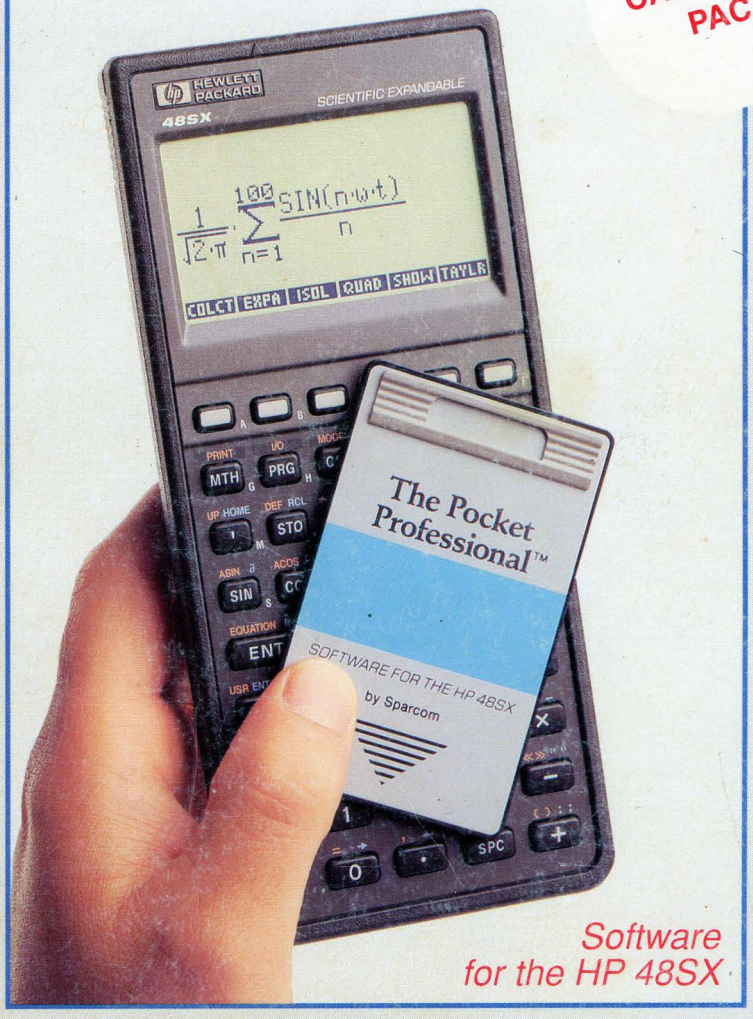
Sparcom

Pocket Professional™

OWNER'S MANUAL

CALCULUS PAC



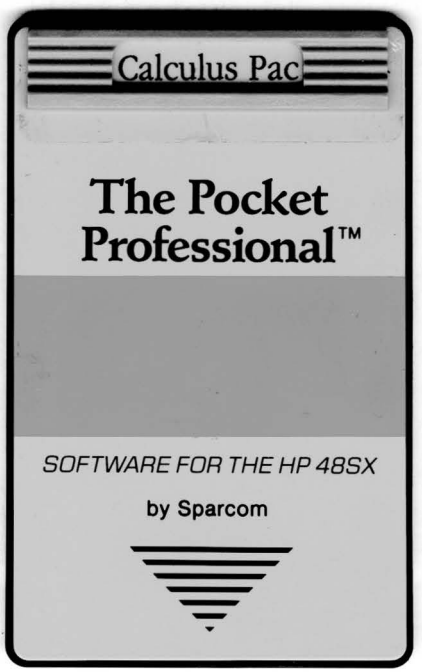
Software for the HP 48SX

JOSEPH R. HORN

The Pocket Professional™

Calculus

Owner's Manual



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Getting Started

Sparcom's Pocket Professional™ software is the first of its kind, developed to provide speed, efficiency and portability to students and professionals in the technical fields. When you slide the Pocket Professional™ Calculus Pac into your HP 48SX, your calculator is instantly transformed into an "electronic textbook," ready to efficiently solve your Calculus problems.

This section covers:

- ❑ How to Use This Manual and Pac
- ❑ Manual Conventions
- ❑ Installing and Removing an Application Card
- ❑ Using the Library Menu
- ❑ Stack and Flags
- ❑ Memory Requirements
- ❑ The 'SPARCOM' Directory

How to Use This Manual and Pac

This manual is designed to be used with your Sparcom Pocket Professional™ Calculus Pac in the following sequence:

❶ Read this section, "Getting Started," to learn how to install and operate the Calculus Pac and to get an overview of the structure of the Calculus Pac.

❷ Read the chapters in "Part 1: Interactive Menus," to learn how to use the interactive menus of the Calculus Pac, which provide easy-to-use, intuitive access to many of the functions in the Calculus Pac. The interactive menus introduce you to a "recognition" approach to problem-solving, of which the central feature is the *browser menu*—a vertical list of choices in full English words or standard abbreviations. A choice is selected by moving the arrow pointer up and down the menu with the cursor keys and pressing ENTER. (For more information, see Chapters 1 through 7.)

❸ Read the chapters in "Part 2: Stack-Based Toolkits," to learn how to use the various Toolkits of the Calculus Pac, which provide advanced functions and

custom environments. The stack-based Toolkits introduce you to a "recall" approach to problem-solving, of which the central feature is the *Toolkit menu*—a horizontal list of commands on HP 48SX softkeys (menukeys). Each command requires a specific number of arguments to be placed on the stack before pressing the softkey. (For more information, see Chapters 8 through 14.)

❹ Use the table of contents and index to locate further topics of interest.

Manual Conventions

There are a few simple conventions used throughout this and other Pocket Professional™ manuals:

- ❑ Keys on the HP 48SX keyboard are shown in a boxed typeface, such as ENTER or ATTN.
- ❑ Menukeys (softkeys), which are located at the bottom of the HP 48SX screen and correspond directly to the top row of keys on the HP 48SX keyboard, are shown in an inverse typeface, such as CALCU or QUIT.
- ❑ Programmable commands are always shown in uppercase letters, such as SIN or SIMPL.

Installing and Removing an Application Card

The HP 48SX has two ports for installing plug-in application cards. You can install your Calculus Pac in either port.

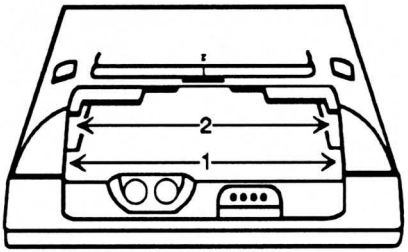
WARNING: Turn off the HP 48SX while installing or removing an application card! Otherwise, user memory may be erased.

Installing an Application Card

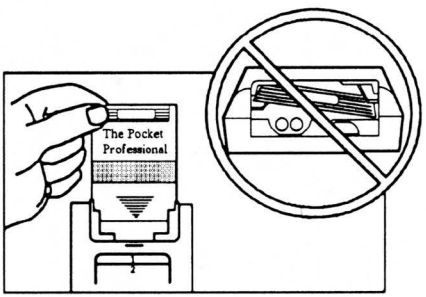
To install an application card, follow these steps:

❶ Turn the HP 48SX off. Do not press ON until you have completed the installation procedure.

❷ Remove the port cover. Press against the grip lines and push forward. Lift the cover to expose the two plug-in ports, as shown below:



❸ Select either empty port for the Pocket Professional™ card, and position the card just outside the slot. Point the triangular arrow on the card toward the HP 48SX port opening, as shown below:



❹ Slide the card firmly into the slot. After you first feel resistance, push the card about 1/4 inch further, until it is fully seated.

❺ Replace the port cover.

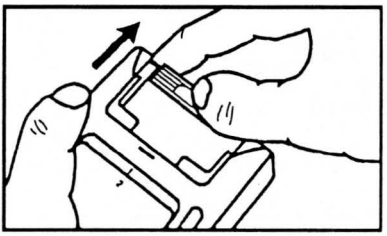
Removing an Application Card

To remove an application card, follow these steps:

❶ Turn the HP 48SX off. Do not press [ON] until you have completed the removal procedure.

❷ Remove the port cover. Press against the grip lines and push forward. Lift the cover to expose the two plug-in ports, as shown above.

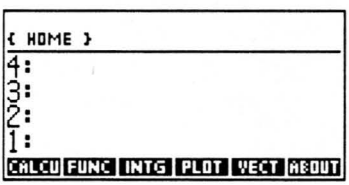
❸ Press against the card's grip and slide the card out of the port, as shown below:



❹ Replace the port cover.

Using the Library Menu

After you turn on your HP 48SX, press ← LIBRARY to display available libraries. Find and press CALCU to display the Calculus Pac Library menu. The screen displays new menukeys (softkeys) along the bottom, as shown:



The first six Library menu softkeys provide access to the interactive menus, the four Toolkit menus, and product information about the Calculus Pac. (The other 92 softkeys in the Library menu are all of the programmable commands in the Calculus Pac. They are organized into the four Toolkit menus so that you only need to use the first six softkeys in the Library menu.)

Library Menu Operations

Key	Description	See
CALCU	Provides access to the interactive menus.	Chapters 1–7
FUNC	Displays the Function Toolkit menu.	Chapter 8
INTG	Displays the Integration Toolkit menu.	Chapter 9
PLOT	Displays the Plotting Toolkit menu.	Chapters 10-13
VECT	Displays the Vector Toolkit menu.	Chapter 14
ABOUT	Shows product information about the Calculus Pac.	–

Stack and Flags

The flag settings of your HP 48SX will never be modified by the Calculus Pac unless you specifically change them from inside an interactive prompt, and the stack will only be changed as a direct result of a command or if you push →STK from the interactive menus to leave results on the stack. However, pressing ATTN multiple times in rapid succession may abort a command or the interactive menus prematurely, in which case your stack and flag settings may be modified.

