products, once sold.

Consumer Transactions in the United Kingdom. This warranty shall not apply to consumer transactions and shall not affect the statutory rights of a consumer. In relation to such transactions, the rights and obligations of Seller and Buyer shall be determined by statute.

If the Calculator Requires Service



Note

If the contents of your calculator's memory are important, you should back up the memory on a plug-in RAM card, another HP 48, or a computer before sending in the calculator for repair.

Hewlett-Packard maintains service centers in many countries. These centers will repair a calculator, or replace it with the same model or one of equal or better functionality, whether it is under warranty or not. There is a service charge for service after the warranty period. Calculators normally are serviced and reshipped within 5 working days.

- **In the United States:** Send the calculator to the Corvallis Service Center listed on the inside of the back cover.
- **In Europe:** Contact your Hewlett-Packard sales office or dealer, or Hewlett-Packard's European headquarters (address below) for the location of the nearest service center. *Do not ship the calculator for service without first contacting a Hewlett-Packard office.*

  Hewlett-Packard S.A.
  150, Route du Nant-d'Avril
  P.O. Box CH 1217 Meyrin 2
  Geneva, Switzerland
  Telephone: 022 780.81.11

- **In other countries:** Contact your Hewlett-Packard sales office or dealer or write to the Corvallis Service Center (listed on the inside of the back cover) for the location of other service centers. If local service is unavailable, you can ship the calculator to the Corvallis Service Center for repair.

All shipping, reimportation arrangements, and customs costs are your responsibility.

Service Charge. Contact the Corvallis Service Center (inside back cover) for the standard out-of-warranty repair charges. This charge is subject to the customer's local sales or value-added tax wherever applicable.

Calculator products damaged by accident or misuse are not covered by the fixed charges. These charges are individually determined based on time and material.

Shipping Instructions. If your calculator requires service, ship it to the nearest authorized service center or collection point.

- Include your return address and a description of the problem.
- Include proof of purchase date if the warranty has not expired.
- Include a purchase order, check, or credit card number plus expiration date (VISA or MasterCard) to cover the standard repair charge.
- Ship your calculator postage *prepaid* in adequate protective packaging to prevent damage. Shipping damage is not covered by the warranty, so we recommend that you insure the shipment.

Warranty on Service. Service is warranted against defects in materials and workmanship for 90 days from the date of service.

Service Agreements. In the U.S., a support agreement is available for repair and service. For additional information, contact the Corvallis Service Center (see the inside of the back cover).

Regulatory Information

U.S.A. The HP 48 generates and uses radio frequency energy and may interfere with radio and television reception. The calculator complies with the limits for a Class B computing device as specified in Subpart J of Part 15 of FCC Rules, which provide reasonable protection against such interference in a residential installation. In the unlikely event that there is interference to radio or television reception (which can be determined by turning the HP 48 off and on or by removing the batteries), try the following:

- Reorienting the receiving antenna.
- Relocating the calculator with respect to the receiver.

For more information, consult your dealer, an experienced radio/television technician, or the following booklet, prepared by the Federal Communications Commission: *How to Identify and Resolve Radio-TV Interference Problems*. This booklet is available from the U.S. Government Printing Office, Washington, D.C. 20402, Stock Number 004-000-00345-4. At the first printing of this manual, the telephone number was (202) 783-3238.

West Germany. This is to certify that this equipment is in accordance with the Radio Interference Requirements of Directive FTZ 1046/84. The German Bundespost was notified that this equipment was put into circulation, the right to check the serie for compliance with the requirements was granted.

B

Messages

This appendix lists selected HP 48 messages.

In the following tables, messages are first arranged alphabetically by name and then numerically by message number.

Messages Listed Alphabetically

Message	Meaning	# (hex)
Acknowledged	Alarm acknowledged.	619
Autoscaling	Calculator is autoscaling *x*- and/or *y*- axis.	610
Awaiting Server Cmd.	Indicates Server mode active.	C0C
Bad Argument Type	One or more stack arguments were incorrect type for operation.	202
Bad Argument Value	Argument value out of operation's range.	203
Bad Guess(es)	Guess(es) supplied to HP Solve application or ROOT lie outside domain of equation.	A01

Messages Listed Alphabetically (continued)

Message	Meaning	# (hex)
Bad Packet Block check	Computed packet checksum doesn't match checksum in packet.	C01
Can't Edit Null Char.	Attempted to edit a string containing character "0".	102
Circular Reference	Attempted to store a variable name into itself.	129
Connecting	Indicates verifying IR or serial connection.	C0A
Constant?	HP Solve application or ROOT returned same value at every sample point of current equation.	A02
Copied to stack	→STK copied selected equation to stack.	623
Current equation:	Identifies current equation.	608
Deleting Column	MatrixWriter application is deleting a column.	504
Deleting Row	MatrixWriter application is deleting a row.	503
Directory Not Allowed	Name of existing directory variable used as argument.	12A
Directory Recursion	Attempted to store a directory into itself.	002
Empty catalog	No data in current catalog (Equation, Statistics, Alarm)	60D

Messages Listed Alphabetically (continued)

Message	Meaning	# (hex)
`Enter alarm, press SET`	Alarm entry prompt.	61A
`Enter eqn, press NEW`	Store new equation in *EQ*.	60A
`Enter value (zoom out if >1), press ENTER`	Zoom operations prompt.	622
`Extremum`	Result returned by HP Solve application or ROOT is an extremum rather than a root.	A06
`HALT Not Allowed`	A program containing HALT executed while MatrixWriter application, DRAW, or HP Solve application active.	126
`I/O setup menu`	Identifies I/O setup menu.	61C
`Implicit () off`	Implicit parentheses off.	207
`Implicit () on`	Implicit parentheses on.	208
`Incomplete Subexpression`	[▶], [▼], or [ENTER] pressed before all function arguments supplied.	206
`Inconsistent Units`	Attempted unit conversion with incompatible units.	B02
`Infinite Result`	Math exception: Calculation such as 1/0 infinite result.	305
`Inserting Column`	MatrixWriter application is inserting a column.	504

Messages Listed Alphabetically (continued)

Message	Meaning	# (hex)
`Inserting Row`	MatrixWriter application is inserting a row.	503
`Insufficient Memory`	Not enough free memory to execute operation.	001
`Insufficient Σ Data`	A Statistics command was executed when Σ*DAT* did not contain enough data points for calculation.	603
`Interrupted`	The HP Solve application or ROOT was interrupted by [ATTN].	A03
`Invalid Array Element`	[ENTER] returned object of wrong type for current matrix.	502
`Invalid Card Data`	HP 48 does not recognize data on plug-in card.	008
`Invalid Date`	Date argument not real number in correct format, or was out of range.	D01
`Invalid Definition`	Incorrect structure of equation argument for DEFINE.	12C
`Invalid Dimension`	Array argument had wrong dimensions.	501

Messages Listed Alphabetically (continued)

Message	Meaning	# (hex)
`Invalid EQ`	Attempted operation from GRAPHICS FCN menu when *EQ* did not contain algebraic, or, attempted DRAW with CONIC plot type when *EQ* did not contain algebraic.	607
`Invalid IOPAR`	*IOPAR* not a list, or one or more objects in list missing or invalid.	C12
`Invalid Name`	Received illegal filename, or server asked to send illegal filename.	C17
`Invalid PPAR`	*PPAR* not a list, or one or more objects in list missing or invalid.	12E
`Invalid PRTPAR`	*PRTPAR* not a list, or one or more objects in list missing or invalid.	C13
`Invalid PTYPE`	Plot type invalid for current equation.	620
`Invalid Repeat`	Alarm repeat interval out of range.	D03
`Invalid Server Cmd.`	Invalid command received while in Server mode.	C08
`Invalid Syntax`	HP 48 unable execute ENTER or STR→ due to invalid object syntax.	106

Messages Listed Alphabetically (continued)

Message	Meaning	# (hex)
Invalid Time	Time argument not real number in correct format, or out of range.	D02
Invalid Unit	Unit operation attempted with invalid or undefined user unit.	B01
Invalid User Function	Type or structure of object executed as user-defined function was incorrect.	103
Invalid Σ Data	Statistics command executed with invalid object stored in *ΣDAT*.	601
Invalid Σ Data LN(Neg)	Non-linear curve fit attempted when *ΣDAT* matrix contained a negative element.	605
Invalid Σ Data LN(0)	Non-linear curve fit attempted when *ΣDAT* matrix contained a 0 element.	606
Invalid ΣPAR	*ΣPAR* not list, or one or more objects in list missing or invalid.	604
LAST CMD Disabled	LAST CMD pressed while that recovery feature disabled.	125
LAST STACK Disabled	LAST STACK pressed while that recovery feature disabled.	124
LASTARG Disabled	LASTARG executed while that recovery feature disabled.	205

Messages Listed Alphabetically (continued)

Message	Meaning	# (hex)
Low Battery	System batteries too low to safely print or perform I/O.	C14
Memory Clear	HP 48 memory was cleared.	005
Name Conflict	Execution of | (where) attempted to assign value to variable of integration or summation index.	13C
Name the equation, press ENTER	Name equation and store it in *EQ*.	60B
Name the stat data, press ENTER	Name statistics data and store it in Σ*DAT*.	621
Negative Underflow	Math exception: Calculation returned negative, non-zero result greater than −MINR.	302
No Current Equation	SOLVR, DRAW, or RCEQ executed with nonexistent *EQ*.	104
No current equation	Plot and HP Solve application status message.	609
No Room in Port	Insufficient free memory in specified RAM port.	00B
No Room to Save Stack	Not enough free memory to save copy of the stack. LAST STACK is automatically disabled.	101

Messages Listed Alphabetically (continued)

Message	Meaning	# (hex)
No Room to Show Stack	Stack objects displayed by type only due to low memory condition.	131
No stat data to plot	No data stored in Σ*DAT*.	60F
Non-Empty Directory	Attempted to purge non-empty directory.	12B
Non-Real Result	Execution of HP Solve application, ROOT, DRAW, or ∫ returned result other than real number or unit.	12F
Nonexistent Alarm	Alarm list did not contain alarm specified by alarm command.	D04
Nonexistent ΣDAT	Statistics command executed when Σ*DAT* did not exist.	602
Object Discarded	Sender sent an EOF (Z) packet with a "D" in the data field.	C0F
Object In Use	Attempted PURGE or STO into a backup object when its stored object was in use.	009
Object Not in Port	Attempted to access a nonexistent backup object or library.	00C
(OFF SCREEN)	Function value, root, extremum, or intersection was not visible in current display.	61F

Messages Listed Alphabetically (continued)

Message	Meaning	# (hex)
Out of Memory	One or more objects must be purged to continue calculator operation.	135
Overflow	Math exception: Calculation returned result greater in absolute value than MAXR.	303
Packet #	Indicates packet number during send or receive.	C10
Parity Error	Received bytes' parity bit doesn't match current parity setting.	C05
Port Closed	Possible I/R or serial hardware failure. Run self-test.	C09
Port Not Available	Used a port command on an empty port, or one containing ROM instead of RAM. Attempted to execute a server command that itself uses the I/O port.	00A
Positive Underflow	Math exception: Calculation returned positive, non-zero result less than MINR.	301
Power Lost	Calculator turned on following a power loss. Memory may have been corrupted.	006

Messages Listed Alphabetically (continued)

Message	Meaning	# (hex)
Processing Command	Indicates processing of host command packet.	C11
Protocol Error	Received a packet whose length was shorter than a null packet.	C07
	Maximum packet length parameter from other machine is illegal.	
Receive Buffer Overrun	Kermit: More than 255 bytes of retries sent before HP 48 received another packet.	C04
	SRECV: Incoming data overflowed the buffer.	
Receive Error	UART overrun or framing error.	C03
Receiving	Identifies object name while receiving.	C0E
Retry #	Indicates number of retries while retrying packet exchange.	C0B
Select a model	Select statistics curve fitting model.	614
Select plot type	Select plot type.	60C
Select repeat interval	Select alarm repeat interval.	61B

Messages Listed Alphabetically (continued)

Message	Meaning	# (hex)
Sending	Identifies object name while sending.	C0D
Sign Reversal	HP Solve application or ROOT unable to find point at which current equation evaluates to zero, but did find two neighboring points at which equation changed sign.	A05
Timeout	Printing to serial port: Received XOFF and timed out waiting for XON. Kermit: Timed out waiting for packet to arrive.	C02
Too Few Arguments	Command required more arguments than were available on stack.	201
Transfer Failed	10 successive attempts to receive a good packet were unsuccessful.	C06
Unable to Isolate	ISOL failed because specified name absent or contained in argument of function with no inverse.	130
Undefined Local Name	Executed or recalled local name for which corresponding local variable did not exist.	003

Messages Listed Alphabetically (continued)

Message	Meaning	# (hex)
Undefined Name	Executed or recalled global name for which corresponding variable does not exist.	204
Undefined Result	Calculation such as 0/0 generated mathematically undefined result.	304
Undefined XLIB Name	Executed an XLIB name when specified library absent.	004
Wrong Argument Count	User-defined function evaluated with an incorrect number of parenthetical arguments.	128
x and y-axis zoom.	Identifies zoom option.	627
x axis zoom.	Identifies zoom option.	625
x axis zoom w/AUTO.	Identifies zoom option.	624
y axis zoom.	Identifies zoom option.	626
ZERO	Result returned by the HP Solve application or ROOT is a root (a point at which current equation evaluates to zero).	A04
""	Identifies no execution action when EXECS pressed.	61E

Messages Listed Numerically

# (hex)	Message
	General Messages
001	Insufficient Memory
002	Directory Recursion
003	Undefined Local Name
004	Undefined XLIB Name
005	Memory Clear
006	Power Lost
008	Invalid Card Data
009	Object In use
00A	Port Not available
00B	No Room in Port
00C	Object Not in Port
101	No Room to Save Stack
102	Can't Edit Null Char.
103	Invalid User Function
104	No Current Equation
106	Invalid Syntax
124	LAST STACK Disabled
125	LAST CMD Disabled
126	HALT Not Allowed
128	Wrong Argument Count
129	Circular Reference
12A	Directory Not Allowed
12B	Non-Empty Directory
12C	Invalid Definition
12E	Invalid PPAR
12F	Non-Real Result

Messages Listed Numerically (continued)

# (hex)	Message
	General Messages (continued)
130	Unable to Isolate
131	No Room to Show Stack
	Out-of-Memory Prompts
135	Out of Memory
13C	Name Conflict
	Stack Errors
201	Too Few Arguments
202	Bad Argument Type
203	Bad Argument Value
204	Undefined Name
205	LASTARG Disabled
	EquationWriter Application Messages
206	Incomplete Subexpression
207	Implicit () off
208	Implicit () on
	Floating-Point Errors
301	Positive Underflow
302	Negative Underflow
303	Overflow
304	Undefined Result
305	Infinite Result
	Array Messages
501	Invalid Dimension
502	Invalid Array Element
503	Deleting Row
504	Deleting Column
505	Inserting Row

Messages Listed Numerically (continued)

# (hex)	Message
	Array Messages (continued)
506	Inserting Column
	Statistics Messages
601	Invalid Σ Data
602	Nonexistent ΣDAT
603	Insufficient Σ Data
604	Invalid ΣPAR
605	Invalid Σ Data LN(Neg)
606	Invalid Σ Data LN(0)
	Plot, I/O, Time and HP Solve Application Messages
607	Invalid EQ
608	Current equation:
609	No current equation.
60A	Enter eqn, press NEW
60B	Name the equation, press ENTER
60C	Select plot type
60D	Empty catalog
60F	No Statistics data to plot
610	Autoscaling
614	Select a model
619	Acknowledged
61A	Enter alarm, press SET
61B	Select repeat interval
61C	I/O setup menu
61D	Plot type:
61E	""
61F	(OFF SCREEN)
620	Invalid PTYPE
621	Name the stat data, press ENTER

Messages Listed Numerically (continued)

# (hex)	Message
	Application Messages (continued)
622	Enter value (zoom out if >1), press ENTER
623	Copied to stack
624	x axis zoom w/AUTO.
625	x axis zoom.
626	y axis zoom.
627	x and y-axis zoom.
A01	Bad Guess(es)
A02	Constant?
A03	Interrupted
A04	Zero
A05	Sign Reversal
A06	Extremum
	Unit Management
B01	Invalid Unit
B02	Inconsistent Units

Messages Listed Numerically (continued)

# (hex)	Message
	I/O and Printing
C01	Bad Packet Block check
C02	Timeout
C03	Receive Error
C04	Receive Buffer Overrun
C05	Parity Error
C06	Transfer Failed
C07	Protocol Error
C08	Invalid Server Cmd
C09	Port Closed
C0A	Connecting
C0B	Retry #
C0C	Awaiting Server Cmd.
C0D	Sending
C0E	Receiving
C0F	Object Discarded
C10	Packet #
C11	Processing Command
C12	Invalid IOPAR
C13	Invalid PRTPAR
C14	I/O: Batt Too Low
C15	Empty Stack
C17	Invalid Name
	Time Messages
D01	Invalid Date
D02	Invalid Time
D03	Invalid Repeat
D04	Nonexistent Alarm

C

HP 48 Character Codes

Most of the characters in the HP 48 character set can be directly typed into the display from the Alpha keyboard. For example, to display ⇕, type [α] [←] [4]. (The Alpha keyboard is presented in chapter 2.) Any character in the set can be displayed by typing its corresponding character code and then executing the CHR command. The syntax is *char#* CHR. Certain characters in the set are *not* on the Alpha keyboard. To display one of these characters, you *must* type its character code and execute CHR.