The display font size for the interactive menus is controlled by the setting of user flag 57. If flag 57 is clear, the smaller display font will be used; if flag 57 is set, the larger display font will be used. Hidden line removal for 3D function graphs is controlled by the setting of user flag 58. If flag 58 is clear, hidden line removal will be active for 3D function graphs; if flag 58 is set, hidden line removal will not be active for 3D function graphs. The state of units for the interactive menus (on or off) is controlled by the setting of user flag 61. If flag 61 is clear, units are on; if flag 61 is set, units are off. These three user flags will be modified by the Calculus Pac if you press FONT, HLINE, or UNITS during operation.

Memory Requirements

A minimum of about 1.7K free memory is required to access the interactive menus of the Calculus Pac. To use the various Toolkit commands may require more memory for complicated operations, such as a high order Taylor expansion. If the Calculus Pac appears to be functioning incorrectly, it is possible that there is not enough free memory in your HP 48SX to complete the operation. (For more information, see Chapter 5 of the HP 48SX Owner's Manual, "Calculator Memory.")

The 'SPARCOM' Directory

Sparcom Pocket Professional™ Pacs create the directory 'SPARCOM' in the HOME directory of your HP 48SX. Inside the 'SPARCOM' directory, each Pac creates a subdirectory—for the Calculus Pac, that subdirectory is 'CALCUD'. When using the interactive menus, all variables for the Calculus Pac are stored inside 'CALCUD', so as not to conflict with your variables in other directories. If you are extremely low on free memory, you can purge the 'CALCUD' directory, using the command PGDIR. The next time you access the interactive menus, the 'CALCUD' directory will automatically be re-created. (For more information, see Chapter 7 of the HP 48SX Owner's Manual, "Directories.")

Part 1

Interactive Menus

Chapter 1

Main Menu

The Main menu lists the interactive modules of the Calculus Pac. From the Main menu you can solve functions, numerically integrate expressions, perform limit analyses, access the Sparcom Graphics Environments, work with symbolic vectors, look up constants, solve integrals, or view reference data.

This chapter covers:

- ❑ Using the Main Menu
- ❑ Moving Around the Screen
- ❑ Changing the Font Size
- ❑ Viewing Items Too Wide for the Display
- ❑ Using the Search Mode
- ❑ Text Editing
- ❑ Alpha Lock
- ❑ How to Load Data from the Stack

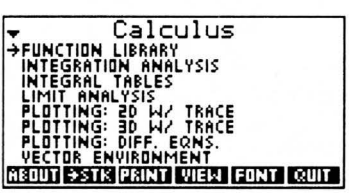
Using the Main Menu

To get to the Main menu, follow these steps:

❶ Press [↩] [LIBRARY] to display all libraries available to your HP 48SX.

❷ Find and press **CALCU** to display the Calculus Pac Library menu.

❸ Press the first softkey, **CALCU**, to start the Calculus Pac interactive menus:



The Main menu lists the interactive modules of the Calculus Pac. A module is selected by moving the pointer to it and pressing [ENTER].

Items in the Main Menu

Each item in the Main menu is briefly described below and is discussed in detail in the various chapters of this manual.

Main Menu Items

Item	Description	See
Function Library	Interactive prompts for 7 functions.	Chapter 2
Integration Analysis	Interactive methods to perform numerical approximation of integrals.	Chapter 3
Integral Tables	Nearly 100 integrals in six sections.	Chapter 4
Limit Analysis	Interactive analysis of functions, sequences, series, and recursions.	Chapter 5
Plotting: 2D w/ Trace	Information about and direct access to the Sparcom PLOT2 menu.*	Chapter 11
Plotting: 3D w/ Trace	Information about and direct access to the Sparcom PLOT3 menu.*	Chapter 12
Plotting: Diff. Eqns.	Information about and direct access to the Sparcom DIFEQ menu.*	Chapter 13
Vector Environment	Information about and direct access to the Vector Toolkit menu.†	Chapter 14
Constant Library	Includes 43 universal constants.	Chapter 6
Reference Data	Includes Greek alphabet, SI prefixes, trigonometric/hyperbolic definitions and relations, and vector formulas.	Chapter 7

Main Menu Operations

Screen	Softkeys
Main Menu	ABOUT ←STK PRINT VIEW FONT QUIT

* Accessing the Sparcom PLOT2, PLOT3, or DIFEQ menus in this manner automatically installs the Sparcom Plotting Keys and turns on User mode. (For more information, see "PKEY: Sparcom Plotting Keys" in Chapter 10.)

† Accessing the Vector Toolkit menu in this manner automatically installs the Sparcom Vector Keys and turns on User mode. (For more information, see "VKEY: Sparcom Vector Keys" in Chapter 14.)

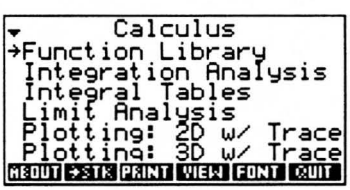
Key	Action
ABOUT	Displays a screen containing the revision number and product information about the Calculus Pac.
FONT	Toggles between the small and large fonts.
PRINT	Prompts for ONE or ALL to select items, and then sends those items to an IR printer.
QUIT	Quits the Calculus Pac to the HP 48SX stack.
→STK	Prompts for ONE or ALL to select items, and then copies those items to the stack.
VIEW	Displays entire text of an item too wide to fit on the screen.
ATTN	Quits the Calculus Pac to the HP 48SX stack.
ENTER	Moves down one level in the menu structure, entering the module selected by the pointer.
ON–MTH	Dumps the current screen to an IR printer.

Moving Around the Screen

Use the ▲ and ▼ keys to move the pointer up and down in a menu screen. Press ◀ ▼ to move the pointer to the bottom of the screen, or to page down one screen at a time if the pointer is already at the bottom of the screen. Press ◀ ▲ to move the pointer to the top of the screen, or to page up one screen at a time. Press ▶ ▼ to move the pointer to the very end of the menu or press ▶ ▲ to move the pointer to the very beginning of the menu.

Changing the Font Size

The default font for the Calculus Pac displays information in condensed, uppercase letters only. Pressing FONT will toggle the information to a larger font, which is case-sensitive:



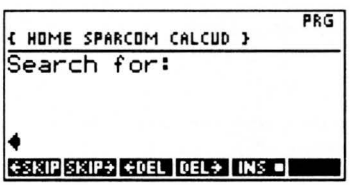
The font size will remain the same until FONT is pressed again.

Viewing Items Too Wide for the Display

If the text of a menu item is too wide to fit within the display, an ellipsis (...) appears at the end of the line. On some screens, the VIEW softkey will be present—press VIEW to display the entire text of an item, up to one entire screen size. Once the full text has been displayed, press ENTER or ATTN to return to the menu. At *all* screens, including those screens where VIEW is not present, pressing → VISIT will perform the same function. If an item does fit entirely on the screen, VIEW or → VISIT will beep and do nothing.

Using the Search Mode

When menu lists are long, it is faster to locate an item using the search mode. To initiate a search, press ↷ to display the following screen:



The HP 48SX is now locked in alpha-entry mode, as indicated by the alpha annunciator at the top of the screen (not shown). Alpha entry mode activates the white capital letters printed to the lower right of many keys. (For more information, see "Alpha Lock" below and Chapter 2 of the HP 48SX Owner's Manual, "The Keyboard and Display.")

To perform a search, enter the first letter or letters of the desired string and press ENTER. The search function is case-sensitive, and will scan through all information in the current menu. To enter a lowercase letter in the alpha entry mode, precede the letter with ←. To abort the search, press ATTN.

Text Editing

The softkeys present at the search screen and at many data input screens are command line editing keys. They allow you to edit the search string or input data. Their functions are summarized below. (For more information, see Chapter 3 of the HP 48SX Owner's Manual, "The Stack and Command Line.")

Text Editing Operations

Screen	Softkeys
Text Editing	←SKIP SKIP→ ←DEL DEL→ INS ↑STK

Key	Action
←DEL	Deletes all characters in the current word prior to the cursor.
DEL→	Deletes all characters between the cursor's current position and the first character of the next word.
INS	Toggles between insert and type-over modes.
←SKIP	Moves the cursor to the beginning of the current word.
SKIP→	Moves the cursor to the beginning of the next word.
↑STK	Activates a limited version of the Interactive Stack, allowing arguments to be copied from the stack to the command line for editing by pressing ECHO.
▲	
ATTN	Clears the command line if there is text present, or aborts text entry if the command line is already blank.
ENTER	Accepts the current command line as the entry and returns to the previous menu or list.

Alpha Lock

Flag –60 controls whether or not Alpha Lock mode is set. The default setting for flag –60 is clear, which means that pressing [α] places the HP 48SX in alpha-entry mode for only one character, and you must press [α] [α] to lock alpha-entry mode. If flag –60 is set, then pressing [α] only once locks alpha-entry mode. The examples in this manual assume that flag –60 is clear. (For more information, see Chapter 2 of the HP 48SX Owner's Manual, "The Keyboard and Display.")

How to Load Data from the Stack

At all data input prompts, it is possible to copy values from the HP 48SX stack to the command line, even though the Calculus Pac is executing. This is achieved through a limited version of the Interactive Stack. To activate the Interactive Stack at a data input prompt, press [▲], or if that does not work, press [↩] [EDIT] to display the EDIT menu and then press [↑STK]. At this point, unless the stack is empty, the screen will display the contents of the stack. Move the pointer up and down the stack by pressing [▲] and [▼], and when you reach the desired value, press [ECHO] to copy it to the command line for editing. To exit the Interactive Stack and return to the command line, press [ENTER] or [ATTN]. After returning to the command line, you can edit the value with the editing softkeys described above. (For more information, see Chapter 3 of the HP 48SX Owner's Manual, "The Stack and Command Line.")

Chapter 2

Function Library

The Function Library provides interactive prompts for seven functions, including point-slope, polynomial, and cubic spline fitting, piecewise function entry, polynomial building and root-finding, and arbitrary point Taylor expansions.

This chapter covers:

- ❑ Using the Function Library
- ❑ Fitting to One Point and One Slope
- ❑ Fitting to Two Points and Two Slopes
- ❑ Fitting to Many Points
- ❑ Entering a Piecewise Function
- ❑ Building a Polynomial from the Roots
- ❑ Finding the Roots of a Polynomial
- ❑ Calculating a Taylor Expansion
- ❑ Result Screen Operations

Using the Function Library

To get to the Function Library, follow these steps:

❶ Press ↩ LIBRARY to display all libraries available to your HP 48SX.

❷ Find and press CALCU to display the Calculus Pac Library menu.

❸ Press the first softkey, CALCU, to start the Calculus Pac interactive menus.

❹ At Main menu, make sure pointer is at "Function Library" and press ENTER:

The Function Library menu lists the seven interactive functions of the Calculus Pac. A function is selected by moving the pointer to it and pressing ENTER.

Items in the Function Library Menu

Each item in the Function Library menu is briefly described below and is discussed in detail in the various sections of this chapter.

Function Library Menu Items

Item	Description
Fitting (1 Pt/Slope)	Produces a linear function whose graph passes through a given point with a given slope.
Fitting (2 Pt/Slopes)	Produces the cubic function (spline) whose graph passes through two given points with given slopes.
Fitting (Many Points)	Finds the interpolating polynomial of many points.
Piecewise Functions	A series of prompts to define a piecewise function.
Polynomial Builder	Finds the polynomial with a given series of roots.
Polynomial Solver	Returns the real or complex roots of a polynomial.
Taylor Expansion	Finds the Taylor expansion about any point.

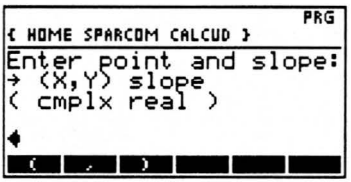
Function Library Menu Operations

Screen	Softkeys
Function Lib.	MAIN →STK PRINT VIEW FONT UP

Key	Action
FONT	Toggles between the small and large fonts.
MAIN	Returns to the Main menu.
PRINT	Prompts for ONE or ALL to select items to print.
→STK	Prompts for ONE or ALL to select items, and then copies those items to the stack.
UP	Returns to the Main menu.
VIEW	Displays entire text of an item too wide to fit on the screen.
ATTN	Quits the Calculus Pac to the HP 48SX stack.
ENTER	Moves down one level in the menu structure, executing the function selected by the pointer.

Fitting to One Point and One Slope

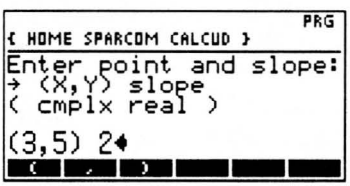
Make sure the pointer is at "Fitting (1 Pt/Slope)" and press ENTER:



The input required is a point and slope.

The result obtained will be an equation describing the line passing through the point with the specified slope.

Example: Calculate the equation of the line passing through the point (3,5) with a slope of 2. Type in ◀ (3 ◀ , 5 ▶ SPC 2 as your input (use the softkeys to aid entry if desired):

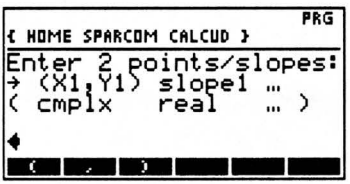


Press ENTER to calculate the equation, and it will appear:

The result can be viewed in the EquationWriter, copied to the stack, or printed on an IR printer. When you have finished viewing the result, press UP to return to the Function Library menu, MAIN to return to the Main menu, or ATTN to quit the Calculus Pac. For a complete summary of operations, see "Result Screen Operations."

Fitting to Two Points and Two Slopes

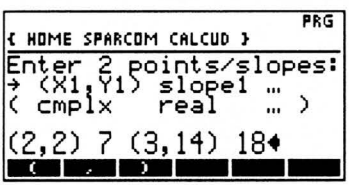
Make sure the pointer is at "Fitting (2 Pt/Slopes)" and press ENTER:



The input required is a point and slope and another point and slope.

The result obtained will be an equation describing the cubic polynomial passing through the two point with the specified slopes. (This is called a *cubic spline.*)

Example: Calculate the equation of the cubic polynomial passing through the point (2,2) with a slope of 7 and through the point (3,14) with a slope of 18. Type in ◁ ( ) 2 ◁ , 2 ▷ SPC 7 SPC ◁ ( ) 3 ◁ , 14 ▷ SPC 18 as your input (use the softkeys to aid entry if desired):

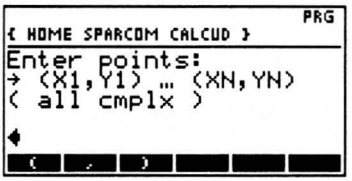


Press ENTER to calculate the equation, and it will appear:

The result can be viewed in the EquationWriter, copied to the stack, or printed on an IR printer. When you have finished viewing the result, press UP to return to the Function Library menu, MAIN to return to the Main menu, or ATTN to quit the Calculus Pac. For a complete summary of operations, see "Result Screen Operations."

Fitting to Many Points

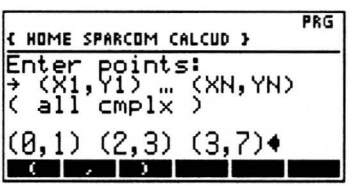
Make sure the pointer is at "Fitting (Many Points)" and press ENTER:



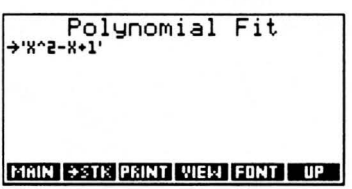
The input required is a series of points.

The result obtained will be an equation describing the polynomial passing through the specified points. (This is called the *interpolating polynomial.*)

Example: Calculate the equation of the polynomial passing through the points (0,1), (2,3), and (3,7). Type in ◀() 0 ◀, 1 ▶SPC◀() 2 ◀, 3 ▶SPC◀() 3 ◀, 7 as your input (use the softkeys to aid entry if desired):



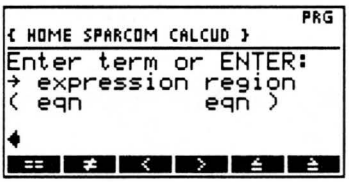
Press ENTER to calculate the equation, and it will appear:



The result can be viewed in the EquationWriter, copied to the stack, or printed on an IR printer. When you have finished viewing the result, press UP to return to the Function Library menu, MAIN to return to the Main menu, or ATTN to quit the Calculus Pac. For a complete summary of operations, see "Result Screen Operations."

Entering a Piecewise Function

Make sure the pointer is at "Piecewise Functions" and press ENTER:

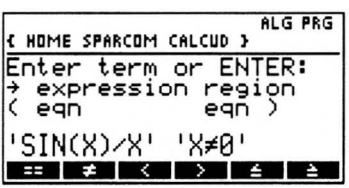


The input required is one or more terms, each consisting of an expression and a region.

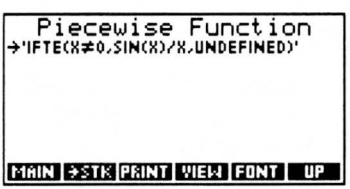
The result obtained will be an equation describing the piecewise function.

(For more information and examples, see Appendix B, "Piecewise Functions.")

Example: Define the piecewise function $f(x) = \begin{cases} \sin(x)/x & x \neq 0 \\ undefined & x = 0 \end{cases}$. Type in ' SIN ⍺ X ▶ ÷ ⍺ X ▶ SPC ' ⍺ $X \neq 0$ as your input:



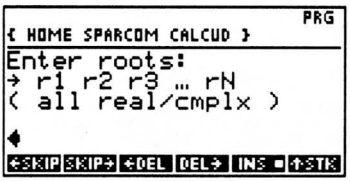
Press ENTER to accept this function term, and then press ENTER in response to the second prompt, to terminate entry and calculate the piecewise function:



The result can be viewed in the EquationWriter, copied to the stack, or printed on an IR printer. When you have finished viewing the result, press UP to return to the Function Library menu, MAIN to return to the Main menu, or ATTN to quit the Calculus Pac. For a complete summary of operations, see "Result Screen Operations."

Building a Polynomial from the Roots

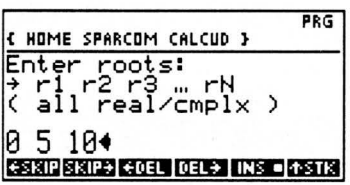
Make sure the pointer is at "Polynomial Builder" and press ENTER:



The input required is a series of real or complex roots of a polynomial.

The result obtained will be the polynomial with the specified roots.

Example: Calculate the polynomial whose roots are 0, 5, and 10. Type in 0 SPC 5 SPC 10 as your input:

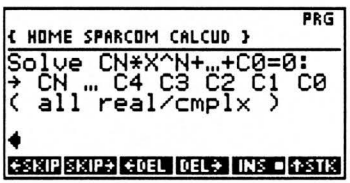


Press ENTER to calculate the polynomial, and it will appear:

The result can be viewed in the EquationWriter, copied to the stack, or printed on an IR printer. When you have finished viewing the result, press UP to return to the Function Library menu, MAIN to return to the Main menu, or ATTN to quit the Calculus Pac. For a complete summary of operations, see "Result Screen Operations."

Finding the Roots of a Polynomial

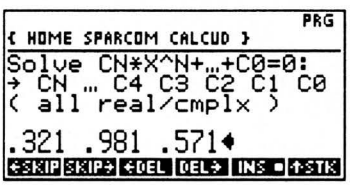
Make sure the pointer is at "Polynomial Solver" and press ENTER:



The input required is a series of real or complex coefficients of a polynomial.

The result obtained will be a series of real and complex roots of the polynomial.

Example: Calculate the roots of $0.321x^2 + 0.981x + 0.571$. Type in .321 SPC .981 SPC .571 as your input:



Press ENTER to calculate the roots, and they will appear:

The first item is the polynomial that was solved, and the remaining items are the roots of that polynomial. The polynomial can be viewed in the EquationWriter by selecting it with the pointer and pressing ENTER, and all of the items can be copied to the stack or printed on an IR printer. When you have finished viewing the results, press UP to return to the Function Library menu, MAIN to return to the Main menu, or ATTN to quit the Calculus Pac. For a complete summary of operations, see "Result Screen Operations."