The character tables on the following pages show the HP 48 characters and their corresponding character codes. (This set, except for character numbers 128 through 159, is based on the ISO 8859 Latin 1 character set.)



Note

If you find that a character you frequently use is not available on the primary or alpha keyboards (see chapter 2 for all the available characters), you can assign that character to the user keyboard for easy access. See "Making User Key Assignments" on page 217 for more information.

Character Codes (0 — 127)

NUM	CHR	NUM	CHR	NUM	CHR	NUM	CHR
0	■	32		64	@	96	'
1	■	33	!	65	A	97	a
2	■	34	"	66	B	98	b
3	■	35	#	67	C	99	c
4	■	36	$	68	D	100	d
5	■	37	%	69	E	101	e
6	■	38	&	70	F	102	f
7	■	39	'	71	G	103	g
8	■	40	(	72	H	104	h
9	■	41	)	73	I	105	i
10	■	42	*	74	J	106	j
11	■	43	+	75	K	107	k
12	■	44	,	76	L	108	l
13	■	45	-	77	M	109	m
14	■	46	.	78	N	110	n
15	■	47	/	79	O	111	o
16	■	48	0	80	P	112	p
17	■	49	1	81	Q	113	q
18	■	50	2	82	R	114	r
19	■	51	3	83	S	115	s
20	■	52	4	84	T	116	t
21	■	53	5	85	U	117	u
22	■	54	6	86	V	118	v
23	■	55	7	87	W	119	w
24	■	56	8	88	X	120	x
25	■	57	9	89	Y	121	y
26	■	58	:	90	Z	122	z
27	■	59	;	91	[	123	{
28	■	60	<	92	\	124	|
29	■	61	=	93	]	125	}
30	■	62	>	94	^	126	~
31	...	63	?	95	_	127	■

Character Codes (128 — 255)

NUM	CHR	NUM	CHR	NUM	CHR	NUM	CHR
128	∠	160		192	À	224	à
129	⌅	161	¡	193	Á	225	á
130	▽	162	¢	194	Â	226	â
131	√	163	£	195	Ã	227	ã
132	∫	164	¤	196	Ä	228	ä
133	Σ	165	¥	197	Å	229	å
134	▶	166	¦	198	Æ	230	æ
135	π	167	§	199	Ç	231	ç
136	∂	168	¨	200	È	232	è
137	≤	169	©	201	É	233	é
138	≥	170	ª	202	Ê	234	ê
139	≠	171	«	203	Ë	235	ë
140	α	172	¬	204	Ì	236	ì
141	→	173	-	205	Í	237	í
142	←	174	®	206	Î	238	î
143	↓	175	¯	207	Ï	239	ï
144	↑	176	°	208	Ð	240	ð
145	γ	177	±	209	Ñ	241	ñ
146	δ	178	²	210	Ò	242	ò
147	ε	179	³	211	Ó	243	ó
148	η	180	´	212	Ô	244	ô
149	θ	181	µ	213	Õ	245	õ
150	λ	182	¶	214	Ö	246	ö
151	ρ	183	·	215	×	247	÷
152	σ	184	¸	216	Ø	248	ø
153	τ	185	¹	217	Ù	249	ù
154	ω	186	º	218	Ú	250	ú
155	Δ	187	»	219	Û	251	û
156	Π	188	¼	220	Ü	252	ü
157	Ω	189	½	221	Ý	253	ý
158	■	190	¾	222	Þ	254	þ
159	∞	191	¿	223	ß	255	ÿ

D

Menu Numbers

The following table lists the HP 48 built-in menus and the corresponding menu numbers.

Menu #	Menu Name	Menu #	Menu Name
0	Last Menu	19	I/O SETUP
1	CST	20	MODES
2	VAR	21	MODES Customization
3	MTH	22	MEMORY
4	MTH PARTS	23	MEMORY Arithmetic
5	MTH PROB	24	LIBRARY
6	MTH HYP	25	PORT 0
7	MTH MATR	26	PORT 1
8	MTH VECTR	27	PORT 2
9	MTH BASE	28	EDIT
10	PRG	29	SOLVE
11	PRG STK	30	SOLVE SOLVR
12	PRG OBJ	31	PLOT
13	PRG DISP	32	PLOT PTYPE
14	PRG CTRL	33	PLOT PLOTR
15	PRG BRCH	34	ALGEBRA
16	PRG TEST	35	TIME
17	PRINT	36	TIME ADJST
18	I/O	37	TIME ALRM

Menu #	Menu Name	Menu #	Menu Name
38	TIME ALRM RPT	49	UNITS FORCE
39	TIME SET	50	UNITS ENRG
40	STAT	51	UNITS POWR
41	STAT MODL	52	UNITS PRESS
42	UNITS Catalog	53	UNITS TEMP
43	UNITS LENG	54	UNITS ELEC
44	UNITS AREA	55	UNITS ANGL
45	UNITS VOL	56	UNITS LIGHT
46	UNITS TIME	57	UNITS RAD
47	UNITS SPEED	58	UNITS VISC
48	UNITS MASS	59	UNITS Command

E

Listing of HP 48 System Flags

This appendix lists the HP 48 system flags in functional groups. All flags can be set, cleared, and tested. The default state of the flags is *clear*, except for the Binary Integer Wordsize flags (flags −5 through −10).

System Flags

Flag	Description
	Symbolic Math Flags
−1	Principal Solution. *Clear*: QUAD and ISOL return a result representing all possible solutions. *Set*: QUAD and ISOL return only the principal solution.
−2	Symbolic Constants. *Clear*: Symbolic constants (e, i, π, MAXR, and MINR) retain their symbolic form when evaluated, unless the Numerical Results flag −3 is set. *Set*: Symbolic constants evaluate to numbers, regardless of the state of the Numerical Results flag −3.
−3	Numerical Results. *Clear*: Functions with symbolic arguments, including symbolic constants, evaluate to symbolic results. *Set*: Functions with symbolic arguments, including symbolic constants, evaluate to numbers.
−4	Not used.

System Flags (continued)

Flag	Description
	Binary Integer Math Flags
−5 thru −10	Binary Integer Wordsize. Combined states of flags −5 through −10 set the wordsize from 1 to 64 bits.
−11 and −12	Binary Integer Base. HEX: −11 *set*, −12 *set*. DEC: −11 *clear*, −12 *clear*. OCT: −11 *set*, −12 *clear*. BIN: −11 *clear*, −12 *set*.
−13 and −14	Not used.
	Coordinate System Flags
−15 and −16	Rectangular: −15 *clear*, −16 *clear*. Polar/Cylindrical: −15 *clear*, −16 *set*. Polar/Spherical: −15 *set*, −16 *set*.
	Trigonometric Angle Mode Flags
−17 and −18	Degrees: −17 *clear*, −18 *clear*. Radians: −17 *set*, −18 *clear*. Grads: −17 *clear*, −18 *set*.
	Complex Mode Flag
−19	*Clear*:→V2 and [→] [2D] create a 2-dimensional vector from 2 real numbers. *Set*:→V2 and [→] [2D] create a complex number from 2 real numbers.

System Flags (continued)

Flag	Description
	Math Exception-Handling Flags
−20	Underflow Exception. *Clear*: Underflow exception returns 0. *Set*: Underflow exception treated as an error.
−21	Overflow Exception. *Clear*: Overflow exception returns ±9.99999999999E499. *Set*: Overflow exception treated as an error.
−22	Infinite Result Exception. *Clear*: Infinite result exception treated as an error. *Set*: Infinite result exception returns ±9.99999999999E499.
−23 −24 −25 −26	Negative Underflow Indicator. Positive Underflow Indicator. Overflow Indicator. Infinite Result Indicator. When an exception occurs, corresponding flag (−23 through −26) is *set*, regardless of whether or not the exception is treated as an error.
−27 thru −29	Not used.

System Flags (continued)

Flag	Description
	Plotting and Graphics Flags
−30	Function Plotting. *Clear*: For equations of form $y = f(x)$, only $f(x)$ is drawn. *Set*: For equations of form $y = f(x)$, separate plots of y and $f(x)$ are drawn.
−31	Curve Filling. *Clear*: Curve filling between plotted points enabled. *Set*: Curve filling between plotted points suppressed.
−32	Graphics Cursor. *Clear*: Graphics cursor always dark. *Set*: Graphics cursor dark on light background and light on dark background.
	I/O and Printing Flags
−33	I/O Device. *Clear*: I/O directed to serial port. *Set*: I/O directed to IR port.
−34	Printing Device. *Clear*: Printer output directed to IR printer. *Set*: Printer output directed to serial port if flag −33 is clear.
−35	I/O Data Format. *Clear*: Objects transmitted in ASCII form. *Set*: Objects transmitted in memory image form.
−36	RECV Overwrite. *Clear*: If file name received by HP 48 matches existing HP 48 variable name, new variable name with number extension is created to prevent overwrite. *Set*: If file name received by HP 48 matches existing HP 48 variable name, existing variable is overwritten.

System Flags (continued)

Flag	Description
	I/O and Printing Flags (continued)
-37	Double-Spaced Printing. *Clear*: Single-spaced printing. *Set*: Double-spaced printing.
-38	Linefeed. *Clear*: Linefeed added at end of each print line. *Set*: No linefeed added at end of each print line.
-39	I/O Messages. *Clear*: I/O messages displayed. *Set*: I/O messages suppressed.
	Time Management Flags
-40	Clock Display. *Clear*: Ticking clock displayed only when TIME menu selected. *Set*: Ticking clock displayed at all times.
-41	Clock Format. *Clear*: 12-hour clock. *Set*: 24-hour clock.
-42	Date Format. *Clear*: MM/DD/YY (month/day/year) format. *Set*: DD.MM.YY (day.month.year) format.
-43	Repeat Alarms Not Rescheduled. *Clear*: Unacknowledged repeat appointment alarms automatically rescheduled. *Set*: Unacknowledged repeat appointment alarms not rescheduled.

System Flags (continued)

Flag	Description
	Time Management Flags (continued)
−44	Acknowledged Alarms Saved. *Clear*: Acknowledged appointment alarms deleted from alarm list. *Set*: Acknowledged appointment alarms saved in alarm list.
	Display Format Flags
−45 thru −48	Number of Decimal Digits. Combined states of flags −45 through −48 sets number of decimal digits in Fix, Scientific, and Engineering modes.
−49 and −50	Number Display Format. Standard: −49 *clear*, −50 *clear*. Fix: −49 *set*, −50 *clear*. Scientific: −49 *clear*, −50 *set*. Engineering: −49 *set*, −50 *set*.
−51	Fraction Mark. *Clear*: Fraction mark is . (period). *Set*: Fraction mark is , (comma).
−52	Single-Line Display. *Clear*: Display gives preference to object in level 1, using up to four lines of stack display. *Set*: Display of object in level 1 restricted to one line.
−53	Precedence. *Clear*: Certain parentheses in algebraic expressions suppressed to improve legibility. *Set*: All parentheses in algebraic expressions displayed.
−54	Not used.

System Flags (continued)

Flag	Description
	Miscellaneous Flags
−55	Last Arguments. *Clear*: Operation arguments saved. *Set*: Operation arguments not saved.
−56	Error Beep. *Clear*: Error and BEEP-command beeps enabled. *Set*: Error and BEEP-command beeps suppressed.
−57	Alarm Beep. *Clear*: Alarm beep enabled. *Set*: Alarm beep suppressed.
−58	Verbose Messages. *Clear*: Prompt messages and data automatically displayed. *Set*: Automatic display of prompt messages and data suppressed.
−59	Fast Catalog Display. *Clear*: Equation Catalog (and messages in SOLVE, SOLVR, PLOT, and PLOTR menus) show equation and equation name. *Set*: Equation Catalog (and messages in SOLVE, SOLVR, PLOT, and PLOTR menus) show equation name only.
−60	Alpha Lock. *Clear*: Alpha lock activated by pressing [α] twice. *Set*: Alpha lock activated by pressing [α] once.
−61	User-Mode Lock. *Clear*: 1-User mode activated by pressing [↰][USR] once. User mode activated by pressing [↰][USR] twice. *Set*: User mode activated by pressing [↰][USR] once.

System Flags (continued)

Flag	Description
	Miscellaneous Flags (continued)
-62	User Mode. *Clear*: User mode not active. *Set*: User mode active.
-63	Vectored [ENTER]. *Clear*: [ENTER] evaluates command line. *Set*: User-defined [ENTER] activated.
-64	Index Wrap Indicator. *Clear*: Last execution of GETI or PUTI did not increment index to first element. *Set*: Last execution of GETI or PUTI did increment index to first element.

Operation Index

This index contains reference information for all operations in the HP 48. For each operation, this index shows:

Name, Key, or Label. The name, key, or menu label associated with the operation. Operation names appear as keys or menu labels.

Description. What the operation does (or its value if a unit).

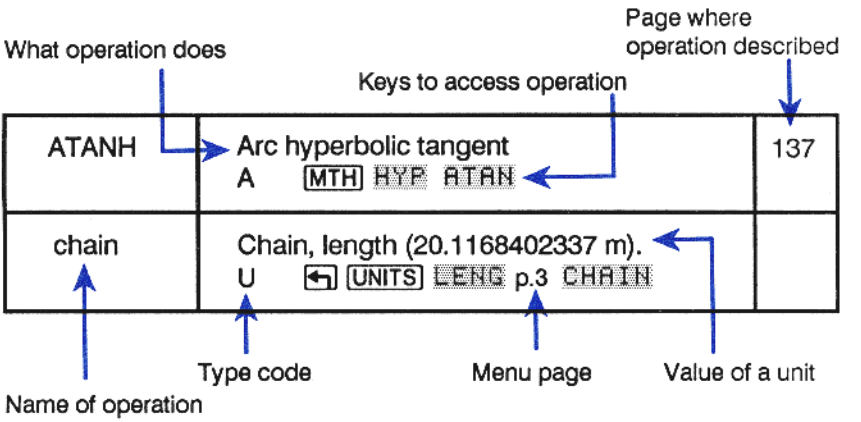
Type. The type of operation is given by one of the following codes.