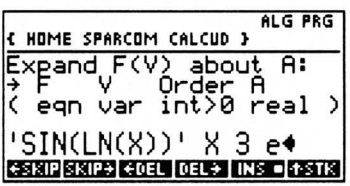
Calculating a Taylor Expansion

Make sure the pointer is at "Taylor Expansion" and press ENTER:

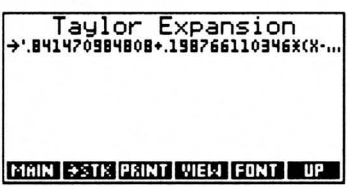
The input required is a function, an independent variable, an integer order to which to expand, and a real point about which to expand.

The result obtained will be an equation which is the desired Taylor expansion.

Example: Find the Taylor series of the function $\sin(\ln(x))$ about the point $x = e$ to the 3rd order. To do this, type in ' SIN → LN ∂ X ▶ ▶ ▶ SPC ∂ X SPC 3 SPC ∂ ← E as your input (if necessary, press ← RAD to enter Radians mode):



Press ENTER to calculate the specified Taylor expansion, which will appear:



The result can be viewed in the EquationWriter, copied to the stack, or printed on an IR printer. When you have finished viewing the result, press UP to return to the Function Library menu, MAIN to return to the Main menu, or ATTN to quit the Calculus Pac. For a complete summary of operations, see "Result Screen Operations."

For information about simplifying the result, see "SIMPL: Symbolic Simplification" in Chapter 8.

Result Screen Operations

These are the operations available at all result screens.

Result Screen Operations

Screen	Softkeys
Result Screen	MAIN →STK PRINT VIEW FONT UP

Key	Action
FONT	Toggles between the small and large fonts.
MAIN	Returns to the Main menu.
PRINT	Prompts for ONE or ALL to select items, and then sends those items to an IR printer.
→STK	Prompts for ONE or ALL to select items, and then copies those items to the stack. The items are placed in a list if ALL was chosen.
UP	Returns to the Function Library menu.
VIEW	Displays the entire text of an item too wide to fit on the screen, up to one entire screen size.
ATTN	Quits the Calculus Pac to the HP 48SX stack.
ENTER	Either views the result in the EquationWriter (equation) or displays the result expanded to a full screen (not equation).

Chapter 3

Integration Analysis

Integration Analysis includes interactive methods to numerically approximate integrals, including left, right, midpoint, trapezoids, and Simpson's Rule.

This chapter covers:

- ❑ Using Integration Analysis
- ❑ Parameter Screen Tips
- ❑ Integration Analysis
- ❑ Result Screen Operations

Using Integration Analysis

To get to Integration Analysis, follow these steps:

❶ Press [←] [LIBRARY] to display all libraries available to your HP 48SX.

❷ Find and press **CALCU** to display the Calculus Pac Library menu.

❸ Press the first softkey, **CALCU**, to start the Calculus Pac interactive menus.

❹ At the menu, make sure pointer is at "Integration Analysis" and press [ENTER]:

The Integration Analysis parameter screen lists the various parameters necessary to perform an integration analysis, including the ability to select one of the five integration techniques supported by the Calculus Pac.

Integration Analysis Techniques

Each technique available from the Integration Analysis parameter screen is briefly described below and is discussed in detail in the various sections of this chapter.

Integration Analysis Techniques

Item	Description
Left Rectangles (LEFT)	Calculates the Riemann lower sum of the definite integral of a function.
Right Rectangles (RIGHT)	Calculates the Riemann upper sum of the definite integral of a function.
Midpoint Rectangles (MIDPT)	Calculates the Riemann midpoint sum of the definite integral of a function.
Trapezoidal Method (TRAPZ)	Approximates the definite integral of a function, using the trapezoidal method.
Simpson's Rule (SIMPS)	Approximates the definite integral of a function, using Simpson's Rule.

Integration Analysis Parameter Screen Operations

Screen	Softkeys
Integration	MAIN →STK PRINT CALC FONT UP

Key	Action
CALC	Performs the actual analysis with the specified parameters.
FONT	Toggles between the small and large fonts.
MAIN	Returns to the Main menu.
PRINT	Prompts for ONE or ALL to select items to print.
→STK	Prompts for ONE or ALL to select items, and then copies those items to the stack.
UP	Returns to the Main menu.
ATTN	Quits the Calculus Pac to the HP 48SX stack.
ENTER	Prompts for value of the parameter selected by the pointer.

Parameter Screen Tips

The Integration Analysis parameter screen controls the integration interval starting and ending points, the integrand (a function of X), the number of partitions for the approximation, and the integration technique to be used.

Entry Tips

Here are some useful things to know about entering or editing parameters:

- To enter or edit the value of a parameter, move the pointer to it and press ENTER. After entering or editing the value of a parameter, press ENTER to accept the new value and return to the element parameter screen.

- Once you have begun entering or editing a parameter value, to abort the change, press ATTN to clear the command line (if necessary) and then press ENTER or ATTN to return to the analysis parameter screen without changing the parameter value.

- You only need to enter values for those parameters that initially display, "Press ENTER." Other parameters (e.g., the number of partitions) will be given default values (e.g., 10) which you may modify if you wish.

- Make sure to place tic marks (') around symbolic arguments for the integrand.

- Some HP 48SX modes can be changed at the prompts where parameter values are entered (e.g., pressing ← RAD will toggle Radians mode).

- After entering all parameters, press CALC to begin the actual analysis.

Integration Analysis

After selecting "Integration Analysis" from the Main menu, this screen appears:

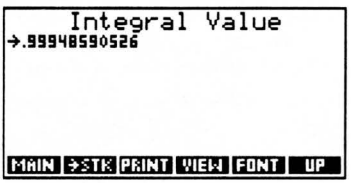
You should now enter or edit the parameter values. When you have finished, press CALC to run the analysis, or at any time press UP or MAIN to return to the Main menu or ATTN to quit the Calculus Pac.

Here are specific descriptions of these parameters:

- **Start**: Starting point of the interval. Must be a real number, or a symbolic expression such as 'π/2' (which resolves to a real number).
- **End**: Ending point of the interval. Must be a real number, or a symbolic expression such as 'π/2' (which resolves to a real number).
- **F(X)**: Must be an equation which is either constant or a function of one variable, X.
- **Partitions**: Number of partitions for the approximation. Must be a positive integer.
- **Technique**: LEFT, RIGHT, MIDPT, TRAPZ, or SIMPS. Change the technique by pressing ENTER, moving the pointer to the desired technique, and pressing ENTER .

Example: Approximate $\int_0^{\pi/2} \sin(x)dx$ according to the trapezoidal method, using 20 partitions. To do this, enter 0 as the interval start, 'π/2' as the interval end, 'SIN(X)' as F(X), 20 as the number of partitions, and TRAPZ as the integration technique. (If necessary, press ↰ RAD while entering F(X) to enter Radians mode.) When finished, the screen should appear as follows:

Once the parameters have been specified, press **CALC** to run the analysis, and the result will appear:



The result can be copied to the stack or printed on an IR printer. When you have finished viewing the result, press **UP** to return to the Integration Analysis parameter screen, **MAIN** to return to the Main menu, or ATTN to quit the Calculus Pac. For a complete summary of operations, see "Result Screen Operations."

Result Screen Operations

These are the operations available at all result screens.

Result Screen Operations

Screen	Softkeys
Result Screen	MAIN →STK PRINT VIEW FONT UP

Key	Action
FONT	Toggles between the small and large fonts.
MAIN	Returns to the Main menu.
PRINT	Prompts for ONE or ALL to select items, and then sends those items to an IR printer.
→STK	Prompts for ONE or ALL to select items, and then copies those items to the stack. The items are placed in a list if ALL was chosen.
UP	Returns to the Integration Analysis parameter screen.
VIEW	Displays the entire text of an item too wide to fit on the screen, up to one entire screen size.
ATTN	Quits the Calculus Pac to the HP 48SX stack.
ENTER	Displays the result expanded to a full screen.

Chapter 4

Integral Tables

The Integral Tables include nearly 100 integrals organized in six sections for quick reference: user-defined, rational, irrational, trigonometric/hyperbolic, exponential/logarithmic, and definite. You can add as many integrals as you wish to the user-defined section.

This chapter covers:

- Using the Integral Tables
- Choosing a Section
- Solving an Integral
- Storing User-Defined Integrals

Using the Integral Tables

To get to the Integral Tables, follow these steps:

1. Press ← LIBRARY to display all libraries available to your HP 48SX.
2. Find and press CALCU to display the Calculus Pac Library menu.
3. Press the first softkey, CALCU, to start the Calculus Pac interactive menus.
4. At the Main menu, make sure the pointer is at "Integral Tables" and press ENTER:

The Integration Tables menu lists the six sections of integrals stored in the Calculus Pac. A section is selected by moving the pointer to it and pressing ENTER.

Items in the Integral Tables Menu

Each item in the Integral Tables menu is briefly described below and is discussed in detail in the various sections of this chapter.

Integral Tables Menu Items

Item	Description
User-Defined	User-defined indefinite and definite integrals.
Rational	Indefinite integrals involving rational arguments.
Irrational	Indefinite integrals involving irrational arguments.
Trig/Hyperbolic	Indefinite integrals involving trig/hyp arguments.
Exp/Logarithmic	Indefinite integrals involving exp/log arguments.
Definite	Definite integrals.

Integral Tables Menu Operations

Screen	Softkeys
Integral Table	MAIN →STK PRINT VIEW FONT UP

Key	Action
FONT	Toggles between the small and large fonts.
MAIN	Returns to the Main menu.
PRINT	Prompts for ONE or ALL to select items, and then sends those items to an IR printer.
→STK	Prompts for ONE or ALL to select items, and then copies those items to the stack.
UP	Returns to the Main menu.
VIEW	Displays the entire text of an item too wide to fit on the screen, up to one entire screen size. If the item fits on the screen, this key is non-functional.
ATTN	Quits the Calculus Pac to the HP 48SX stack.
ENTER	Moves down one level in the menu structure, entering the selected integral section.

Choosing a Section

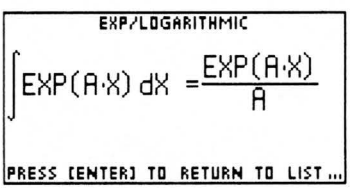
Each of the six sections of integrals contains a group of related integrals. Each integral can be displayed in EquationWriter or text format, copied to the stack, or solved, indefinitely or definitely. You can also search for a specific integral using the search mode. (For more information, see "Using the Search Mode" in Chapter 1.) The user-defined integral section behaves identically to all other sections, once you have entered your own integrals.

Example: Investigate the section of integrals with forms containing exponentials. To do this, make sure the pointer is at "Exp/Logarithmic" and press ENTER:

This particular section contains thirteen integrals.

Viewing an Integral

Example (cont.): View the third integral in this section in EquationWriter format. To do this, make sure the pointer is at the third equation and press ENTER. After a brief delay, the integral will be displayed in EquationWriter format:



When you have finished viewing the integral, press ENTER or ATTN to return to the integration section menu. Many integrals are too large for the screen, and will be displayed with the cursor keys activated for scrolling purposes.

WARNING: While the HP 48SX is building the EquationWriter format of an integral, key presses will cause strange behavior, resulting in no display of the equation. Therefore, do not press any keys until the integral has been drawn, erased, and re-drawn with the accompanying messages. If you change your mind during a long integral build, press ATTN to abort the build process and return to the integral screen.

Integral Section Menu Operations

Screen	Softkeys
Integral Sect.	MAIN →STK PRINT SOLVE FONT ▲UP

Key	Action
FONT	Toggles between the small and large fonts.
MAIN	Returns to the Main menu.
PRINT	Prompts for ONE or ALL to select items, and then sends those items to an IR printer.
SOLVE	Solves the integral selected by the pointer.
→STK	Prompts for ONE or ALL to select items, and then copies those items to the stack. The items are placed in a list if ALL was chosen.
▲UP	Returns to the Integral Tables menu.
ATTN	Quits the Calculus Pac to the HP 48SX stack.
ENTER	Displays the integral selected by the pointer in the EquationWriter.
↵ VISIT	Displays the entire text of an item too wide to fit on the screen, up to one entire screen size. If the item fits on the screen, this key is non-functional.

Solving an Integral

The integral solving process is one of substitution and algebraic simplification.

Example (cont.): To solve the third integral, make sure the pointer is at it and press SOLVE.

Selecting Indefinite or Definite

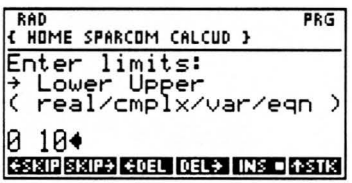
The first step in solving an integral is choosing the type of integration to perform. You can perform either definite or indefinite integrations. If you choose to perform an indefinite integration, then a constant of integration will be added to the final result.

Example (cont.): Perform a definite integration by pressing DEFIN.

Entering Limits of Integration

If you choose to perform a definite integration, you will be prompted to enter the limits of integration. Limits can be real numbers, variables, or expressions. This means you can integrate from 0 to 1, or from A to B, or even from $\sin(t)$ to $\cos(t+u)$, provided that none of the variables used in the limits are identical to the variable of integration, which is always X.

Example (cont.): Integrate from 0 to 10. Type 0 [SPC] 10:



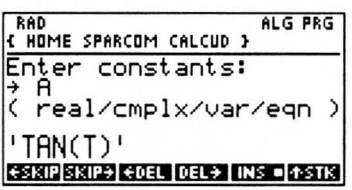
Press [ENTER] to accept those limits of integration.

NOTE: Be sure to enclose *symbolic* limits within tic marks (') and to set Radians mode for correct trigonometric results.

Entering Values of Constants

When solving an integral (either indefinitely or definitely), you must specify values for all the unknown constants in the integral. This does *not* include the variable of integration, for which you do not enter a value. These constants must be constant with respect to the variable of integration, X. Like the limits of integration, the constants can be real numbers, variables, or expressions.

Example (cont.): Set the value of A to $\tan(T)$, where T is a constant. Type [']TAN[α] T:



Press [ENTER] to accept that constant value.

NOTE: If you wish to enter a variable as a limit or a constant, the surrounding tic marks are optional. For example, T can be entered as 'T' or T.

Viewing the Result

After the limits and constants have been specified, the integration will be performed and the desired result displayed:

The result can be viewed in the EquationWriter, copied to the stack, or printed on an IR printer. When you have finished viewing the result, press **UP** to return to the integral section menu, **MAIN** to return to the Main menu, or ATTN to quit the Calculus Pac.

(For information about simplifying the result, see "SIMPL: Symbolic Simplification" in Chapter 8.)

Result Screen Operations

Screen	Softkeys
Result Screen	**MAIN** **→STK** **PRINT** **VIEW** **FONT** **UP**

Key	Action
FONT	Toggles between the small and large fonts.
MAIN	Returns to the Main menu.
PRINT	Prompts for **ONE** or **ALL** to select items, and then sends those items to an IR printer.
→STK	Prompts for **ONE** or **ALL** to select items, and then copies those items to the stack. The items are placed in a list if **ALL** was chosen.
UP	Moves up one level in the menu structure, returning to the integral section.
VIEW	Displays the entire text of an item too wide to fit on the screen, up to one entire screen size. If the item fits on the screen, this key is non-functional.
ATTN	Quits the Calculus Pac to the HP 48SX stack.
ENTER	Displays the result in the EquationWriter.

Storing User-Defined Integrals

To add an integral to the user-defined section of the Integral Tables, follow these steps:

❶ Go to the HP 48SX stack. (If necessary, press [ATTN] to quit the interactive menus.)

❷ Enter or recall the integral you wish to store to level 1 of the stack. The syntax of the integral must satisfy the following conditions:

① The integral must be entered as an equation. It can be entered with the HP 48SX EquationWriter and copied to the stack. (For more information, see Chapter 16 of the HP 48SX Owner's Manual, "The Equation Writer Application.") The equation must include an equal sign with an integral on the left side and an expression on the right side representing the solution of the integral.

NOTE: The Calculus Pac does not *solve* arbitrary integrals—it merely stores them for reference and provides substitution and evaluation help. When entering a new user-defined integral, you must derive or look up the solution to the integral and specify it as a part of the equation to be stored.

② The variable of integration should be an uppercase X. If the variable of integration is *not* X, INDEF or DEFIN will automatically convert it to X during the storage process, but an error will occur if X appears elsewhere in the integral.

③ Valid integrals always require limits of integration, but the limits will be ignored if you store the integral in an indefinite form with INDEF (see below).

④ To store a constraint label with the integral (such as $a \neq 1$), enter the integral as an equation and the constraint label as a string and then press [PRG] OBJ→ →TAG to tag the integral with the string.

❸ To store the integral in an indefinite form (ignoring the limits of integration), press INDEF; to store the integral in a definite form (preserving the limits of integration), press DEFIN.

(For more information, see "INDEF: Store Indefinite Integral" and "DEFIN: Store Definite Integral" in Chapter 9.)

Example: To store the indefinite integral $\int \cos(x)dx = \sin(x)$, press ◀ CANCEL ▶ ∫ 0 ► 0 ► COS α X ► ► α X ◀ = SIN α X ENTER to place the integral on level 1. (Note that the HP-48SX requires limits on the integral, but since the integral will be stored indefinitely, the limits will be ignored.) To place the constraint label "TEST" on this integral, type ▶ ' α α TEST ENTER PRG OBJ →TAG. Then press INDEF to store the integral in an indefinite form in the user-defined section of the integral tables.

Chapter 5

Limit Analysis

Limit Analysis includes interactive methods to examine limit behavior of functions, sequences, series, and recursion relations.

This chapter covers:

- ❑ Using Limit Analysis
- ❑ Parameter Screen Tips
- ❑ Functions
- ❑ Sequences
- ❑ Series (Partial Sums)
- ❑ Recursion Relations

Using Limit Analysis

To get to Limit Analysis, follow these steps:

❶ Press ← LIBRARY to display all libraries available to your HP 48SX.

❷ Find and press CALCU to display the Calculus Pac Library menu.

❸ Press the first softkey, CALCU, to start the Calculus Pac interactive menus.

❹ At the Main menu, make sure the pointer is at "Limit Analysis" and press ENTER:

The Limit Analysis menu lists the four types of limit analysis performed by the Calculus Pac. A type is selected by moving the pointer to it and pressing ENTER.

Items in the Limit Analysis Menu

Each item in the Limit Analysis menu is briefly described below and is discussed in detail in the various sections of this chapter.

Limit Analysis Menu Items

Item	Description
Functions	Displays the parameter screen for functions, which controls analysis of 1–3 functions approaching a target point from the left or right.
Sequences	Displays the parameter screen for sequences, which controls analysis of 1–3 sequences, sweeping from a start index to a stop index.
Series	Displays the parameter screen for series, which controls analysis of the partial sums of 1–3 series, sweeping from a start index to a stop index.
Recursions	Displays the parameter screen for recursion relations, which controls analysis of 1–3 recursion relations, starting from an initial point.

Limit Analysis Menu Operations

Screen	Softkeys
Limit Anal.	MAIN →STK PRINT VIEW FONT UP

Key	Action
FONT	Toggles between the small and large fonts.
MAIN	Returns to the Main menu.
PRINT	Prompts for ONE or ALL to select items to print.
→STK	Prompts for ONE or ALL to select items, and then copies those items to the stack.
UP	Returns to the Main menu.
VIEW	Displays the entire text of an item too wide to fit on the screen, up to one entire screen size. If the item fits on the screen, this key is non-functional.
ATTN	Quits the Calculus Pac to the HP 48SX stack.
ENTER	Moves down one level in the menu structure, displaying the parameter screen for the analysis selected by the pointer.