Type Code	Description
O	Operation. An operation that cannot be included in the command line, in a program, or in an algebraic.
C	Command. An operation that can be included in programs but *not* in algebraics.
F	Function. A command that can be included in algebraics.
A	Analytic Function. A function for which the HP 48 provides an inverse and derivative.
U	Unit.

Keys. The keys to access the operation. Keystroke sequences preceded by "..." can be accessed through more than one menu—to see the keystrokes represented by the "...", refer to the listing in this index for the operation that immediately follows the "...". Operations in multi-page menus show the applicable menu page number. Operations that are not key-accessible are identified by "Must be typed in."

Page. Where the operation is described in this manual.

The entries in this index are arranged as follows:



Operations whose names contain both alpha and special characters are listed alphabetically; operations whose names contain special characters only are listed at the end of this index.

Name, Key or Label	Description Type, Keys	Page
a	Are, area (100 m^2). U UNITS AREA p.2 A	
A	Ampere, electric current (1 A). U UNITS p.2 ELEC A	
Å	Angstrom, length (1×10^{-10} m). U UNITS LENG p.4 A	

Name, Key or Label	Description Type, Keys	Page
←A	Associate left. O ↰ EQUATION ◀ RULES ←A	405
↱ ←A	Executes ←A until no change in subexpression. O ↰ EQUATION ◀ RULES ↱ ←A	410
A→	Associate right. O ↰ EQUATION ◀ RULES →A	405
↱ A→	Executes A→ until no change in subexpression. O ↰ EQUATION ◀ RULES ↱ A→	410
ABS	Absolute value. MTH PARTS ABS MTH MATR p.2 ABS F MTH VECTR ABS	148
ACK	Acknowledges displayed past due alarm. C ↰ TIME ACK	447
ACKALL	Acknowledges all past due alarms. C ↰ TIME ACKA	447

Name, Key or Label	Description Type, Keys	Page
ACOS	Arc cosine. A ◀ ACOS	140
ACOSH	Arc hyperbolic cosine. A MTH HYP ACOSH	137
acre	Acre, area (4046.87260987 m^2). U ◀ UNITS AREA p.2 ACRE	
ADJST	Selects TIME ADJST (adjust) menu. O ◀ TIME ADJST	
AF	Add fractions. O ◀ EQUATION ◀ RULES AF	409
◀ ALGEBRA	Selects ALGEBRA menu. O ◀ ALGEBRA	
▶ ALGEBRA	Selects Equation Catalog. O ▶ ALGEBRA	259
ALOG	Common (base 10) antilogarithm. A ◀ 10^x	137

Name, Key or Label	Description Type, Keys	Page
ALRM	Selects TIME ALRM (alarm) menu. O ◀ TIME ALRM	
AND	Logical or binary AND. MTH BASE p.4 AND F PRG TEST AND	210 493
ANGL	Selects UNITS ANGL menu. O ◀ UNITS p.3 ANGL	
APPLY	Returns evaluated expression(s) as argument(s) to unevaluated local name. F ◀ ALGEBRA p.2 APPLY	
ARC	Draws arc in *PICT* from θ_1 to θ_2 with center at (x,y) and radius r. C PRG DSPL ARC	339
ARCHIVE	Makes backup copy of HOME directory. C ◀ MEMORY p.3 ARCHI	648
arcmin	Minute of arc, plane angle. $(4.62962962963 \times 10^{-5})$ U ◀ UNITS p.3 ANGL ARCMI	
arcs	Second of arc, plane angle. $(7.71604938272 \times 10^{-7})$ U ◀ UNITS p.3 ANGL ARCS	

Name, Key or Label	Description Type, Keys	Page
AREA	Calculates and displays area under function graph between two *x*-values specified by the mark and cursor; returns area to stack. O ... FCN AREA	308
AREA	Selects UNITS AREA menu. O ◀ UNITS AREA	
ARG	Returns polar angle θ. F MTH PARTS ARG	166
ARG	Enables/disables LASTARG recovery. O ◀ MODES p.2 ARG	221
ARRY→	Returns array elements to stack. C Must be typed in.	
→ARRY	Combines numbers into array. C PRG OBJ →ARR	90
ASCII	Switches between ASCII and binary mode. O ◀ I/O SETUP ASCII	617
ASIN	Arc sine. A ◀ ASIN	140
ASINH	Arc hyperbolic sine. A MTH HYP ASINH	137

Name, Key or Label	Description Type, Keys	Page
ASN	Makes a single user-key assignment. C ▶ MODES ASN	217
ASR	1-bit arithmetic shift right. C MTH BASE p.3 ASR	210
ATAN	Arc tangent. A ◀ ATAN	140
ATANH	Arc hyperbolic tangent. A MTH HYP ATAN	137
atm	Atmosphere, pressure (101325 $kg/m \cdot s^2$) U ◀ UNITS p.2 PRESS ATM	
ATTACH	Attaches specified library to current directory. C ◀ MEMORY p.2 ATTAC	651
ATTN (ON)	Aborts program execution, aborts command line; exits special environments; clears messages. O ON	54
AU	Astronomical unit, length (1.495979×10^{11} m). U ◀ UNITS LENG p.2 AU	

Name, Key or Label	Description Type, Keys	Page
AUTO	Scales *y*-axis. ... PLOTR AUTO C ↱ PLOT AUTO	293
AUTO	Scales *y*-axis; then plots equation. ... PLOTR AUTO O ↱ PLOT AUTO	295
AXES	Sets specified coordinates of axes intersection; stores labels. ... PLOTR p.3 AXES C ↱ PLOT p.3 AXES	320
↱ AXES	Recalls axes intersection to stack. ... PLOTR p.3 ↱ AXES O ↱ PLOT p.3 ↱ AXES	319
A/PM	Switches clock between AM and PM. O ↰ TIME SET A/PM	442
	Switches alarm time between AM and PM. O ↰ TIME ALRM A/PM	444
b	Barn, area (1×10^{-28} m^2). U ↰ UNITS AREA B	
bar	Bar, pressure (100000 kg/m·s^2). U ↰ UNITS p.2 PRESS BAR	
BAR	Selects BAR plot type. C ... PTYPE BAR	328

Name, Key or Label	Description Type, Keys	Page
BARPLOT	Draws bar plot of data in Σ*DAT*. C ◀ STAT p.3 BARPL	378
BASE	Selects MTH BASE menu. O MTH BASE	
BAUD	Sets one of four available baud rates. C ◀ I/O SETUP BAUD	617
bbl	Barrel, volume (.158987294928 m^3). U ◀ UNITS VOL p.4 BBL	
BEEP	Sounds beep. C PRG CTRL p.3 BEEP	523
BEEP	Enables/disables error BEEP. O ◀ MODES BEEP	221
BESTFIT	Selects statistics model yielding largest correlation coefficient (absolute value) and executes LR. C ◀ STAT p.4 MODL BEST	377
BIN	Sets binary base. MTH BASE BIN C ◀ MODES p.4 BIN	208
BINS	Sorts elements in independent variable column of Σ*DAT* into $N + 2$ bins (up to a maximum of 1048573 bins). C ◀ STAT p.2 BINS	382

Name, Key or Label	Description Type, Keys	Page
BLANK	Creates blank graphics object. C [PRG] DSPL p.3 BLAN	343
BOX	Draws box with opposite corners defined by specified coordinates. C [PRG] DSPL BOX	339
BOX	Draws box with opposite corners defined by mark and cursor. ... DRAW p.2 BOX ... AUTO p.2 BOX O [↰] [GRAPH] p.2 BOX	337
Bq	Becquerel, activity (1 1/s). U [↰] [UNITS] p.3 RAD BQ	
BRCH	Selects PRG BRCH (program branch) menu. O [PRG] BRCH	
Btu	International Table Btu, energy (1055.05585262 $kg \cdot m^2/s^2$) U [↰] [UNITS] p.2 ENRG BTU	
bu	Bushel, volume (.03523907 m^3). U [↰] [UNITS] VOL p.4 BU	
BUFLEN	Returns number of characters in serial buffer. C [↰] [I/O] p.3 BUFLE	634

Name, Key or Label	Description Type, Keys	Page
BYTES	Returns object size (in bytes) and checksum for object. C ◀ MEMORY BYTES	101
B→R	Binary-to-real conversion. C MTH BASE p.2 B→R	210
c	Speed of light (299792458 m/s). U ◀ UNITS SPEED p.2 c	
C	Coulomb, electric charge (1 A·s). U ◀ UNITS p.2 ELEC C	
°C	Degrees Celsius, temperature. U ◀ UNITS p.2 TEMP °C	
cal	Calorie, energy (4.186 $kg \cdot m^2/s^2$) U ◀ UNITS p.2 ENRG CAL	
CASE	Begins CASE structure. C PRG BRCH CASE	498
◀ CASE	Types CASE THEN END END. O PRG BRCH ◀ CASE	498
▶ CASE	Types THEN END. O PRG BRCH ▶ CASE	498

Name, Key or Label	Description Type, Keys	Page
CAT	Selects Equation Catalog. ◀ PLOT CAT ◀ SOLVE CAT O ▶ ALGEBRA Selects STAT Catalog. O ◀ STAT CAT Selects Alarm Catalog. ◀ TIME CAT O ▶ TIME	259 370 449
cd	Candela, luminous intensity (1 cd). U ◀ UNITS p.3 LIGHT p.2 CD	
CEIL	Returns next greater integer. F MTH PARTS p.3 CEIL	148
CENT	Redraws graph with center at cursor position. ... DRAW CENT ... AUTO CENT O ◀ GRAPH CENT	302

Name, Key or Label	Description Type, Keys	Page
CENTR	Sets center of plot display at specified (*x*, *y*) coordinates. ... PLOTR p.2 CENT C ↱ PLOT p.2 CENT	295
↱ CENT	Recalls plot-center coordinates to stack. ... PLOTR p.2 ↱ CENT O ↱ PLOT p.2 ↱ CENT	293
CF	Clears specified flag. PRG TEST p.3 CF C ↱ MODES p.2 CF	516
%CH	Returns % change from level 2 to level 1. F MTH PARTS p.2 %CH	138
chain	Chain, length (20.1168402337 m). U ↰ UNITS LENG p.3 CHAIN	
CHR	Converts character code to one-character string. C PRG OBJ p.3 CHR	90
Ci	Curie, activity (3.7×10^{10} 1/s). U ↰ UNITS p.3 RAD CI	

Name, Key or Label	Description Type, Keys	Page
CIRCL	Draws circle with center at the mark and radius equal to the distance from cursor to mark. ... DRAW p.2 CIRCL ... AUTO p.2 CIRCL O ↰ GRAPH p.2 CIRCL	337
CKSM	Selects one of three available checksum error-detect schemes. C ↰ I/O SETUP CKSM	618
CLEAR	Clears stack. C ↱ CLR	64
CLR	In EquationWriter entry mode, clears screen. O ↰ EQUATION ↱ CLR Clears *PICT*. ... DRAW ↱ CLR ... AUTO ↱ CLR O ↰ GRAPH ↱ CLR	230 303
CLK	Switches ticking clock display on and off. O ↰ MODES p.2 CLK	221

Name, Key or Label	Description Type, Keys	Page
CLKADJ	Adds specified number of clock ticks to system time. C ◀ TIME ADJST p.2 CLKA	443
CLLCD	Blanks stack display. C PRG DSPL p.4 CLLCD	520
CLOSEIO	Closes I/O port. C ◀ I/O p.2 CLOSE	615
CLΣ	Purges statistical data in Σ*DAT*. C ◀ STAT CLΣ	368
CLUSR	Purges all user variables. C Must be typed in.	
CLVAR	Purges all user variables. C ▶ PURGE	115
cm	Centimeter, length (.01 m). U ◀ UNITS LENG CM	
CMD	Enables/disables last command line recovery. O ◀ MODES p.2 CMD	221
cm^2	Square centimeter, area (1×10^{-4} m^2). U ◀ UNITS AREA CM^2	

Name, Key or Label	Description Type, Keys	Page
cm^3	Cubic centimeter, volume (1×10^{-6} m^3). U ◀ UNITS VOL CM^3	
cm/s	Centimeters per second, speed (.01 m/s). U ◀ UNITS SPEED CM/S	
CNCT	Switches curve filling on and off. O ◀ MODES p.2 CNCT	221
CNRM	Calculates column norm of array. C MTH MATR p.2 CNRM	359
+COL	Inserts a row of zeros at current column in MatrixWriter application. O ▶ MATRIX p.2 +COL	351
-COL	Deletes current column in MatrixWriter application. O ▶ MATRIX p.2 -COL	351
COLCT	Collects like terms in expression. C ◀ ALGEBRA COLCT	395
COLCT	Collects like terms in specified subexpression. O ◀ EQUATION ◀ RULES COLCT	402
COLΣ	Specifies dependent and independent columns in Σ*DAT*. C Must be typed in.	

Name, Key or Label	Description Type, Keys	Page
COMB	Returns number of combinations of *n* items taken *m* at a time. F [MTH] PROB COMB	147
CON	Creates constant array. C [MTH] MATR CON	359
CONIC	Selects CONIC plot type. C ... PTYPE CONIC	327
CONJ	Returns complex conjugate. F [MTH] PARTS CONJ	166
CONT	Continues halted program. C [↰] [CONT]	520
CONVERT	Converts unit object to dimensions of specified compatible unit. C [↱] [UNITS] CONV	194
COORD	Displays cursor coordinates at bottom left of display. ... DRAW COORD ... AUTO COORD O [↰] [GRAPH] COORD	302

Name, Key or Label	Description Type, Keys	Page
CORR	Calculates correlation coefficient of statistical data in Σ*DAT*. C ◀ STAT p.4 CORR	377
COS	Cosine. A COS	140
COSH	Hyperbolic cosine. A MTH HYP COSH	137
COV	Calculates covariance of statistical data in Σ*DAT*. C ◀ STAT p.4 COV	377
CR	Causes printer to do carriage return/line feed. C ◀ PRINT CR	608
CRDIR	Creates a directory. C ◀ MEMORY CRDIR	120
CROSS	Cross product of 2- or 3-element vector. C MTH VECTR CROSS	353
CST	Selects CST (custom) menu. O CST	212
CST	Returns contents of *CST* variable. O ▶ MODES CST	213

Name, Key or Label	Description Type, Keys	Page
ct	Carat, mass (.0002 kg). U ◀ UNITS MASS p.2 CT	
CTRL	Selects PRG CTRL (program control) menu. O PRG CTRL	
cu	US cup, volume ($2.365882365 \times 10^{-4}$ m^3). U ◀ UNITS VOL p.3 CU	
C→PX	Converts user-unit coordinates to pixel coordinates. C PRG DSPL p.2 C→PX	324
C→R	Separates complex number into two real numbers. C PRG OBJ pg.2 C→R	91
d	Day, time (86400 s). U ◀ UNITS TIME D	
2D	Assembles or takes apart a complex number or 2D vector. O ◀ 2D	160
3D	Assembles or takes apart a 3D vector. O ▶ 3D	173

Name, Key or Label	Description Type, Keys	Page
◂D	Distribute left. O ↰ EQUATION ◀ RULES ◂D	406
↱ ◂D	Executes ◂D until no change in subexpression. O ↰ EQUATION ◀ RULES ↱ ◂D	410
D▸	Distribute right. O ↰ EQUATION ◀ RULES D▸	406
↱ D▸	Executes D▸ until no change in subexpression. O ↰ EQUATION ◀ RULES ↱ D▸	410
DATE	Returns system date. C ↰ TIME p.2 DATE	455
DATE+	Returns new date from specified date and number of days. C ↰ TIME p.2 DATE+	454
→DATE	Sets specified system date. C ↰ TIME SET →DAT	441
>DATE	Sets specified alarm date. O ↰ TIME ALRM >DATE	445
DAY	Sets alarm repeat interval to *n* days. O ↰ TIME ALRM RPT DAY	445

Name, Key or Label	Description Type, Keys	Page
DBUG	Halts program execution before first object. O [PRG] CTRL DBUG	484
DDAYS	Returns number of days between two dates. C [↰] [TIME] p.2 DDAYS	455
DEC	Sets decimal base. [MTH] BASE DEC C [↰] MODES p.4 DEC	208
DECR	Decrements value of specified variable. C [↱] [MEMORY] DECR	513
DEFINE	Creates variable or user-defined function. C [↰] [DEF]	107 151
→DEF	Expands trigonometric and hyperbolic functions in terms of EXP and LN. O [↰] [EQUATION] [◀] RULES →DEF	409
DEG	Sets Degrees mode. C [↰] [MODES] p.3 DEG	139
[DEL]	Deletes character under cursor. O [DEL]	75

Name, Key or Label	Description Type, Keys	Page
DEL	Erases area whose opposite corners are defined by mark and cursor. ... DRAW p.3 DEL ... AUTO p.3 DEL O ↰ GRAPH p.3 DEL	337
←DEL	Deletes all characters from cursor to start of word. ↰ EDIT ←DEL O ... EDIT ←DEL	68
↱ ←DEL	Deletes all characters from cursor to start of line. ↰ EDIT ↱ ←DEL O ... EDIT ↱ ←DEL	68
DEL→	Deletes all characters from cursor to start of next word. ↰ EDIT DEL→ O ... EDIT DEL→	68
↱ DEL→	Deletes all characters from cursor to end of line. ↰ EDIT ↱ DEL→ O ... EDIT ↱ DEL→	68

Name, Key or Label	Description Type, Keys	Page
DELALARM	Deletes alarm from system alarm list. C ◀ TIME ALRM p.2 DELAL	453
DELAY	Sets delay time between lines sent to printer. C ◀ PRINT p.2 DELAY	607
DELKEYS	Clears specified user-key assignment. C ▶ MODES DELK	219
DEPND	Specifies name of dependent plot variable. ... PLOTR p.2 DEPN C ▶ PLOT p.2 DEPN	318
▶ DEPN	Recalls dependent plot variable to stack. ... PLOTR p.2 ▶ DEPN O ▶ PLOT p.2 ▶ DEPN	318
DEPTH	Returns number of objects on stack. C PRG STK DEPTH	78
DET	Determinant of a matrix. C MTH MATR DET	360
DETACH	Detaches specified library from current directory. C ◀ MEMORY p.2 DETAC	653

Name, Key or Label	Description Type, Keys	Page
DINV	Double invert. O ↰ EQUATION ◀ RULES DINV	401
DISP	Displays object in specified display line. PRG DSPL p.4 DISP C PRG CTRL p.2 DISP	523
DNEG	Double negate. O ↰ EQUATION ◀ RULES DNEG	400
DO	Begins indefinite loop. C PRG BRCH DO	510
↰ DO	Types DO UNTIL END. O PRG BRCH ↰ DO	510
DOERR	Aborts program execution and displays specified message. C PRG CTRL p.3 DOERR	546
DOT	Dot product of two vectors. C MTH VECTR DOT	353

Name, Key or Label	Description Type, Keys	Page
DOT+	Turns on pixels as cursor moves. ... DRAW p.2 DOT+ ... AUTO p.2 DOT+ O ↰ GRAPH p.2 DOT+	337
DOT-	Turns off pixels as cursor moves. ... DRAW p.2 DOT- ... AUTO p.2 DOT- O ↰ GRAPH p.2 DOT-	337
DRAW	Plots equation without axes. ... PLOTR DRAW C ↱ PLOT DRAW	292
DRAW	Plots equation with axes. ... PLOTR DRAW O ↱ PLOT DRAW	296
DRAX	Draws axes. ... PLOTR p.3 DRAX C ↱ PLOT p.3 DRAX	319

Name, Key or Label	Description Type, Keys	Page
DROP	Drops object in level 1; moves all remaining objects down one level. C ◀ DROP	64
DROPN	Drops *n* objects from stack. C PRG STK pg.2 DRPN	78
DRPN	Drops all objects from stack at and below pointer. O ... ↑STK p.2 DRPN	71
DROP2	Drops first two objects from stack. C PRG STK pg.2 DROP2	78
DSPL	Selects PRG DSPL (program display) menu. O PRG DSPL	
DTAG	Removes all tags from object. C PRG OBJ pg.2 DTAG	91
DUP	Duplicates object in level 1. C PRG STK pg.2 DUP	65
DUPN	Duplicates *n* objects on stack. C PRG STK pg.2 DUPN	78
DUPN	Duplicates all objects on stack from pointer through stack level 1. O ... ↑STK p.2 DUPN	71

Name, Key or Label	Description Type, Keys	Page
DUP2	Duplicates objects in level 1 and level 2. C [PRG] STK pg.2 DUP2	78
dyn	Dyne, force (.00001 kg·m/s^2). U [↰][UNITS] p.2 FORCE DYN	
D→R	Degrees-to-radians conversion. F [MTH] VECTR p.2 D→R	142
e	Symbolic constant *e* (2.71828182846). F [α] [↰][E]	144
ECHO	Copies object in current level to command line. O ... ↑STK ECHO	71
EDEQ	Returns contents of *EQ* to command line for editing. [↰][PLOT] EDEQ O [↰][SOLVE] EDEQ	256

Name, Key or Label	Description Type, Keys	Page
[EDIT]	When command line not active, copies level-1 object into command line and selects EDIT menu.	66
	When command line active, selects EDIT menu.	68
	O [◀][EDIT]	
	Selects EDIT menu.	350
	O [▶][MATRIX] [◀][EDIT]	
	Returns equation to command line and selects EDIT menu.	242
	O [◀][EQUATION] [◀][EDIT]	
	Edits current stack level.	72
	O ... ↑STK [◀][EDIT]	
EDIT	Copies selected equation into command line and selects EDIT menu.	259
	[◀][PLOT] CAT EDIT	
	[◀][SOLVE] CAT EDIT	
	O [▶][ALGEBRA] EDIT	
	Copies subexpression into command line and selects EDIT menu.	244
	O [◀][EQUATION] [◀] EDIT	
	Copies selected matrix to MatrixWriter application.	371
	O [◀][STAT] CAT EDIT	
	Edits current matrix cell.	351
	O [▶][MATRIX] EDIT	
	Displays selected alarm and selects ALRM (alarm) menu.	450
	O [◀][TIME] CAT EDIT	

Name, Key or Label	Description Type, Keys	Page
EDITΣ	Copies statistical data in Σ*DAT* to MatrixWriter application. O ◀ STAT EDITΣ	368
EEX	Types E or moves cursor to existing exponent in command line. O EEX	47
ELEC	Selects UNITS ELEC (electrical) menu. O ◀ UNITS p.2 ELEC	
erg	Erg, energy (.0000001 kg·m^2/s^2) U ◀ UNITS p.2 ENRG ERG	
ELSE	Begins ELSE clause. C PRG BRCH p.3 ELSE	496
END	Ends program structures. C PRG BRCH p.2 END	494
ENG	Sets display mode to Engineering. C ◀ MODES ENG	58
ENRG	Selects UNITS ENRG (energy) menu. O ◀ UNITS p.2 ENRG	
ENTER	Enters contents of command line. If no command line is present, executes DUP. O ENTER	99

Name, Key or Label	Description Type, Keys	Page
[ENTRY]	Switches Algebraic- and Program-entry modes. O [→][ENTRY]	77
[EQUATION]	Selects EquationWriter application. O [←][EQUATION]	
EQ+	Adds selected equation to list in *EQ*. [←][PLOT] CAT EQ+ [←][SOLVE] CAT EQ+ O [→][ALGEBRA] EQ+	272
[←] EQ+	Removes the last entry from the list in *EQ*. [←][PLOT] CAT [←] EQ+ [←][SOLVE] CAT [←] EQ+ O [→][ALGEBRA] [←] EQ+	272
EQ→	Separates equation into left and right sides. C [PRG] OBJ EQ→	91
ERASE	Erases *PICT*. ... PLOTR ERASE C [→][PLOT] ERASE	292

Name, Key or Label	Description Type, Keys	Page
ERRM	Returns last error message. C PRG CTRL p.3 ERRM	542
ERRN	Returns last error number. C PRG CTRL p.3 ERRN	542
ERR0	Clears last error number. C PRG CTRL p.3 ERR0	542
eV	Electron volt, energy (1.60219×10^{-19} kg·m^2/s^2) U ↰ UNITS p.2 ENRG p.2 EV	
EVAL	Evaluates object. C EVAL	98
EXEC	Sets alarm execution action. O ↰ TIME ALRM EXEC Recalls alarm execution action to stack. O ↰ TIME ALRM ↱ EXEC	444 444
EXECS	Shows alarm-execution action. ↰ TIME CAT EXECS O ↱ TIME EXECS	450

Name, Key or Label	Description Type, Keys	Page
EXIT	Exits Selection environment. O ◀ EQUATION ◀ EXIT Exits FCN (function) menu. O ... FCN EXIT Exits ZOOM menu. O ... ZOOM EXIT	399 308 305
EXP	Constant e raised to power of object in level 1. A ◀ e^x	137
EXPAN	Expands algebraic object. C ◀ ALGEBRA EXP	396
EXPFIT	Sets curve-fitting model to exponential. C ◀ STAT p.4 MODL EXPA	377
EXPM	Natural exponential minus 1 ($e^x - 1$). A MTH HYP p.2 EXPM	137
EXPR	Highlights subexpression for which specified object is top level function. O ◀ EQUATION ◀ EXPR	247 398
EXPR=	Returns expression value or equation values. O ... SOLVR EXPR=	265
EXTR	Moves graphics cursor to nearest extremum, displays coordinates, and returns them to stack. O ... FCN EXTR	308
E^	Replace power-product with power-of-power. O ◀ EQUATION ◀ RULES E^	408

Name, Key or Label	Description Type, Keys	Page
E( )	Replace power-of-power with power-product. O ↰ EQUATION ◀ RULES E( )	408
F	Farad, capacitance (1 $A^2 \cdot s^4/kg \cdot m^2$). U ↰ UNITS p.2 ELEC F	
°F	Degrees Fahrenheit, temperature. U ↰ UNITS p.2 TEMP °F	
FAST	Switches displaying equation names only and names plus contents of equations. O ... CAT p.2 FAST	260
fath	Fathom, length (1.82880365761 m). U ↰ UNITS LENG p.3 FATH	
fbm	Board foot, volume (.002359737216 m^3). U ↰ UNITS VOL p.4 FBM	
fc	Footcandle, illuminance (.856564774909 cd/m^2) U ↰ UNITS p.3 LIGHT FC	
FCN	Selects GRAPHICS FCN (function) menu. ... DRAW FCN ... AUTO FCN O ↰ GRAPH FCN	

Name, Key or Label	Description Type, Keys	Page
FC?	Tests if specified flag is clear. PRG TEST p.3 FC? C ↱ MODES p.3 FC?	516
FC?C	Tests if specified flag is clear, then clears it. PRG TEST p.3 FC?C C ↱ MODES p.3 FC?C	516
Fdy	Faraday, electric charge (96487 A·s). U ↰ UNITS p.2 ELEC p.2 FDY	
fermi	Fermi, length (1×10^{-15} m). U ↰ UNITS LENG p.4 FERMI	
FINDALARM	Returns first alarm due after specified time. C ↰ TIME ALRM p.2 FINDA	454
FINISH	Terminates Kermit server mode. C ↰ I/O FINIS	615
FIX	Selects Fix display mode. C ↰ MODES FIX	58
flam	Footlambert, luminance ($3.42625909964\ cd/m^2$) U ↰ UNITS p.3 LIGHT FLAM	

Name, Key or Label	Description Type, Keys	Page
FLOOR	Next smaller integer. F [MTH] PARTS p.3 FLOOR	148
FM,	Switches period and comma fraction mark. O [◁] MODES p.4 FM,	58
FOR	Begins definite loop. C [PRG] BRCH FOR	506
[◁] FOR	Types FOR NEXT. O [PRG] BRCH [◁] FOR	506
[▷] FOR	Types FOR STEP. O [PRG] BRCH [▷] FOR	508
FORCE	Selects UNITS FORCE menu. O [◁][UNITS] p.2 FORCE	
FP	Returns fractional part of a number. F [MTH] PARTS p.3 FP	148
FREE	Replaces object in RAM with new copy of object. C [◁][MEMORY] p.3 FREE	649
FREEZE	Freezes one or more of three display areas. C [PRG] DSPL p.4 FREEZ	344 523

Name, Key or Label	Description Type, Keys	Page
FS?	Tests if specified flag is set. PRG TEST p.3 FS? C ↱ MODES p.3 FS?	516
FS?C	Tests if specified flag is set, then clears it. PRG TEST p.3 FS?C C ↱ MODES p.3 FS?C	516
ft	International foot, length (.3048 m). U ↰ UNITS LENG FT	
ft^2	Square foot, area (.09290304 m^2). U ↰ UNITS AREA FT^2	
ft^3	Cubic foot, volume (.028316846592 m^3). U ↰ UNITS VOL FT^3	
ftUS	Survey foot, length (.304800609601 m). U ↰ UNITS LENG p.3 FTUS	
ft/s	Feet/second, speed (.3048 m/s). U ↰ UNITS SPEED FT/S	
ft*lbf	Foot-poundf, energy (1.35581794833 $kg \cdot m^2/s^2$). U ↰ UNITS p.2 ENRG FT*LB	

Name, Key or Label	Description Type, Keys	Page
FUNCTION	Selects FUNCTION plot type. C ... PTYPE FUNC	327
F(X)	Displays value of function at *x*-value specified by cursor. Returns function value to stack. O ... FCN p.2 F(X)	308
F'	Plots first derivative of function, replots function, and adds derivative to *EQ*. O ... FCN p.2 F'	309
g	Gram, mass (.001 kg). U ↰ UNITS MASS G	
ga	Standard freefall, acceleration (9.80665 m/s^2). U ↰ UNITS SPEED p.2 GA	
gal	US gallon, volume (.003785411784 m^3). U ↰ UNITS VOL p.2 GAL	
galC	Canadian gallon, volume (.00454609m^3). U ↰ UNITS VOL p.2 GALC	
galUK	UK gallon, volume (.004546092 m^3). U ↰ UNITS VOL p.2 GALU	
GET	Gets element from array or list. C PRG OBJ p.4 GET	91

Name, Key or Label	Description Type, Keys	Page
GETI	Gets element from array or list and increments index. C [PRG] OBJ p.4 GETI	92
gf	Gram-force (.00980665 kg·m/s^2). U [↰][UNITS] p.2 FORCE GF	
GOR	Superposes graphics object onto graphics object. C [PRG] DSPL p.3 GOR	343
GO↓	Sets top-to-bottom entry mode. O [↱][MATRIX] GO↓	357
GO→	Sets left-to-right entry mode. O [↱][MATRIX] GO→	351
GRAD	Selects Grads mode. C [↰][MODES] p.3 GRAD	139
grad	Grade, plane angle (.0025). U [↰][UNITS] p.3 ANGL GRAD	
grain	Grain, mass (.00006479891 kg). U [↰][UNITS] MASS p.2 GRAIN	
GRAPH	Enters Graphics environment. C [↰][GRAPH]	301
[GRAPH]	Invokes scrolling mode. [↰][EQUATION] [↰][GRAPH] ... DRAW [↰][GRAPH] ... AUTO [↰][GRAPH] O [↰][GRAPH] [↰][GRAPH]	229 303