Parameter Screen Tips

Each of the four types of limit analysis starts at a parameter screen, where the specific functions/sequences/series/recursion relations are entered, along with other information about the particular analysis to be performed, including starting or ending points and approach sides.

Entry Tips

Here are some useful things to know about entering or editing parameters:

- To enter or edit the value of a parameter, move the pointer to it and press ENTER. After entering or editing the value of a parameter, press ENTER to accept the new value and return to the element parameter screen.
- Once you have begun entering or editing a parameter value, to abort the change, press ATTN to clear the command line (if necessary) and then press ENTER or ATTN to return to the analysis parameter screen without changing the parameter value.
- You only need to enter values for those parameters that initially display, "Press ENTER." Other parameters (e.g., the initial index) will be given default values (e.g., 1) which you may modify if you wish.
- Make sure to place tic marks (') around symbolic arguments.
- Some HP 48SX modes can be changed at the prompts where parameter values are entered (e.g., pressing ← RAD will toggle Radians mode).
- After entering all parameters, press CALC to begin the actual analysis.

Run-Time Modes

Each type of analysis can be run in one of two modes:

- **Single-Step Mode:** This mode of analysis is single-stepped by pressing any key except ATTN, which terminates the analysis. Pressing STO at any step copies the current values to the stack and continues to the next step. This is the default run-time mode for function analysis.
- **Continuous Mode:** This mode of analysis will continue to run until either the stop condition is satisfied or ATTN is pressed. At the final values screen, pressing STO copies the final values to the stack.

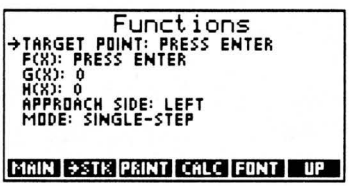
To toggle between the two modes, move the pointer to "Mode" and press ENTER.

Functions

From one to three functions of X are specified, with a target point and approach side. The value of X is then swept toward the target point* , while the values of X and the functions are displayed on-screen.

NOTE: Although the function limit analysis examines a number of points *close* to the target point, the results do not guarantee anything about the actual limit at the target point.

Make sure the pointer is at "Functions" and press ENTER:



You should now enter or edit the parameter values. When you have finished, press CALC to run the analysis, or at any time press UP to return to the Limit Analysis menu or ATTN to quit the Calculus Pac.

Here are specific descriptions of these parameters:

- **Target Point**: Must be a real number.
- **F(X), G(X), H(X)**: Must be equations which are either constant or functions of one variable, X.
- **Approach Side**: LEFT or RIGHT. Toggle by pressing ENTER.
- **Mode**: Continuous or Single-Step. Toggle by pressing ENTER.

Example: Find $\lim_{x \to 0^-} \frac{\sin(x)}{x}$. To do this, enter 0 as the target point and 'SIN(X)/X' as F(X). (If necessary, press ↰ RAD while entering F(X) to enter Radians mode.) Once the parameters have been specified, press CALC to run the analysis. At each step, press ENTER to continue, STO to copy the values to the stack and continue, or ATTN to terminate the analysis. This analysis appears to indicate that the limit is 1.

---

* X is swept from $target - 1$ up to $target - 1 \times 10^{-10}$ or from $target + 1$ down to $target + 1 \times 10^{-10}$ in 10 steps, depending on the approach side.

Sequences

From one to three sequence coefficients (functions of N) are specified, with a start index and stop index. The value of N is then swept from the start index to the stop index, while the values of N and the sequences are displayed on-screen.

Make sure the pointer is at "Sequences" and press ENTER:

You should now enter or edit the parameter values. When you have finished, press CALC to run the analysis, or at any time press UP to return to the Limit Analysis menu or ATTN to quit the Calculus Pac.

Here are specific descriptions of these parameters:

- **Start Index, Stop Index**: Must be positive integers, and the stop index must be greater than or equal to the start index.
- **AN, BN, CN**: Must be equations which are either constant or functions of one variable, N.
- **Mode**: Continuous or Single-Step. Toggle by pressing ENTER.

Example: Examine the sequence $\left\{\left(1+\frac{1}{n}\right)^n\right\}_{n=1}^{100}$ for convergence or divergence. To do this, enter 100 as the stop index and '(1+1/N)^N' as AN. When finished, the screen should appears as follows:

Once the parameters have been specified, press CALC to run the analysis. The value of N will be swept from 1 to 100, and the value of AN will be shown at each point. Although it is slightly ambiguous for such small values of N, the sequence does in fact converge to a limit of e, or 2.7182.... This can be checked by setting the start and stop indices to much larger values, such as 10000 or so.

Series (Partial Sums)

From one to three series (functions of N) are specified, with a start index and stop index. The value of N is then swept from the start index to the stop index, while the values of N and the series partial sums are displayed on-screen.

Make sure the pointer is at "Series" and press ENTER:

You should now enter or edit the parameter values. When you have finished, press CALC to run the analysis, or at any time press UP to return to the Limit Analysis menu or ATTN to quit the Calculus Pac.

Here are specific descriptions of these parameters:

- **Start Index, Stop Index**: Must be positive integers, and the stop index must be greater than or equal to the start index.
- **AN, BN, CN**: Must be equations which are either constant or functions of one variable, N.
- **Mode**: Continuous or Single-Step. Toggle by pressing ENTER.

Example: Compare the series $\sum_{n=1}^{100}\frac{1}{n}$, $\sum_{n=1}^{100}\frac{1}{n^2}$, and $\sum_{n=1}^{100}\frac{1}{n^3}$. To do this, enter 100 as the stop index, '1/N' as AN, '1/N^2' as BN, and '1/N^3' as CN. When finished, the screen should appears as follows:

Once the parameters have been specified, press CALC to run the analysis. The value of N will be swept from 1 to 100, and the partial sums of AN, BN, and CN will be shown at each point. From this analysis, it appears that AN diverges and that BN and CN converge, with CN converging much more quickly than BN.

Recursion Relations

From one to three recursion relations (functions of X) are specified, with an initial point. The initial point is used as the initial value of X, from which values of F(X), G(X), and H(X) are calculated. Then, at each successive step, a new value of F(X), G(X), and H(X) is calculated, using the prior value of F(X), G(X), or H(X), respectively, as the value of X. For example, $f_1 = f(x_0)$, while $f_2 = f(f_1)$. At each step, the values of N (the iteration) and the recursion relations are displayed on-screen.

Make sure the pointer is at "Recursions" and press ENTER:

You should now enter or edit the parameter values. When you have finished, press CALC to run the analysis, or at any time press UP to return to the Limit Analysis menu or ATTN to quit the Calculus Pac.

Here are specific descriptions of these parameters:

- **Initial Point**: Must be a real number.
- **F(X), G(X), H(X)**: Must be equations which are either constant or functions of one variable, X.
- **Mode**: Continuous or Single-Step. Toggle by pressing ENTER.

Chapter 6

Constant Library

The Constant Library lists 43 universal constants for quick reference. Constant values can be displayed on the screen, copied to the stack, or printed on an IR printer, either one at a time or all at once.

This chapter covers:

- ❑ Using the Constant Library
- ❑ Viewing a Constant

Using the Constant Library

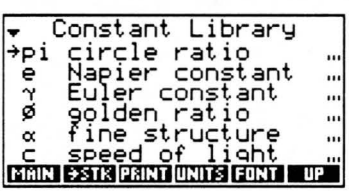
To get to the Constant Library, follow these steps:

❶ Press [↩] [LIBRARY] to display all libraries available to your HP 48SX.

❷ Find and press **CALCU** to display the Calculus Pac Library menu.

❸ Press the first softkey, **CALCU**, to start the Calculus Pac interactive menus.

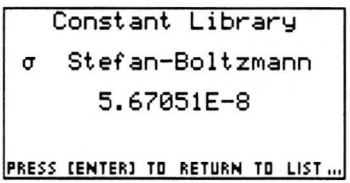
❹ At the Main menu, make sure the pointer is at "Constant Library" and press [ENTER]:



Viewing a Constant

Browse through the list to find a constant, or use the search mode. When you have found the desired constant, press ENTER to display the value on a full screen, →STK to copy the value to the stack, or PRINT to print the value.

Example: Look up the value of the Stefan-Boltzmann constant. Type ∂ → S ENTER to search for the letter σ. Then press ENTER to view the value:



When you have finished viewing the value, press ENTER or ATTN to return to the Constant Library. When you have finished with the Constant Library, press UP or MAIN to return to the Main menu, or ATTN to quit the Calculus Pac.

Constant Library Operations

Screen	Softkeys
Constant Lib.	MAIN →STK PRINT UNITS FONT UP

Key	Action
FONT	Toggles between the small and large fonts.
MAIN	Returns to the Main menu.
PRINT	Prompts for ONE or ALL to select items to print.
→STK	Prompts for ONE or ALL to select items, and then copies those items to the stack.
UNITS	Pressing this key toggles units, stripping units from or appending units to all values.
UP	Returns to the Main menu.
ATTN	Quits the Calculus Pac to the HP 48SX stack.
ENTER	Displays the constant label and value, expanded to a screen.
→ VISIT	Displays entire text of an item too wide to fit on the screen.

Chapter 7

Reference Data

Reference Data includes tables of the Greek alphabet, standard SI prefixes, trigonometric and hyperbolic functions, pictures, and relations, and vector formulas.

This chapter covers:

- ❑ Using Reference Data
- ❑ Greek Alphabet
- ❑ SI Prefixes
- ❑ Trig/Hyp Definitions
- ❑ Trig/Hyp Pictures
- ❑ Trig Relations
- ❑ Vector Formulas

Using Reference Data

To get to Reference Data, follow these steps:

❶ Press ← LIBRARY to display all libraries available to your HP 48SX.

❷ Find and press CALCU to display the Calculus Pac Library menu.

❸ Press the first softkey, CALCU, to start the Calculus Pac interactive menus.

❹ At the menu, make sure the pointer is at "Reference Data" and press ENTER:

The Reference Data menu lists the six areas of reference data included in the Calculus Pac. An area is selected by moving the pointer to it and pressing ENTER.