Name, Key or Label	Description Type, Keys	Page
→GROB	Converts object into graphics object. C PRG DSPL p.3 →GRO	342
GXOR	Superposes inverting graphics object onto graphics object. C PRG DSPL p.3 GXOR	343
Gy	Gray, absorbed dose (1 m^2/s^2). U ↰ UNITS p.3 RAD GY	
h	Hour, time (3600 s). U ↰ UNITS TIME H	
H	Henry, inductance (1 $kg \cdot m^2/A^2 \cdot s^2$). U ↰ UNITS p.2 ELEC p.2 H	
*H	Adjusts vertical plot scale. C ... PLOTR p.3 *H	319
ha	Hectare, area (10000 m^2). U ↰ UNITS AREA p.2 HA	
HALT	Halts program execution. C PRG CTRL HALT	484 523
HEX	Sets hexadecimal base. MTH BASE HEX C ↰ MODES p.4 HEX	208

Name, Key or Label	Description Type, Keys	Page
HISTPLOT	Draws histogram of data in Σ*DAT*. C ◀ STAT p.3 HISTP	378
HISTOGRAM	Selects HISTOGRAM plot type. C ... PTYPE p.2 HIST	328
HMS+	Adds in HMS format. C ◀ TIME p.3 HMS+	142 457
HMS−	Subtracts in HMS format. C ◀ TIME p.3 HMS−	142 457
HMS→	Converts from HMS to decimal format. C ◀ TIME p.3 HMS→	142 456
→HMS	Converts base 10 number to HMS format. C ◀ TIME p.3 →HMS	142 456
HOME	Selects *HOME* directory. C ▶ HOME	122
HOUR	Sets alarm repeat interval to *n* hours. O ◀ TIME ALRM RPT HOUR	445
hp	Horsepower, power (745.699871582 $kg \cdot m^2/s^3$). U ◀ UNITS p.2 POWR HP	
HR+	Increments time by one hour. O ◀ TIME ADJST HR+	443
HR−	Decrements time by one hour. O ◀ TIME ADJST HR−	443

Name, Key or Label	Description Type, Keys	Page
HYP	Selects MTH HYP (math hyperbolic) menu. O [MTH] HYP	
Hz	Hertz, frequency (1/s). U [↰][UNITS] TIME HZ	
i	Symbolic constant *i*. F [α] [↰] [CST]	144
IDN	Creates identity matrix of specified size. C [MTH] MATR IDN	360
IF	Begins test clause. C [PRG] BRCH IF	494
[↰] IF	Types IF THEN END. O [PRG] BRCH [↰] IF	494
[↱] IF	Types IF THEN ELSE END. O [PRG] BRCH [↱] IF	496

Name, Key or Label	Description Type, Keys	Page
IFERR	Begins test clause. C PRG BRCH p.3 IFERR	543
◁IFERR	Types IFERR THEN END. O PRG BRCH p.3 ◁IFERR	543
▷IFERR	Types IFERR THEN ELSE END. O PRG BRCH p.3 ▷IFERR	545
IFT	IF-THEN command. C PRG BRCH p.3 IFT	500
IFTE	IF-THEN-ELSE function. F PRG BRCH p.3 IFTE	500
IM	Returns imaginary part of complex number or array. F MTH PARTS IM	166
in	Inch, length (.0254 m). U ◁UNITS LENG IN	
in^2	Square inch, area (.00064516 m^2). U ◁UNITS AREA IN^2	
in^3	Cubic inch, volume (.000016387064 m^3). U ◁UNITS VOL IN^3	

Name, Key or Label	Description Type, Keys	Page
INCR	Increments value of specified variable. C [→][MEMORY] INCR	513
INDEP	Specifies independent variable in a plot. ... PLOTR INDEP C [→][PLOT] INDEP	294
[→]INDEP	Recalls independent variable to stack. ... PLOTR [→]INDEP O [→][PLOT] [→]INDEP	293
inHg	Inches of mercury, pressure (3386.38815789 kg/m·s^2). U [←][UNITS] p.2 PRESS p.2 INHG	
inH2O	Inches of water, pressure (248.84 kg/m·s^2). U [←][UNITS] p.2 PRESS p.2 INH2O	
INPUT	Suspends program execution, displays message, and waits for data. C [PRG] CTRL p.2 INPUT	524
INS	Switches between insert/replace character. O [←][EDIT] INS	68

Name, Key or Label	Description Type, Keys	Page
INV	Reciprocal. A [1/x]	61
IP	Integer part of real number. F [MTH] PARTS p.3 IP	148
IR/W	Switches IR and Wire transmission modes. O [↰][I/O] SETUP IR/W	617
ISECT	Moves graphics cursor to closest intersection in two-function plot, displays intersection coordinates, and returns coordinates to stack. O ... FCN ISECT	308
ISOL	Isolates variable on one side of equation. C [↰][ALGEBRA] ISOL	389
[↰][I/O]	Selects I/O (input/output) menu. O [↰][I/O]	
[↱][I/O]	Selects Kermit server. O [↱][I/O]	624
J	Joule, energy (1 kg·m^2/s^2). U [↰][UNITS] p.2 ENRG J	
K	Kelvins, temperature (1 K). U [↰][UNITS] p.2 TEMP K	

Name, Key or Label	Description Type, Keys	Page
kcal	Kilocalorie, energy (4186 kg·m²/s²) U ◀ UNITS p.2 ENRG KCAL	
KEEP	Clears all levels above current level. O ... ↑STK p.2 KEEP	72
KERRM	Returns text of most recently-received KERMIT error packet. C ◀ I/O p.2 KERR	615
KEY	Returns number indicating last key pressed. C PRG CTRL p.2 KEY	540
KEYS	Removes menu labels. ... DRAW p.3 KEYS ... AUTO p.3 KEYS O ◀ GRAPH p.3 KEYS	302
kg	Kilogram, mass (1 kg). U ◀ UNITS MASS KG	
KGET	Gets data from another device. C ◀ I/O KGET	615
KILL	Aborts all suspended programs. C PRG CTRL KILL	484

Name, Key or Label	Description Type, Keys	Page
kip	Kilopound-force (4448.22161526 kg·m/s^2). U ◀[UNITS] p.2 FORCE KIP	
km	Kilometer, length (1 km). U ◀[UNITS] LENG p.2 KM	
km^2	Square kilometer, area (1 km^2). U ◀[UNITS] AREA p.2 KM^2	
knot	Nautical miles per hour, speed (.514444444444 m/s). U ◀[UNITS] SPEED KNOT	
kph	Kilometers per hour, speed (.277777777778 m/s). U ◀[UNITS] SPEED KPH	
l	Liter, volume (.001 m^3). U ◀[UNITS] VOL p.2 L	
LABEL	Labels axes with variable names and ranges. ... PLOTR p.3 LABEL C ▶[PLOT] p.3 LABEL	320

Name, Key or Label	Description Type, Keys	Page
LABEL	Labels axes with variable names and ranges. ... DRAW LABEL ... AUTO LABEL O ◀ GRAPH LABEL	302
lam	Lambert, luminance (3183.09886184 cd/m^2). U ◀ UNITS p.3 LIGHT p.2 LAM	
LAST	Returns previous argument(s) to stack. C Must be keyed in.	
LASTARG	Returns previous argument(s) to stack. C ▶ LAST ARG	64
LAST CMD	Displays previous contents of command line. O ◀ LAST CMD	77
LAST MENU	Selects last displayed page of previous menu. O ▶ LAST MENU	57
LAST STACK	Restores previous stack. O ◀ LAST STACK	74

Name, Key or Label	Description Type, Keys	Page
lb	Avoirdupois pound, mass (.45359237 kg). U ◀ UNITS MASS LB	
lbf	Pound-force (4.44822161526 kg·m/s^2). U ◀ UNITS p.2 FORCE LBF	
lbt	Troy pound, mass (.3732417 kg). U ◀ UNITS MASS LBT	
LCD→	Returns graphics object to stack representing stack display. C PRG DSPL p.4 LCD→	344
→LCD	Displays specified graphics object in stack display. C PRG DSPL p.4 →LCD	343
LENG	Selects UNITS LENG (length) menu. O ◀ UNITS LENG	
LEVEL	Enters current level number into level 1. O ... ↑STK p.2 LEVEL	72
LIBRARY	Selects LIBRARY menu. O ◀ LIBRARY	

Name, Key or Label	Description Type, Keys	Page
LIBS	Lists all libraries attached to current directory. C ◀ MEMORY p.2 LIBS	653
LIGHT	Selects UNITS LIGHT menu. O ◀ UNITS p.3 LIGHT	
LINE	Draws line between coordinates in levels 1 and 2. C PRG DSPL LINE	339
LINE	Draws line from mark to cursor. ... DRAW p.2 LINE ... AUTO p.2 LINE O ◀ GRAPH p.2 LINE	337
ΣLINE	Returns best-fit line for data in Σ*DAT* according to selected statistical model. C ◀ STAT p.3 ΣLINE	376
LINFIT	Sets curve-fitting model to linear. C ◀ STAT p.4 MODL LIN	377
LIST→	Returns list elements to stack. C Must be typed in.	
→LIST	Combines specified objects into list. C PRG OBJ →LIST	92

Name, Key or Label	Description Type, Keys	Page
→LIST	Combines objects from level 1 to current level into a list. O ... →STK →LIST	71
lm	Lumen, luminous flux ($7.95774715459 \times 10^{-2}$ cd). U ↰ UNITS p.3 LIGHT LM	
LN	Natural (base e) logarithm. A ↱ LN	61
LNP1	Natural logarithm of (*argument* + 1). A MTH HYP p.2 LNP1	138
LOG	Common (base 10) logarithm. A ↱ LOG	137
LOGFIT	Set curve-fitting model to logarithmic. C ↰ STAT p.4 MODL LOG	377
LR	Calculates linear regression. C ↰ STAT p.4 LR	376
lx	Lux, illuminance ($7.95774715459 \times 10^{-2}$ cd/m^2). U ↰ UNITS p.3 LIGHT LX	
lyr	Light year, length ($9.46052840488 \times 10^{15}$ m). U ↰ UNITS LENG p.2 LYR	
L*	Replace log-of-power with product-of-log. O ↰ EQUATION ◀ RULES L*	408
L()	Replace product-of-log with log-of-power. O ↰ EQUATION ◀ RULES L()	408

Name, Key or Label	Description Type, Keys	Page
←M	Merge-factors-left. O ↰EQUATION◀ RULES ←M	406
↱ ←M	Executes ←M until no change in subexpression. O ↰EQUATION◀ RULES ↱ ←M	410
M→	Merge-factors-right. O ↰EQUATION◀ RULES M→	407
↱ M→	Executes M→ until no change in subexpression. O ↰EQUATION◀ RULES ↱ M→	410
m	Meter, length (1 m). U ↰UNITS LENG M	
m^2	Square meter, area (1 m^2). U ↰UNITS AREA M^2	
m^3	Cubic meter (Stere), volume (1 m^3). U ↰UNITS VOL M^3	
MANT	Mantissa (decimal part) of number. F MTH PARTS p.3 MANT	148

Name, Key or Label	Description Type, Keys	Page
MARK	Sets mark at cursor position. ... DRAW p.3 MARK ... AUTO p.3 MARK O ◀ GRAPH p.3 MARK	302
MASS	Selects UNITS MASS menu. O ◀ UNITS MASS	
↑MATCH	Match-and-replace, beginning with subexpressions. C ◀ ALGEBRA p.2 ↑MAT	415
↓MATCH	Match-and-replace, beginning with top-level expression. C ◀ ALGEBRA p.2 ↓MAT	415
MATR	Selects MTH MATR (math matrices) menu. O MTH MATR	
MATRIX	Selects MatrixWriter application. O ▶ MATRIX	
MAX	Maximum of two real numbers. F MTH PARTS p.2 MAX	148

Name, Key or Label	Description Type, Keys	Page
MAXR	Maximum machine-representable real number (9.99999999999E499). F [MTH] PARTS p.4 MAXR	144
MAXΣ	Maximum column values in statistics matrix in Σ*DAT*. C [↰][STAT] p.2 MAXΣ	374
MEAN	Calculates mean of statistical data in Σ*DAT*. C [↰][STAT] p.2 MEAN	374
MEM	Bytes of available memory. C [↰][MEMORY] MEM	101
[↰][MEMORY]	Selects MEMORY menu. O [↰][MEMORY]	
[↱][MEMORY]	Selects MEMORY Arithmetic menu. O [↱][MEMORY]	
MENU	Displays built-in or custom menu. [↱][MODES] MENU C [PRG] CTRL p.2 MENU	213 534

Name, Key or Label	Description Type, Keys	Page
MERGE	Merges plug-in RAM card memory with main memory. C ◀ MEMORY p.3 MERG	643
μ	Micron, length (1×10^{-6} m). U ◀ UNITS LENG p.4 μ	
MeV	Mega electron volt, energy (1.60219×10^{-13} kg·m²/s²). U ◀ UNITS p.2 ENRG p.2 MEV	
mho	Mho, electric conductance (1 A²·s³/kg·m²). U ◀ UNITS p.2 ELEC p.2 MHO	
mi	International mile, length (1609.344 m). U ◀ UNITS LENG p.2 MI	
mi^2	International square mile, area (2589988.11034 m²). U ◀ UNITS AREA p.2 MI^2	
mil	Mil, length (.0000254 m). U ◀ UNITS LENG p.4 MIL	
min	Minute, time (60 s). U ◀ UNITS TIME MIN	
MIN	Minimum of two real numbers. F MTH PARTS p.2 MIN	148

Name, Key or Label	Description Type, Keys	Page
MIN	Sets alarm repeat interval in minutes. O ◀ TIME ALRM RPT MIN	445
MINR	Minimum machine-representable real number ($1.00000000000E^{-499}$). F MTH PARTS p.4 MINR	144
MIN+	Increments system time by one minute. O ◀ TIME ADJST MIN+	443
MIN−	Decrements system time by one minute. O ◀ TIME ADJST MIN−	443
MINΣ	Finds minimum column values in statistics matrix in ΣDAT. C ◀ STAT p.2 MINΣ	374
miUS	US statute mile, length (1609.34721869 m). U ◀ UNITS LENG p.3 MIUS	
miUS^2	US statute square mile, area (258998.47032 m^2). U ◀ UNITS AREA p.2 MIUS^	
mm	Millimeter, length (.001 m). U ◀ UNITS LENG MM	
mmHg	Millimeter of mercury (torr), pressure (133.322368421 $kg/m \cdot s^2$). U ◀ UNITS p.2 PRESS MMH	

Name, Key or Label	Description Type, Keys	Page
ml	Milliliter (cubic centimeter), volume (1×10^{-6} m^3). U ◀ UNITS VOL p.3 ML	
ML	Switches multi-line and single-line display. O ◀ MODES p.2 ML	221
MOD	Modulo. F MTH PARTS p.2 MOD	148
◀ MODES	Selects MODES menu. O ◀ MODES	
▶ MODES	Selects MODES Customization menu. O ▶ MODES	
MODL	Selects STAT MODL (statistics model) menu. O ◀ STAT p.4 MODL	377
mol	Mole, mass (1 mol). U ◀ UNITS MASS p.3 MOL	
Mpc	Megaparsec, length ($3.08567818585 \times 10^{22}$ m). U ◀ UNITS LENG p.2 MPC	
mph	Miles per hour, speed (.44704 m/s). U ◀ UNITS SPEED MPH	

Name, Key or Label	Description Type, Keys	Page
MTH	Selects MTH (math) menu. O MTH	
M/D	Switches date display format. O ↰ TIME SET M/D	442
m/s	Meters per second, speed (1 m/s). U ↰ UNITS SPEED M/S	
N	Newton, force (1 kg·m/s^2). U ↰ UNITS p.2 FORCE N	
NΣ	Returns number of rows in Σ*DAT*. C ↰ STAT p.5 NΣ	383
NEG	Negate. A +/-	134
NEW	Takes algebraic or matrix from stack, prompts for name, stores named algebraic in *EQ*, or named matrix in Σ*DAT*. ↰ PLOT NEW ↰ SOLVE NEW O ↰ STAT NEW	257 368
NEWOB	Decouples object from list or variable name. C ↰ MEMORY p.2 NEWO	
NEXT	Ends a definite-loop structure. C PRG BRCH p.2 NEXT	502 506

Name, Key or Label	Description Type, Keys	Page
NEXT	Displays but does not execute next one or two objects in suspended program. O [PRG] CTRL NEXT	484
nmi	Nautical mile, length (1852 m). U [◀][UNITS] LENG p.3 NMI	
NONE	Cancels alarm repeat interval and returns to TIME ALRM menu. O [◀][TIME] ALRM RPT NONE	445
NOT	Logical or binary NOT. [PRG] TEST NOT F [MTH] BASE p.4 NOT	 493 210
NUM	Returns character code of first character in string. C [PRG] OBJ p.3 NUM	92
[→NUM]	Evaluates algebraic to number. C [▶][→NUM]	127
NXEQ	Rotates list of equations in *EQ*. ... SOLVR NXEQ O ... FCN p.2 NXEQ	 272 309
[NXT]	Selects next page of menu. O [NXT]	56

Name, Key or Label	Description Type, Keys	Page
OBJ	Selects PRG OBJ (program object) menu. O [PRG] OBJ	
OBJ→	Returns object components to stack. C [PRG] OBJ OBJ→	93
OCT	Sets octal base. [MTH] BASE OCT C ↰ MODES p.4 OCT	208
[OFF]	Turns calculator off. O [↱][OFF]	25
OFF	Turns calculator off. C [PRG] CTRL p.3 OFF	540
OLDPRT	Remaps HP 48 character set to match HP 82240A Infrared Printer. C ↰[PRINT] p.2 OLDPR	603
[ON]	Turns calculator on. O [ON]	25

Name, Key or Label	Description Type, Keys	Page
OPENIO	Opens serial port. C ◀ I/O p.2 OPENI	615
OR	Logical or binary OR. MTH BASE p.4 OR F PRG TEST OR	 210 493
ORDER	Rearranges VAR menu in order specified in list. C ◀ MEMORY ORDER	113
ORDER	Puts selected equation at top of Equation Catalog list. ◀ PLOT CAT p.2 ORDER ◀ SOLVE CAT p.2 ORDER O ▶ ALGEBRA p.2 ORDER Puts selected statistical data at top of Statistics Catalog list. O ◀ STAT CAT p.2 ORDER	260 372
OVER	Duplicates object in level 2 in level 1. C PRG STK OVER	79
oz	Ounce, mass (.028349523135 kg). U ◀ UNITS MASS OZ	

Name, Key or Label	Description Type, Keys	Page
ozfl	US fluid ounce, volume ($2.95735295625 \times 10^{-5}$ m^3). U ◀ UNITS VOL p.3 OZFL	
ozt	Troy ounce, mass (.031103475 kg). U ◀ UNITS MASS p.2 OZT	
ozUK	UK fluid ounce, volume (2.8413075×10^{-5} m^3). U ◀ UNITS VOL p.3 OZUK	
P	Poise, dynamic viscosity (.1 kg/m·s) U ◀ UNITS p.3 VISC P	
Pa	Pascal, pressure (1 kg/m·s^2) U ◀ UNITS p.2 PRESS PA	
PARAMETRIC	Selects PARAMETRIC plot type. C ... PTYPE PARA	327
PARITY	Selects one of 5 possible parity settings. C ◀ I/O SETUP PARIT	617
PARTS	Selects MTH PARTS menu. O MTH PARTS	
PATH	Returns list containing path to current directory. C ◀ MEMORY PATH	120

Name, Key or Label	Description Type, Keys	Page
pc	Parsec, length ($3.08567818585 \times 10^{16}$ m). U ◀ UNITS LENG p.2 PC	
PDIM	Changes size of *PICT*. ... PLOTR p.3 PDIM C ▶ PLOT p.3 PDIM	325
▶ PDIM	Recalls size of *PICT* to stack. ... PLOTR p.3 ▶ PDIM O ▶ PLOT p.3 ▶ PDIM	319
pdl	Poundal, force (.138254954376 kg·m/s^2). U ◀ UNITS p.2 FORCE PDL	
PERM	Permutations. F MTH PROB PERM	147
PGDIR	Purges specified directory. C ◀ MEMORY p.3 PGDIR	123
ph	Phot, illuminance (795.774715459 cd/m^2) U ◀ UNITS p.3 LIGHT PH	

Name, Key or Label	Description Type, Keys	Page
PICK	Copies object in level *n* to level 1. C PRG STK PICK	79
PICK	Copies object in current level to level 1. O ... ↑STK PICK	71
PICT	Returns *PICT* to level 1. C PRG DSPL PICT	341
PIXOFF	Turns off specified pixel in *PICT*. C PRG DSPL p.2 PIXOF	339
PIXON	Turns on specified pixel in *PICT*. C PRG DSPL p.2 PIXON	339
PIX?	Tests whether specified pixel in *PICT* is on or off. C PRG DSPL p.2 PIX?	339
pk	Peck, volume (.0088097675 m^3). U ↶ UNITS VOL p.4 PK	
PKT	Sends KERMIT commands to a server. C ↶ I/O p.2 PKT	615

Name, Key or Label	Description Type, Keys	Page
[PLOT]	Selects PLOT menu. O [←][PLOT] Selects PLOT PLOTR menu. O [→][PLOT]	
PLOT	Makes the selected entry the current statistical matrix and displays the third page of the STAT menu. O [←][STAT] CAT PLOT	371
PLOTR	Selects PLOT PLOTR menu. [←][PLOT] PLOTR [←][PLOT] CAT PLOTR [→][ALGEBRA] PLOTR O [←][SOLVE] CAT PLOTR	
PMAX	Sets upper-right plot coordinates. C Must be typed in.	
PMIN	Sets lower-left plot coordinates. C Must be typed in.	
[POLAR]	Switches rectangular and polar coordinates. O [→][POLAR]	158
POLAR	Selects POLAR plot type. C ... PTYPE POLAR	327

Name, Key or Label	Description Type, Keys	Page
POS	Returns the position of substring in string or object in list. C [PRG] OBJ p.3 POS	93
POWR	Selects UNITS POWR (power) menu. O [◀][UNITS] p.2 POWR	
PREDV	Predicted value. C Must be typed in.	
PREDX	Returns predicted value for independent variable, given value of dependent variable. C [◀][STAT] p.4 PREDX	376
PREDY	Returns predicted value for dependent variable, given value of independent variable. C [◀][STAT] p.4 PREDY	377
PRESS	Selects UNITS PRESS (pressure) menu. O [◀][UNITS] p.2 PRES	
[◀][PREV]	Selects previous page of menu. O [◀][PREV]	56
[▶][PREV]	Selects first page of menu. O [▶][PREV]	56

Name, Key or Label	Description Type, Keys	Page
[PRG]	Selects PRG (program) menu. O [PRG]	
[PRINT]	Selects PRINT menu. O [↰][PRINT]	
PRLCD	Prints display. C [↰][PRINT] PRLCD O Simultaneously press [ON] [MTH]	603
PROB	Selects MATH PROB (probability) menu. O [MTH] PROB	
PROMPT	Displays prompt string in status area and halts program execution. C [PRG] CTRL p.2 PROM	521
PRST	Prints all objects on stack. C [↰][PRINT] PRST	603
PRSTC	Prints all objects on stack in compact format. C [↰][PRINT] PRSTC	603

Name, Key or Label	Description Type, Keys	Page
PRVAR	Prints name and contents of one or more variables (including port names). C ◀ PRINT PRVAR	603
PR1	Prints object in level 1. ◀ PRINT PR1 C ▶ PRINT	603
psi	Pounds per square inch, pressure (6894.75729317 kg/m·s^2). U ◀ UNITS p.2 PRESS PSI	
pt	Pint, volume (.000473176473 m^3). U ◀ UNITS VOL p.2 PT	
PTYPE	Selects PLOT PTYPE menu. ◀ PLOT PTYPE ... PLOTR p.2 PTYPE O ▶ PLOT p.2 PTYPE	
PURGE	Purges one or more specified variables. C ◀ PURGE	114
PURGE	Purges one or more specified variables. If only one untagged variable specified, saves previous contents for recovery by LASTARG. O ◀ PURGE	114

Name, Key or Label	Description Type, Keys	Page
PURG	Purges selected equation. ◀ SOLVE CAT p.2 PURG ▶ PLOT CAT p.2 PURG O ▶ ALGEBRA CAT p.2 PURG Purges selected statistical matrix. O ◀ STAT CAT p.2 PURG Purges selected alarm. ◀ TIME CAT PURG O ▶ TIME PURG	260 372 450
PUT	Replaces element in array or list. C PRG OBJ p.4 PUT	94
PUTI	Replaces element in array or list and increments index. C PRG OBJ p.4 PUTI	94
PVARS	Returns list of current backup objects and libraries within a port. C ◀ MEMORY p.2 PVARS	647
PVIEW	Displays *PICT* with specified pixel at upper-left corner of display. C PRG DSPL PVIEW	342

Name, Key or Label	Description Type, Keys	Page
PWRFIT	Set curve-fitting model to Power. C ◀ STAT p.4 MODL PWR	377
PX→C	Converts pixel coordinates to user-unit coordinates. C PRG DSPL p.2 PX→C	324
→Q	Converts number to fractional equivalent. C ◀ →Q	134
QUAD	Finds solutions of first or second order polynomial. C ◀ ALGEBRA QUAD	391
QUOTE	Returns argument expression unevaluated. F ◀ ALGEBRA p.2 QUOT	
qt	Quart, volume (.000946352946 m^3). U ◀ UNITS VOL p.2 QT	
→Qπ	Calculates and compares quotients of number and number/π. C ◀ ALGEBRA p.2 →Qπ	134
r	Radian, plane angle (.1591549343092). U ◀ UNITS p.3 ANGL R	
R	Roentgen, radiation exposure (.000258 A·s/kg). U ◀ UNITS p.3 RAD p.2 R	

Name, Key or Label	Description Type, Keys	Page
°R	Degrees Rankine, temperature. U ◀ UNITS p.2 TEMP °R	
rad	Rad, absorbed dose (.01 m^2/s^2). U ◀ UNITS p.3 RAD RAD	
RAD	Sets Radians mode. C ◀ MODES p.3 RAD	139
RAD	Switches Radians and Degrees mode. O ◀ RAD	30
RAD	Selects UNITS RAD (radiation) menu. O ◀ UNITS p.3 RAD	
RAND	Returns random number. C MTH PROB RAND	147
RATIO	Prefix form of / used by EquationWriter application. F Must be typed in.	

Name, Key or Label	Description Type, Keys	Page
RCEQ	Returns equation in *EQ* to level 1. ◀ PLOT ▶ STEQ ◀ SOLVE ▶ STEQ ... PLOTR ▶ DRAW C ▶ PLOT ▶ DRAW	256
RCL	Recalls object stored in specified variable to stack. C ▶ RCL	110
RCL	Inserts algebraic from level 1 into EquationWriter equation. O ▶ RCL	246
RCLALARM	Recalls specified alarm from system alarm list. C ◀ TIME ALRM p.2 RCLAL	453
RCLF	Returns binary integer representing states of system flags. C ▶ MODES p.2 RCLF	518
RCLKEYS	Returns list of current user-key assignments. C ▶ MODES RCLK	220
RCLMENU	Returns menu number of current menu. C ▶ MODES p.2 RCLM	535

Name, Key or Label	Description Type, Keys	Page
RCLΣ	Recalls current statistical matrix in Σ*DAT*. C ◀ STAT ▶ STOΣ	368
RCWS	Recalls binary integer wordsize. C MTH BASE RCWS	207
rd	Rod, length (5.0292100584 m). U ◀ UNITS LENG p.3 RD	
RDM	Redimensions array. C MTH MATR RDM	360
RDZ	Sets random number seed. C MTH PROB RDZ	147
RE	Returns real part of complex number or array. F MTH PARTS RE	166
RECN	Waits for stack-specified data from remote source running Kermit software. C ◀ I/O p.2 RECN	615
RECV	Waits for sender-specified data from remote source running Kermit software. C ◀ I/O RECV	614

Name, Key or Label	Description Type, Keys	Page
rem	Rem, dose equivalent (.01 m^2/s^2). U ◀ UNITS p.3 RAD REM	
REPEAT	Begins REPEAT clause. C PRG BRCH p.2 REPEA	512
REPL	Replaces portion of object with another like object. PRG OBJ p.3 REPL C PRG DSPL p.3 REPL	 95 343
REPL	Replaces portion of *PICT* with level-1 graphics object. ... DRAW p.3 REPL ... AUTO p.3 REPL O ◀ GRAPH p.3 REPL	341
REPL	Replaces specified subexpression with algebraic from stack. O ◀ EQUATION ◀ REPL	247 398

Name, Key or Label	Description Type, Keys	Page
RES	Sets spacing between plotted points. ... PLOTR p.2 RES C ↱ PLOT p.2 RES	321
↱ RES	Recalls spacing to stack. ... PLOTR p.2 ↱ RES O ↱ PLOT p.2 ↱ RES	318
RESET	Resets plot parameters in *PPAR* in the current directory to their default states and erases and resizes *PICT*. ... PLOTR p.2 RESET O ↱ PLOT p.2 RESET	323
RESTORE	Replaces *HOME* directory with backup copy. C ↰ MEMORY p.3 RESTO	648

Name, Key or Label	Description Type, Keys	Page
[REVIEW]	Displays statistical data in Σ*DAT*. O [◀] [STAT] [◀] [REVIEW]	368
	Displays current equation and plot parameters. ... PLOTR [◀] [REVIEW] [▶] [PLOT] [◀] [REVIEW] ... DRAW [◀] [REVIEW] ... AUTO [◀] [REVIEW]	294
	O [◀] [GRAPH] [◀] [REVIEW]	303
	Displays current equation. O [◀] [SOLVE] [◀] [REVIEW] [◀] [PLOT] [◀] [REVIEW]	256 290
	Displays current equation and values of SOLVR variables. O ... SOLVR [◀] [REVIEW]	265
	Displays unit names corresponding to selected menu. O [◀] [UNITS] ... [◀] [REVIEW]	191
	Displays pending alarm. O [◀] [TIME] [◀] [REVIEW]	439
	In other menus: Lists operation names and types. O [◀] [REVIEW]	112

Name, Key or Label	Description Type, Keys	Page
RL	Rotates left by one bit. C [MTH] BASE p.2 RL	211
RLB	Rotates left by one byte. C [MTH] BASE p.2 RLB	211
RND	Rounds fractional part of number or name. F [MTH] PARTS p.4 RND	148
RNRM	Calculates row norm of array. C [MTH] MATR p.2 RNRM	360
ROLL	Moves object in level (n + 1) to level 1. C [PRG] STK ROLL	79
ROLL	Rolls object in current level to level 1. O ... ↑STK ROLL	71
ROLLD	Moves object in level 2 to level n. C [PRG] STK ROLLD	79
ROLLD	Moves object in level 1 to current level. O ... ↑STK ROLLD	71
ROOT	Solves for unknown variable in equation. C [↰][SOLVE] ROOT	256