Items in the Reference Data Menu

Each item in the Reference Data menu is briefly described below and is discussed in detail in the various sections of this chapter.

Reference Data Menu Items

Item	Description
Greek Alphabet	Uppercase and lowercase Greek letters.
SI Prefixes	Commonly used SI prefixes.
Trig/Hyp Definitions	Definitions of the basic trigonometric and hyperbolic functions.
Trig/Hyp Pictures	Graphs of basic trigonometric and hyperbolic functions.
Trig Relations	Common trigonometric relations.
Vector Formulas	Common vector formulas involving dot products, cross products, divergence, curl, and gradient.

Reference Data Menu Operations

Screen	Softkeys
Refer. Data	MAIN -STK PRINT VIEW FONT UP

Key	Action
FONT	Toggles between the small and large fonts.
MAIN	Returns to the Main menu.
PRINT	Prompts for ONE or ALL to select items to print.
-STK	Prompts for ONE or ALL to select items, and then copies those items to the stack.
UP	Returns to the Main menu.
VIEW	Displays the entire text of an item too wide to fit on the screen, up to one entire screen size. If the item fits on the screen, this key is non-functional.
ATTN	Quits the Calculus Pac to the HP 48SX stack.
ENTER	Moves down one level in the menu structure, displaying the data section selected by the pointer.

Greek Alphabet

Make sure the pointer is at "Greek Alphabet" and press ENTER:

This screen is a picture displaying representations of all of the uppercase and lowercase Greek letters. Many of these characters are available from the HP 48SX keyboard, but not all of them. To get a printed copy of this screen, press ON–MTH. Press ENTER or ATTN to return to the Reference Data menu.

SI Prefixes

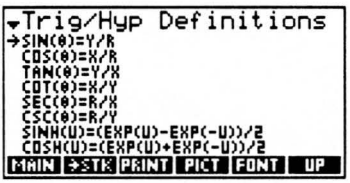
Make sure the pointer is at "SI Prefixes" and press ENTER:

Press ENTER to display a prefix and value on a full screen, →STK to copy a prefix to the stack, or PRINT to print a prefix on an IR printer.

When you have finished browsing the list, press UP to return to the Reference Data menu, MAIN to return to the Main menu, or ATTN to quit the Calculus Pac.

Trig/Hyp Definitions

Make sure the pointer is at "Trig/Hyp Definitions" and press ENTER:



Browse through the list to find the desired definition. Press ENTER to display the definition in the EquationWriter, →STK to copy the definition to the stack, or PRINT to print the definition on an IR printer. Press PICT to view an illustrative diagram.

When you have finished viewing the definitions, press UP to return to the Reference Data menu, MAIN to return to the Main menu, or ATTN to quit the Calculus Pac.

Using COT, SEC, CSC, etc.

The HP 48SX does not include COT, SEC, CSC, ACOT, ASEC, ACSC, COTH, SECH, CSCH, ACOTH, ASECH, or ACSCH functions, but the Calculus Pac defines them as commands so they will work correctly when used in algebraics or programs. For more information, see "Trigonometric Commands" and "Hyperbolic Commands" in Chapter 8.)

Trig/Hyp Pictures

Make sure the pointer is at "Trig/Hyp Pictures" and press ENTER:

Browse through the list to find the desired picture and press ENTER to view it. When you have finished viewing the picture, press ATTN or ENTER to return to the Trig/Hyp Pictures menu, and then press **UP** to return to the Reference Data menu, **MAIN** to return to the Main menu, or ATTN to quit the Calculus Pac.

Relations

Make sure the pointer is at "Trig Relations" and press ENTER:

Browse through the list to find the desired relation. Press ENTER to display the relation in the EquationWriter, →STK to copy the relation to the stack, or PRINT to print the relation on an IR printer. Press PICT to view an illustrative diagram.

When you have finished viewing the relations, press UP to return to the Reference Data menu, MAIN to return to the Main menu, or ATTN to quit the Calculus Pac.

Vector Formulas

Make sure the pointer is at "Vector Formulas" and press ENTER:

Browse through the list to find the desired formula. Press ENTER to display the formula in the EquationWriter, →STK to copy the formula to the stack, or PRINT to print the formula on an IR printer.

When you have finished viewing the formulas, press UP to return to the Reference Data menu, MAIN to return to the Main menu, or ATTN to quit the Calculus Pac.

Part 2

Stack-Based Toolkits

Chapter 8

Function Toolkit

The Function Toolkit organizes 24 of the programmable commands in the Calculus Pac into one menu for easy access from the stack. All of the commands are designed to manipulate functions.

This chapter covers:

- ❑ Using the Function Toolkit
- ❑ SIMPL: Symbolic Simplification
- ❑ TYLRA: Taylor Expansion
- ❑ PROOT: Polynomial Root-Finder
- ❑ ROOTP: Roots to Polynomial
- ❑ PWISE: Piecewise Function
- ❑ QPWR: Rational Power of Function
- ❑ DELTA: Delta Function
- ❑ LOGA: Logarithm, Any Base
- ❑ NROOT: Nth Roots of a Number
- ❑ PINTR: Polynomial Interpolation
- ❑ PTSLP: Point-Slope Fit
- ❑ SPLIN: Cubic Spline Fit
- ❑ Trigonometric Functions
- ❑ Hyperbolic Functions

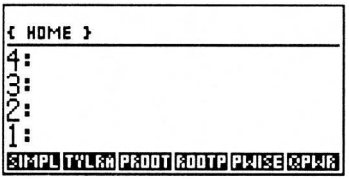
Using the Function Toolkit

To get to the Function Toolkit, follow these steps:

❶ Press ↰ LIBRARY to display all libraries available to your HP 48SX.

❷ Find and press CALCU to display the Calculus Pac Library menu.

❸ Press the second softkey, FUNC , to display the Function Toolkit menu:



The Function Toolkit menu lists the 24 programmable commands designed to manipulate functions.

Function Toolkit Operations

Screen	Softkeys					
Function Toolkit	SIMPL	TYLRA	PROOT	ROOTP	PWISE	QPWR
	DELTA	LOGA	NROOT	PINTR	PTSLP	SPLIN
	COT	SEC	CSC	ACOT	ASEC	ACSC
	COTH	SECH	CSCH	ACOTH	ASECH	ACSCH

SIMPL: Symbolic Simplification

This command simplifies the input object, if appropriate. Simplification only occurs for algebraics, which may occur arbitrarily deep within nested lists. All other objects are returned unchanged. Algebraic objects are simplified by performing EXPAN twice and COLCT as many times as necessary until the algebraic stops changing between repeated COLCTs.

To simplify the result of a calculation performed while using the interactive menus, follow these steps:

❶ Press →STK and then ONE to copy the result to the stack. Then press ATTN to quit the Calculus Pac.

❷ Press ↩ LIBRARY to display all libraries available to your HP 48SX.

❸ Find and press CALCU to display the Calculus Pac Library menu.

❹ Press the second softkey, FUNC, to display the Function Toolkit menu.

❺ Press the first softkey, SIMPL, to simplify the expression.

Entry Method(s)

Input	Output
1: any object	1: simplified object
'SIMPL(object)'	

Example(s)

Input	Output
{ 1 'x+x' { [1 2] } } SIMPL	{ 1 '2*x' { [1 2] } }
'SIMPL(x+x)' EVAL	'2*x'

TYLRA: Taylor Expansion

This command computes a Taylor polynomial of a given function of a given variable to a specified degree about a specified point.

Entry Method(s)

Input	Output
4: function	4:
3: variable (name)	3:
2: degree (integer)	2:
1: point (real)	1: Taylor expansion

Example(s)

Input	Output
'SIN(X)' 'X' 2 2 TYLRA	'.909297426826– .416146836547*(X–2)– .454648713413*(X–2)^2'

Note(s)

Example uses Radians mode.

PROOT: Polynomial Root-Finder

This command returns the real or complex roots of a polynomial with real or complex coefficients. Polynomials can be entered either as symbolic expressions (up to 16th order) or as a vector of coefficients (no limit on order). If entered as a symbolic expression, the independent variable must be X. The roots are automatically rounded to 10 digit accuracy. PROOT is the inverse of ROOTP.

Entry Method(s)

Input	Output
1: coefficients (real/complex vector) or 1: polynomial of X	1: roots (real/complex vector)

Example(s)

Input	Output
{ 1 –12 35 –24 } PROOT	[8 1 3]
[1 –12 35 –24] PROOT	[8 1 3]
'X^3–12*X^2+35*X–24' PROOT	[8 1 3]

Note(s)

A polynomial such as 'A*X^2+B*X+C' is acceptable as input if A, B, and C are defined as real or complex numbers.

Due to round-off error, the roots returned by PROOT may not be exactly correct. To increase the accuracy of a particular root, use the built-in HP 48SX solver to solve the original polynomial algebraic expression for 'X', using the value of the desired root returned by PROOT as a guess. (For more information, see Chapter 17 in the HP 48SX Owner's Manual, "The HP Solve Application.)

ROOTP: Roots to Polynomial

This command returns the polynomial corresponding to the input vector of real or complex roots. ROOTP is the inverse of PROOT. The coefficients are automatically rounded to 8 digit accuracy.

Entry Method(s)

Input	Output
1: roots (real/complex vector)	1: polynomial of X

Example(s)

Input	Output
[8 1 3] ROOTP	'X^3–12*X^2+35*X–24'

PWISE: Piecewise Functions

This command executes a series of interactive prompts to define a piecewise function and returns an expression that will be interpreted correctly by the HP 48SX, using the IFTE command. (For more information, see Appendix B, "Piecewise Functions" and "Entering a Piecewise Function" in Chapter 3.)

Entry Method(s)

Input	Output
1:	1: piecewise function

Example(s)

See Appendix B, "Piecewise Functions."

QPWR: Rational Power of Function

This command produces the rational power of a function $F^{\frac{p}{q}}$, in a way that will be interpreted correctly by the HP 48SX, using the XROOT command.