Name, Key or Label	Description Type, Keys	Page
ROOT	Moves graphics cursor to intersection of function plot and *x*-axis, displays value of root, returns value to stack. O ◀ GRAPH FCN ROOT	308
ROT	Moves object in level 3 to level 1. C PRG STK ROT	79
+ROW	Inserts row of zeros at current row. O ▶ MATRIX p.2 +ROW	351
−ROW	Deletes current row. O ▶ MATRIX p.2 −ROW	351
RPT	Selects TIME ALRM RPT (alarm repeat) menu. O ◀ TIME ALRM RPT	
RR	Rotates right by one bit. C MTH BASE p.2 RR	211
RRB	Rotates right by one byte. C MTH BASE p.2 RRB	211
RSD	Calculates correction to solution of system of equations. C MTH MATR RSD	362
RULES	Activates RULES transformation menu for specified object. O ◀ EQUATION ◀ RULES	398

Name, Key or Label	Description Type, Keys	Page
R→B	Real-to-binary conversion. C [MTH] BASE p.2 R→B	210
R→C	Real-to-complex conversion. C [PRG] OBJ pg.2 R→C	95
R→D	Radians-to-degrees conversion. F [MTH] VECTR p.2 R→D	142
R∠Z	Selects Polar/Cylindrical mode. [MTH] VECTR R∠Z O [◄] [MODES] p.3 R∠Z	171
R∠∠	Selects Polar/Spherical mode. [MTH] VECTR R∠∠ O [◄] [MODES] p.3 R∠∠	171
s	Second, time (1 s). U [◄] [UNITS] TIME S	
S	Siemens, electric conductance ($1\ A^2 \cdot s^3/kg \cdot m^2$). U [◄] [UNITS] p.2 ELEC p.2 S	

Name, Key or Label	Description Type, Keys	Page
SAME	Tests two objects for equality. C [PRG] TEST SAME	492
sb	Stilb, luminance (10000 cd/m^2) U [↰][UNITS] p.3 LIGHT SB	
SBRK	Sends serial break. C [↰][I/O] p.3 SBRK	633
SCALE	Sets scale of PLOT axes. ... PLOTR p.2 SCALE C [↱][PLOT] p.2 SCALE	295
[↱]SCALE	Recalls scale to stack. ... PLOTR p.2 [↱] SCALE O [↱][PLOT] p.2 [↱] SCALE	294
SCATRPLOT	Draws scatter plot of statistical data in ΣDAT. C [↰][STAT] p.3 SCATR	379
SCATTER	Selects SCATTER plot type. C ... PTYPE p.2 SCATT	328

Name, Key or Label	Description Type, Keys	Page
SCI	Selects Scientific display mode. C ◀ MODES SCI	58
SCLΣ	Autoscales data in ΣDAT for scatter plot. C Must be typed in.	
SCONJ	Conjugates contents of variable. C ▶ MEMORY p.2 SCON	116
SDEV	Calculates standard deviation. C ◀ STAT p.2 SDEV	374
SEC	Sets alarm repeat interval to *n* seconds. O ◀ TIME ALRM RPT SEC	445
SEC+	Increments current time by 1 second. O ◀ TIME ADJST SEC+	443
SEC−	Decrements current time by 1 second. O ◀ TIME ADJST SEC−	443
SEND	Sends contents of variable to another device. C ◀ I/O SEND	614
SERVER	Puts HP 48 into Kermit Server mode. ◀ I/O SERV C ▶ I/O	614

Name, Key or Label	Description Type, Keys	Page
SET	Selects TIME SET menu. O ◀ TIME SET	
SET	Sets alarm. O ◀ TIME ALRM SET	445
SETUP	Selects I/O SETUP menu. O ◀ I/O SETUP	
SF	Sets specified flag. PRG TEST p.3 SF C ▶ MODES p.2 SF	516
SHOW	Reconstructs expression to resolve implicit variable name. C ◀ ALGEBRA SHOW	394
SIGN	Returns sign of number. F MTH PARTS SIGN	149
SIN	Sine. A SIN	140
SINH	Hyperbolic sine. A MTH HYP SINH	137

Name, Key or Label	Description Type, Keys	Page
SINV	Replaces contents of variable with its inverse. C [↱][MEMORY] p.2 SINV	116
SIZE	Finds dimensions of list, array, string, algebraic object, or graphics object. [PRG] OBJ p.3 SIZE C [PRG] DSPL p.2 SIZE	 95 342
←SKIP	Moves cursor left to next logical break. [↰][EDIT] ←SKIP O ... EDIT ←SKIP	68
SKIP→	Moves cursor right to next logical break. [↰][EDIT] SKIP→ O ... EDIT SKIP→	68
SL	Shifts left by one bit. C [MTH] BASE p.3 SL	211

Name, Key or Label	Description Type, Keys	Page
SLB	Shifts left by one byte. C [MTH] BASE p.3 SLB	211
SLOPE	Calculates and displays slope of function at cursor position, returns slope to stack. O ... FCN SLOPE	308
slug	Slug, mass (14.5939029372 kg). U [↰][UNITS] MASS SLUG	
SNEG	Negates contents of variable. C [↱][MEMORY] p.2 SNEG	116
[SOLVE]	Selects SOLVE menu. O [↰][SOLVE]	
SOLVR	Selects SOLVR menu. [↰][SOLVE] SOLVR [↰][SOLVE] CAT SOLVR [↱][SOLVE] [↰][PLOT] CAT SOLVR O [↱][ALGEBRA] SOLVR	
[SPC]	Types a blank space in command line. O [SPC]	
SPEED	Selects UNITS SPEED menu. O [↰][UNITS] SPEED	

Name, Key or Label	Description Type, Keys	Page
SQ	Returns square of level-1 object. A ◀ x^2	134
SR	Shifts right by one bit. C MTH BASE p.3 SR	211
sr	Steradian, solid angle ($7.95774715459 \times 10^{-2}$). U ◀ UNITS p.3 ANGL SR	
SRB	Shifts right by one byte. C MTH BASE p.3 SRB	211
SRECV	Reads specified number of characters from I/O port. C ◀ I/O p.3 SRECV	633
SST	Single-steps through suspended program. O PRG CTRL SST	484
SST↓	Single-steps through suspended program and its subroutines. O PRG CTRL SST↓	486
st	Stere, volume (1 m^3). U ◀ UNITS VOL ST	
St	Stokes, kinematic viscosity (.0001 m^2/s) U ◀ UNITS p.3 VISC ST	

Name, Key or Label	Description Type, Keys	Page
START	Begins definite loop. C PRG BRCH START	502
↰START	Types START NEXT. O PRG BRCH ↰START	502
↱START	Types START STEP. O PRG BRCH ↱START	504
↰STAT	Selects STAT (statistics) menu. O ↰STAT	
↱STAT	Selects page 2 of STAT menu. O ↱STAT	
STD	Selects Standard display mode. C ↰MODES STD	58
STEP	Ends definite loop. C PRG BRCH p.2 STEP	504 508

Name, Key or Label	Description Type, Keys	Page
STEQ	Stores level 1 equation in *EQ*. ◀ PLOT STEQ ... PLOTR ◀ DRAW ▶ PLOT ◀ DRAW C ◀ SOLVE STEQ	257
STIME	Sets serial transmit/receive timeout. C ◀ I/O p.3 STIME	633
STK	Selects PRG STK (program stack) menu. O PRG STK	
STK	Switches Last Stack recovery on and off. O ◀ MODES p.2 STK	221
↑STK	Selects Interactive Stack. ... EDIT ↑STK ◀ EDIT ↑STK ▶ VISIT ↑STK O ▶ MATRIX p.2 ↑STK	70 351

Name, Key or Label	Description Type, Keys	Page
→STK	Copies selected equation to level 1. ... CAT p.2 →STK O ↷ ALGEBRA p.2 →STK Copies selected matrix to level 1. O ↶ STAT CAT →STK Copies selected alarm to level 1. ↶ TIME CAT →STK O ↷ TIME →STK Copies selected matrix element to level 1. O ↷ MATRIX p.2 →STK	260 371 450 351
STO	Stores object in variable. C STO	107
STO	Stores object in variable and saves previous contents of variable for recovery by LASTARG. O STO	107
STO	Returns EquationWriter equation or *PICT* to stack. O STO	229 303
STOALARM	Stores level 1 alarm in system alarm list. C ↶ TIME ALRM p.2 STOAL	453
STOF	Sets state of system and user flags. C ↷ MODES p.2 STOF	518
STOKEYS	Makes multiple user-key assignments. C ↷ MODES STOK	217

Name, Key or Label	Description Type, Keys	Page
STO+	Adds specified number or array to contents of specified variable. C [→] [MEMORY] STO+	115
STO−	Subtracts specified number or array from contents of specified variable. C [→] [MEMORY] STO−	116
STO*	Multiplies contents of specified variable by specified number. C [→] [MEMORY] STO*	116
STO/	Divides contents of specified variable by specified number. C [→] [MEMORY] STO/	116
STOΣ	Stores current statistics matrix in Σ*DAT*. C [←] [STAT] STOΣ	368
STR→	Converts string to component objects. C Must be typed in.	
→STR	Converts object into string. C [PRG] OBJ →STR	95
STWS	Sets binary integer wordsize. C [MTH] BASE STWS	207
SUB	Extracts specified portion of list or string, or graphics object. [PRG] OBJ p.3 SUB C [PRG] DSPL p.3 SUB	 96 343

Name, Key or Label	Description Type, Keys	Page
SUB	Returns specified portion of *PICT* to stack. ... DRAW p.3 SUB ... AUTO p.3 SUB O ◀ GRAPH p.3 SUB	341
SUB	Returns specified subexpression to stack. O ◀ EQUATION ◀ SUB	398
Sv	Sievert, dose equivalent (.01 m^2/s^2) U ◀ UNITS p.3 RAD SV	
SWAP	Exchanges objects in levels 1 and 2. C ◀ SWAP	63
SYM	Switches Symbolic and Numerical Results mode. O ◀ MODES SYM	144
SYSEVAL	Evaluates system object. *Use only as specified by HP applications.* C Must be typed in.	

Name, Key or Label	Description Type, Keys	Page
t	Metric ton, mass (1000 kg). U ◀ UNITS MASS p.2 T	
T	Tesla, magnetic flux (1 kg/As^2). U ◀ UNITS p.2 ELEC p.2 T	
←T	Move term left. O ◀ EQUATION ◀ RULES ←T Executes ←T until no change in subexpression. O ◀ EQUATION ◀ RULES ▶ ←T	402 410
T→ ▶ T→	Move term right. O ◀ EQUATION ◀ RULES T→ Executes T→ until no change in subexpression. O ◀ EQUATION ◀ RULES ▶ T→	402 410
%T	Returns percent fraction that level-1 is of level-2. F MTH PARTS p.2 %T	138
→TAG	Combines objects in levels 1 and 2 to create tagged object. C PRG OBJ →TAG	96
TAN	Tangent. A TAN	140

Name, Key or Label	Description Type, Keys	Page
TANH	Hyperbolic tangent. A [MTH] HYP TANH	137
TAYLR	Calculates Taylor's polynomial. C [↰][ALGEBRA] TAYLR	426
tbsp	Tablespoon, volume ($1.47867647813 \times 10^{-5}$ m^3). U [↰][UNITS] VOL p.3 TBSP	
TEMP	Selects UNITS TEMP (temperature) menu. O [↰][UNITS] p.2 TEMP	
TEST	Selects PRG TEST (program test) menu. O [PRG] TEST	
TEXT	Displays stack display. C [PRG] DSPL p.4 TEXT	344
THEN	Begins THEN clause. C [PRG] BRCH p.2 THEN	494
therm	EEC therm, energy (105506000 $kg \cdot m^2/s^2$) U [↰][UNITS] p.2 ENRG p.2 THER	
TICKS	Returns system time as binary integer in units of clock ticks. C [↰][TIME] p.2 TICKS	456

Name, Key or Label	Description Type, Keys	Page
TIME	Returns current time as a number. C ◀ TIME p.2 TIME	456
◀ TIME	Selects TIME menu. O ◀ TIME	
▶ TIME	Selects Alarm Catalog. O ▶ TIME	449
TIME	Selects UNITS TIME menu. O ◀ UNITS TIME	
→TIME	Sets system time. C ◀ TIME SET →TIM	442
>TIME	Sets alarm time. O ◀ TIME ALRM >TIME	445
TLINE	Switches pixels on line defined by coordinates in levels 1 and 2. C PRG DSPL TLINE	339

Name, Key or Label	Description Type, Keys	Page
TLINE	Switches pixels on and off on line between mark and cursor. ... DRAW p.2 TLINE ... AUTO p.2 TLINE O ↰ GRAPH p.2 TLINE	337
TMENU	Displays list-defined menu but does not change contents of *CST*. C ↱ MODES p.2 TMEN	539
ton	Short ton, mass (907.18474 kg). U ↰ UNITS MASS p.2 TON	
tonUK	Long (UK) ton, mass (1016.0469088 kg). U ↰ UNITS MASS p.2 TONU	
torr	Torr (mmHg), pressure (133.322368421 kg/ms^2). U ↰ UNITS p.2 PRESS TORR	
TOT	Sums each column of matrix in Σ*DAT*. C ↰ STAT p.2 TOT	374
TRANSIO	Selects one of three character translation settings. C ↰ I/O SETUP TRAN	618

Name, Key or Label	Description Type, Keys	Page
TRG*	Expands trigonometric and hyperbolic functions of sums and differences. O ◁ EQUATION ◀ RULES TRG*	409
TRN	Transposes matrix. C MTH MATR TRN	360
TRNC	Truncates (rounds down) number in level 2 as specified in level 1. F MTH PARTS p.4 TRNC	149
TRUTH	Selects TRUTH plot type. C ... PTYPE TRUTH	327
tsp	Teaspoon, volume ($4.92892159375 \times 10^{-6}$ m^3). U ◁ UNITS VOL p.3 TSP	
TSTR	Converts date and time in number form to string form. C ◁ TIME p.2 TSTR	455
TVARS	Returns variables containing specified object type. C ◁ MEMORY p.2 TVARS	98
TYPE	Returns type-number of argument object. PRG OBJ p.2 TYPE C PRG TEST TYPE	97
u	Unified atomic mass (1.66057×10^{-27} kg). U ◁ UNITS MASS p.3 U	

Name, Key or Label	Description Type, Keys	Page
UBASE	Converts unit object to SI base units. F [→] [UNITS] UBASE	196
UFACT	Factors specified compound unit. C [→] [UNITS] UFACT	199
→UNIT	Combines objects in levels 1 and 2 to create unit object. [PRG] OBJ p.2 →UNIT C [→] [UNITS] →UNIT	96
[←] [UNITS]	Selects UNITS Catalog menu. O [←] [UNITS]	
[→] [UNITS]	Selects UNITS Command menu. O [→] [UNITS]	
UNTIL	Begins UNTIL clause. C [PRG] BRCH p.2 UNTIL	510
UPDIR	Makes parent directory the current directory. C [←] [UP]	122
[USR]	Turns User mode on and off. O [←] [USR]	216
UTPC	Returns probability that chi-square random variable is greater than *x*. C [MTH] PROB p.2 UTPC	384

Name, Key or Label	Description Type, Keys	Page
UTPF	Returns probability that Snedecor's F random variable is greater than *x*. C [MTH] PROB p.2 UTPF	384
UTPN	Returns probability that normal random variable is greater than *x*. C [MTH] PROB p.2 UTPN	384
UTPT	Returns probability that Student's t random variable is greater than *x*. C [MTH] PROB p.2 UTPT	384
UVAL	Returns scalar of specified unit object. F [→] [UNITS] UVAL	206
V	Volt, electrical potential (1 $kg \cdot m^2/A \cdot s^3$). U [←] [UNITS] p.2 ELEC V	
VAR	Calculates variance of statistical data columns in ΣDAT. C Must be typed in.	
[VAR]	Selects VAR (variables) menu. O [VAR]	112
1-VAR	Makes the selected entry the current statistical matrix and displays the second page of the STAT menu. O [←] [STAT] CAT 1-VAR	371
2-VAR	Makes the selected entry the current statistical matrix and displays the fourth page of the STAT menu. O [←] [STAT] CAT 2-VAR	371
VARS	Returns list of variables in current directory. C [←] [MEMORY] VARS	113

Name, Key or Label	Description Type, Keys	Page
VEC	Switches vector and array modes. O ↱ MATRIX VEC	351
VECTR	Selects MTH VECTR (math vector) menu. O MTH VECTR	
VIEW	Copies level 1 object into appropriate environment for viewing. O ▼	67
	Copies object in current level into appropriate environment for viewing. O ... ↑STK VIEW	73
	Displays selected equation. O ... CAT VIEW	260
	Displays selected matrix. O ↰ STAT CAT VIEW	372
	Displays selected alarm. O ↰ TIME CAT VIEW	450
↱ VIEW	Copies object stored in variable in the current level into appropriate environment for viewing. O ... ↑STK ↱ VIEW	71
VISC	Selects UNITS VISC (viscosity) menu. O ↰ UNITS p.3 VISC	
VISIT	If argument is name, copies contents of associated variable into command line for editing. If argument is a stack level number, copies object in that level into command line for editing. O ↱ VISIT	66

Name, Key or Label	Description Type, Keys	Page
VOL	Selects UNITS VOL (volume) menu. O ◀ UNITS VOL	
VTYPE	Returns type number of object stored in local or global name. C PRG OBJ p.2 VTYPE	97
→V2	Combines two real numbers into a 2-D vector or complex number. C MTH VECTR p.2 →V2	167
→V3	Combines three real numbers into 3-D vector. C MTH VECTR p.2 →V3	183
V→	Separates 2- or 3-element vector according to current angle mode. C MTH VECTR p.2 V→	167
W	Watt, power (1 $kg \cdot m^2/s^3$) ◀ UNITS p.2 POWR W U ◀ UNITS p.2 ELEC W	
*W	Adjusts horizontal plot scale. C ... PLOTR p.3 *W	319
WAIT	Halts program execution for specified number of seconds or until key pressed. C PRG CTRL p.2 WAIT	534
Wb	Weber, magnetic flux (1 $kg \cdot m^2/A \cdot s^2$). U ◀ UNITS p.2 ELEC p.2 WB	

Name, Key or Label	Description Type, Keys	Page
WEEK	Sets alarm repeat interval to *n* weeks. O ◁ TIME ALRM RPT WEEK	445
WHILE	Begins indefinite loop. C PRG BRCH WHILE	512
◁ WHILE	Types WHILE REPEAT END O PRG BRCH ◁ WHILE	512
WID→	Increases column width and decrements number of columns. O ▷ MATRIX WID→	351
←WID	Decreases column width and increments number of columns. O ▷ MATRIX ←WID	351
X	Selects *x*-axis zoom. O ... ZOOM X	305
ΣX	Returns sum of data in independent column in Σ*DAT*. C ◁ STAT p.5 ΣX	383
ΣX^2	Returns sum of squares of data in independent column in Σ*DAT*. C ◁ STAT p.5 ΣX^2	383
XAUTO	Selects *x*-axis zoom with autoscaling. O ... ZOOM XAUTO	305

Name, Key or Label	Description Type, Keys	Page
XCOL	Specifies independent-variable column in matrix in ΣDAT. C ◀ STAT p.3 XCOL	376
▶ XCOL	Recalls independent-variable column number to stack. O ◀ STAT p.3 ▶ XCOL	376
XMIT	Without Kermit protocol, performs serial send of string. C ◀ I/O p.3 XMIT	632
XOR	Logical or binary exclusive OR. MTH BASE p.4 XOR F PRG TEST XOR	 211 493
XPON	Returns exponent of number. F MTH PARTS p.3 XPON	149
XRNG	Specifies *x*-axis display range. ... PLOTR XRNG C ▶ PLOT XRNG	295
▶ XRNG	Recalls *x*-axis display range to stack. ... PLOTR ▶ XRNG O ▶ PLOT ▶ XRNG	293

Name, Key or Label	Description Type, Keys	Page
XROOT	Returns level 1 root of the real number in level 2. A [→] [$\sqrt[y]{}$]	134
XY	Selects *x*- and *y*-axis zoom. O ... ZOOM XY	305
XYZ	Selects Rectangular mode. [MTH] VECTR XYZ O [←] [MODES] p.3 XYZ	171
ΣX*Y	Returns sum of products of data in independent and dependent columns in Σ*DAT*. C [←] [STAT] p.5 ΣX*Y	383
Y	Selects *y*-axis zoom. O ... ZOOM Y	305
ΣY	Returns sum of data in dependent column in Σ*DAT*. C [←] [STAT] p.5 ΣY	383
ΣY^2	Returns sum of squares of data in dependent column in Σ*DAT*. C [←] [STAT] p.5 ΣY^2	383

Name, Key or Label	Description Type, Keys	Page
YCOL	Selects indicated column of Σ*DAT* as dependent-variable column for two-variable statistics. C ◀ STAT p.3 YCOL	376
▶ YCOL	Recalls dependent-variable column number to stack. O ◀ STAT p.3 ▶ YCOL	376
yd	International yard, length (.9144 m). U ◀ UNITS LENG YD	
yd^2	Square yard, area (.83612736 m^2). U ◀ UNITS AREA YD^2	
yd^3	Cubic yard, volume (.764554857984 m^3). U ◀ UNITS VOL YD^3	
yr	Year, time (31556925.9747 s). U ◀ UNITS TIME YR	

Name, Key or Label	Description Type, Keys	Page
YRNG	Specifies *y*-axis display range. ... PLOTR YRNG C → PLOT YRNG	293
→ YRNG	Recalls *y*-axis display range to stack. ... PLOTR → YRNG O → PLOT → YRNG	293
Z-BOX	Zooms in to box whose opposite corners are defined by mark and cursor. ... DRAW Z-BOX ... AUTO Z-BOX O ← GRAPH Z-BOX	306
←Z-BOX	Zooms to box, autoscaling *y*-axis. ... DRAW ←Z-BOX ... AUTO ←Z-BOX O ← GRAPH ←Z-BOX	306

Name, Key or Label	Description Type, Keys	Page
ZOOM	Selects GRAPHICS ZOOM menu. ... DRAW ZOOM ... AUTO ZOOM O ↰ GRAPH ZOOM	304
+	Adds two objects. A +	90
+/−	If cursor is on a number, changes sign of mantissa or exponent of that number. Otherwise, acts as NEG key. C +/−	47
+⁄−	Switches cursor style between superimposing and inverting cross. ... DRAW p.3 +⁄− ... AUTO p.3 +⁄− O ↰ GRAPH p.3 +⁄−	302
+1−1	Add and subtract 1. O ↰ EQUATION ◀ RULES +1−1	402
−	Subtracts two objects. A −	134

Name, Key or Label	Description Type, Keys	Page
-()	Double negate and distribute. O ↰ EQUATION ◀ RULES -()	407
*	Multiplies two objects. A ×	134
*1	Multiply by 1. O ↰ EQUATION ◀ RULES *1	401
/	Divides two objects. A ÷	134
/1	Divide by 1. O ↰ EQUATION ◀ RULES /1	401
^	Raises number to specified power. A y^x	134
^1	Raise to power 1. O ↰ EQUATION ◀ RULES ^1	401
<	"Less-than" comparison. PRG TEST p.2 < F α ↰ 2	491

Name, Key or Label	Description Type, Keys	Page
≤	"Less-than-or-equal" comparison. PRG TEST p.2 ≤ F α ↰ 3	491
>	"Greater-than" comparison. PRG TEST p.2 > F α ↱ 2	491
≥	"Greater-than-or-equal" comparison. PRG TEST p.2 ≥ F α ↱ 3	491
=	"Equals" function. A ↰ =	129
= =	"Equality" comparison. PRG TEST p.2 == F α ↰ 1	492

Name, Key or Label	Description Type, Keys	Page
≠	"Not-equal" comparison. PRG TEST p.2 ≠ F α ◀ 0	492
α	Turns alpha-entry mode on and off. O α	52
{ }	Switches implicit parentheses on and off. O ◀ EQUATION ◀ { }	237
" "	Returns equation to stack as string. O ◀ EQUATION ▶ " "	230
°	Degree, plane angle ($2.77777777778 \times 10^{-3}$). U ◀ UNITS p.3 ANGL °	
!	Factorial. MTH PROB ! F α ◀ DEL	147

Name, Key or Label	Description Type, Keys	Page
$\int$	Integral. A [→][∫]	428
∂	Derivative. A [→][∂]	419
Ω	Ohm, electric resistance (1 kg·m^2/A^2·s^3). U [←][UNITS] p.2 ELEC Ω	
%	Returns level 2 percent of level 1. A [MTH] PARTS p.2 %	138
π	Symbolic constant π (3.14159265359). F [←][π]	144
Σ	Summation. F [→][Σ]	423
$\Sigma+$	Adds data point to matrix in ΣDAT. C [←][STAT] $\Sigma+$	368
$\Sigma-$	Subtracts data point from matrix in ΣDAT. C [←][STAT][←] $\Sigma+$	368
$\sqrt{}$	Returns square root of level-1 object. A [$\sqrt{x}$]	134
|	Appends local name, or variable of integration, and its value to evaluated expression. F [←][ALGEBRA] p.2 |	416

Name, Key or Label	Description Type, Keys	Page
1/( )	Double-invert and distribute. O ↰ EQUATION ◀ RULES 1/( )	407
12/24	Switches between 12-hour and 24-hour display formats. O ↰ TIME SET 12/24	442
(( ))	Parenthesize neighbors. O ↰ EQUATION ◀ RULES (( ))	403
(←	Expand-subexpression-left. O ↰ EQUATION ◀ RULES (← ↱ (← Executes (← until no change in subexpression. O ↰ EQUATION ◀ RULES ↱ (←	404 410
→( )	Distribute prefix function. O ↰ EQUATION ◀ RULES →( )	405
→)	Expand-subexpression-right. O ↰ EQUATION ◀ RULES →) ↱ →) Executes →) until no change in subexpression. O ↰ EQUATION ◀ RULES ↱ →)	404 410
↔	Commute arguments. O ↰ EQUATION ◀ RULES ↔	404

Name, Key or Label	Description Type, Keys	Page
→	Creates local variables. C [→] [→]	473
[◀]	Left shift key. O [◀]	52
[▶]	Right shift key. O [▶]	52
[⌫]	In command line, deletes character to left of cursor. O [⌫]	47
	Deletes contents of current stack level. O ... ↑STK [⌫]	72
[▲]	In multi-line command line: Moves cursor up one line.	75
	In Interactive Stack: Moves pointer up one level.	72
	In Graphics environment: Moves cursor up one pixel.	303
	In scrolling mode: Moves window up one pixel.	229
	In MatrixWriter application: Moves cell cursor up one row.	350
	In EquationWriter application: Starts numerator.	229
	In Selection environment: Moves cursor up one object.	399
	In catalogs: Moves pointer up one entry. O [▲]	

Name, Key or Label	Description Type, Keys	Page
[→][▲]	In multi-line command line: Moves cursor to top line.	75
	In Interactive Stack: Moves pointer to highest numbered stack level.	72
	In Graphics environment: Moves cursor to top edge of *PICT*.	303
	In MatrixWriter application: Moves cell cursor to top element of current column.	350
	In Selection environment: Moves cursor to topmost object.	399
	In catalogs: Moves pointer to top of list. O [→][▲]	
[←][▲]	In catalogs: Moves pointer up one page.	
	In Interactive Stack: Moves pointer up 4 levels. O [←][▲]	72

Name, Key or Label	Description Type, Keys	Page
▼	In multi-line command line: Moves cursor down one line.	75
	In Interactive Stack: Moves pointer down one level.	72
	In Graphics environment: Moves cursor down one pixel.	303
	In scrolling mode: Moves window down one pixel.	229
	In MatrixWriter application: Moves cell cursor down one row.	350
	In EquationWriter application: Ends subexpression.	229
	In Selection environment: Moves cursor down one object.	399
	In catalogs: Moves pointer down one entry. O ▼	
↱▼	In multi-line command line: Moves cursor to bottom line.	75
	In Interactive Stack: Moves pointer to level 1.	72
	In Graphics environment: Moves cursor to bottom edge of *PICT*.	303
	In MatrixWriter application: Moves cell cursor to last element of current column.	350
	In EquationWriter application: Ends all subexpressions.	229
	In Selection environment: Moves cursor to bottommost object.	399
	In catalogs: Moves pointer to end of list. O ↱▼	

Name, Key or Label	Description Type, Keys	Page
↰ ▼	In catalogs: Moves pointer down page. In Interactive Stack: Moves pointer down 4 levels. O ↰ ▼	72
◀	In command line: Moves cursor one character left. In Graphics environment: Moves cursor one pixel left. In scrolling mode: Moves window left one pixel. In MatrixWriter application: Moves cell cursor one column left. In EquationWriter application: Activates Selection environment. In Selection environment: Moves cursor one object left. O ◀	75 303 229 350 398 399
↰ ◀ (↰ GRAPH)	In EquationWriter application and Graphics environments: Invokes scrolling mode. O ↰ ◀ (↰ GRAPH)	229 303

Name, Key or Label	Description Type, Keys	Page
↱◀	In command line: Moves cursor to start of current line.	75
	In Graphics environment: Moves cursor to left edge of *PICT*.	303
	In MatrixWriter application: Moves cell cursor to first element of current row.	350
	In Selection environment: Moves cursor to leftmost object.	399
	O ↱◀	
▶	In command line: Moves cursor one character right.	75
	In Graphics environment: Moves cursor one pixel right.	303
	In scrolling mode: Moves window right one pixel.	229
	In MatrixWriter application: Moves cell cursor one column right.	350
	In EquationWriter application: Ends subexpression.	229
	In Selection environment: Moves cursor one object right.	399
	O ▶	

Name, Key or Label	Description Type, Keys	Page
⇥▶	In command line: Moves cursor to end of current line.	75
	In Graphics environment: Moves cursor to right edge of *PICT*.	303
	In MatrixWriter application: Moves cell cursor to last element of current row.	350
	In EquationWriter application: Ends all subexpressions.	229
	In Selection environment: Moves cursor to rightmost object. O ⇥▶	399

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For Information About Using the Calculator. If you have questions about how to use the calculator, first check the table of contents, the index, and "Answers to Common Questions" in appendix A. If you can't find an answer in the manual, you can contact the Calculator Support department:

Hewlett-Packard
Calculator Support
1000 N.E. Circle Blvd.
Corvallis, OR 97330, U.S.A.

(503) 757-2004
8:00 a.m. to 3:00 p.m. Pacific time
Monday through Friday

For Service. If your calculator doesn't seem to work properly, refer to appendix A for diagnostic instructions and information on obtaining service. If you are in the United States and your calculator requires service, mail it to the Corvallis Service Center:

Hewlett-Packard
Corvallis Service Center
1030 N.E. Circle Blvd.
Corvallis, OR 97330, U.S.A.
(503) 757-2002

If you are outside the United States, refer to appendix A for information on locating the nearest service center.

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HEWLETT PACKARD

Reorder Number
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00048-90078 English
Printed in Canada 7/90