Entry Method(s)

Input	Output
3: function, F 2: numerator, p (integer) 1: denominator, q (integer)	3: 2: 1: rational power of function
'QPWR(F, p, q)'	

Example(s)

Input	Output
125 5 3 QPWR	3125
'QPWR(X,5,2)' EVAL	'XROOT(2,X)^5'

Note(s)

First example is $125^{\frac{5}{3}}$.

Second example is $X^{\frac{5}{2}}$ and assumes 'X' is undefined.

DELTA: Delta Function

This command produces the delta function $\delta(F,G)$, in a way that will be interpreted correctly by the HP 48SX, using the == command.

Entry Method(s)

Input	Output
2: function, F 1: function, G	2: 1: delta function
'DELTA(F, G)'	

Example(s)

Input	Output
10 8 DELTA	0
'DELTA(X,8)' EVAL	'X==8'

Note(s)

Second example assumes 'X' is undefined.

LOGA: Logarithm, Any Base

This command produces the logarithm of a function to the specified base a.

Entry Method(s)

Input	Output
2: function, F 1: base, a (integer)	2: 1: logarithm, base a
'LOGA(F, a)'	

Example(s)

Input	Output
8 2 LOGA	3
'LOGA(X,2)' EVAL	'LN(X)/.69314718056'

Note(s)

Second example assumes 'X' is undefined.

NROOT: Nth Roots of a Number

This command produces the *n nth* roots of a real or complex number. The *n*th roots will be returned as a real or complex vector. The *n*th roots are automatically rounded to 10 digit accuracy.

Entry Method(s)

Input	Output
2: number (real/complex) 1: n (integer)	2: 1: roots (real/complex vector)

Example(s)

Input	Output
(2,5) 3 NROOT	[(1.6166388851,.6773444774) (–1.394916967,1.0613781045) (–.221721918,–1.7387225819)]
4 2 NROOT	[2 –2]

PINTR: Polynomial Interpolation

This command determines the coefficients of the interpolating polynomial of an arbitrarily large number of data points. The order of the polynomial produced is equal to one less than the total number of points, because a precise interpolation is performed. There must be at least two input points, but there is no upper limit on the number of points. The points are input as a complex vector. The coefficients are automatically rounded to 10 digit accuracy.

Entry Method(s)

Input	Output
1: points (complex vector)	1: polynomial of X

Example(s)

Input	Output
{ (0,1) (2,3) } PINTR	'X+1'
{ (0,1) (2,3) (3,7) } PINTR	'X^2–X+1'
[(0,1) (2,3) (3,7) (5,10)] PINTR	'–(11/30*X^3)+17/6*X^2–16/5*X+1'

Note(s)

Third example uses FIX 8 mode. Apply  to result.

Due to round-off error and numerical instabilities in the algorithm, the coefficients returned by PINTR may not be exactly correct.

PTSLP: Point-Slope Fit

This command produces a linear function whose graph passes through a given point with a given slope at that point.

Entry Method(s)

Input	Output
2: point (complex) 1: slope (real)	2: 1: linear polynomial of X

Example(s)

Input	Output
(3,5) 2 PTSLP	'2*X–1'

SPLIN: Cubic Spline Fit

This command produces the cubic function (spline) whose graph passes through two given points with given slopes at those points.

Entry Method(s)

Input	Output
4: point 1 (complex)	4:
3: slope at point 1 (real)	3:
2: point 2 (complex)	2:
1: slope at point 2 (real)	1: cubic polynomial of X

Example(s)

Input	Output
(3,5) 2 (6,2) 4 SPLIN	'8/9*X^3–35/3*X^2+48*X–58'

Note(s)

Apply ← → to result.

Trigonometric Functions

This section covers the functions COT, SEC, CSC, ACOT, ASEC, ACSC, and ACSC, which are the standard trigonometric functions and their inverses. They all have the same types of input and output arguments, so the entry methods and examples are shown only for COT.

Entry Method(s)

Input	Output
1: function, F	1: cotangent
'COT(F)'	

Example(s)

Input	Output
45 COT	1
'COT(X)' EVAL	'INV(TAN(X))'

Note(s)

First example uses Degrees mode.

Second example assumes 'X' undefined.

Hyperbolic Functions

This section covers the functions COTH, SECH, CSCH, ACOTH, ASECH, and ACSCH, which are the standard hyperbolic functions and their inverses. They all have the same types of input and output arguments, so the entry methods and examples are shown only for COTH.

Entry Method(s)

Input	Output
1: function, F	1: hyperbolic cotangent
'COTH(F)'	

Example(s)

Input	Output
45 COTH	1
'COTH(X)' EVAL	'INV(TANH(X))'

Note(s)

First example uses Degrees mode.

Second example assumes 'X' undefined.

Chapter 9

Integration Toolkit

The Integration Toolkit organizes seven of the programmable commands in the Calculus Pac into one menu for easy access from the stack. All of the commands are designed to numerically approximate integrands and store user-defined integrals.

This chapter covers:

- ❑ Using the Function Toolkit
- ❑ LEFT: Left Rectangles
- ❑ RIGHT: Right Rectangles
- ❑ MIDPT: Midpoint Rectangles
- ❑ TRAPZ: Trapezoidal Method
- ❑ SIMPS: Simpson's Rule
- ❑ INDEF: Store Indefinite Integral
- ❑ DEFIN: Store Definite Integral

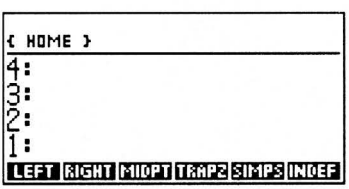
Using the Integration Toolkit

To get to the Integration Toolkit, follow these steps:

❶ Press [↩] [LIBRARY] to display all libraries available to your HP 48SX.

❷ Find and press **CALCU** to display the Calculus Pac Library menu.

❸ Press the third softkey, **INTG**, to display the Integration Toolkit menu:



The Integration Toolkit menu lists the seven programmable commands designed to numerically approximate integrands and store user-defined integrals.

Integration Toolkit Operations

Screen	Softkeys					
Integration Toolkit	LEFT	RIGHT	MIDPT	TRAPZ	SIMPS	INDEF
	DEFIN					

LEFT: Left Rectangles

This command calculates the Riemann lower sum of the definite integral of a function over a specified closed interval [x,y] and number of partitions n. The partition endpoints x and y should resolve to real numbers upon the application of →NUM, so symbolic values like 'π' are acceptable.

Entry Method(s)

Input	Output
4: interval start, x (real)	4:
3: interval end, y (real)	3:
2: function of X, F	2:
1: partitions, n (integer)	1: Riemann lower sum
'LEFT(x, y, F, n)'	

Example(s)

Input	Output
0 'π/2' 'SIN(X)' 10 LEFT	.91940317002
'LEFT(0,π/2,SIN(X),10)' EVAL	.91940317002

Note(s)

Examples use Radians mode.

RIGHT: Right Rectangles

This command calculates the Riemann upper sum of the definite integral of a function over a specified closed interval [x,y] and number of partitions n. The partition endpoints x and y should resolve to real numbers upon the application of →NUM, so symbolic values like 'π' are acceptable.

Entry Method(s)

Input	Output
4: interval start, x (real)	4:
3: interval end, y (real)	3:
2: function of X, F	2:
1: partitions, n (integer)	1: Riemann upper sum
'RIGHT(x, y, F, n)'	

Example(s)

Input	Output
0 'π/2' 'SIN(X)' 10 RIGHT	1.0764828027
'RIGHT(0,π/2,SIN(X),10)' EVAL	1.0764828027

Note(s)

Examples use Radians mode.

MIDPT: Midpoint Rectangles

This command calculates the Riemann midpoint sum of the definite integral of a function over a specified closed interval [x,y] and number of partitions n. The partition endpoints x and y should resolve to real numbers upon the application of →NUM, so symbolic values like 'π' are acceptable.

Entry Method(s)

Input	Output
4: interval start, x (real)	4:
3: interval end, y (real)	3:
2: function of X, F	2:
1: partitions, n (integer)	1: Riemann midpoint sum
'MIDPT(x, y, F, n)'	

Example(s)

Input	Output
0 'π/2' 'SIN(X)' 10 MIDPT	1.00102882415
'MIDPT(0,π/2,SIN(X),10)' EVAL	1.00102882415

Note(s)

Examples use Radians mode.

TRAPZ: Trapezoidal Method

This command approximates the value of the definite integral of a function over a specified closed interval [x,y] and number of partitions n, using the trapezoidal method. The partition endpoints x and y should resolve to real numbers upon the application of →NUM, so symbolic values like 'π' are acceptable.

Entry Method(s)

Input	Output
4: interval start, x (real)	4:
3: interval end, y (real)	3:
2: function of X, F	2:
1: partitions, n (integer)	1: Trapezoidal method sum
'TRAPZ(x, y, F, n)'	

Example(s)

Input	Output
0 'π/2' 'SIN(X)' 10 TRAPZ	.99794298636
'TRAPZ(0,π/2,SIN(X),10)' EVAL	.99794298636

Note(s)

Examples use Radians mode.

SIMPS: Simpson's Rule

This command approximates the value of the definite integral of a function over a specified closed interval [x,y] and number of partitions n, using Simpson's Rule. The partition endpoints x and y should resolve to real numbers upon the application of →NUM, so symbolic values like 'π' are acceptable.

Entry Method(s)

Input	Output
4: interval start, x (real)	4:
3: interval end, y (real)	3:
2: function of X, F	2:
1: partitions, n (integer)	1: Simpson's Rule sum
'SIMPS(x, y, F, n)'	

Example(s)

Input	Output
0 'π/2' 'SIN(X)' 10 SIMPS	1.00000339223
'SIMPS(0,π/2,SIN(X),10)' EVAL	1.00000339223

Note(s)

Examples use Radians mode.

INDEF: Store Indefinite Integral

This command stores indefinite integrals into the user-defined integrals section of the Integral Tables in the Calculus Pac. The integrals can optionally be tagged with a string, to store variable constraint information. The integrals are stored in the global variable 'USRINTEG' in the 'SPARCOM' directory, and are accessible to the Physics Pac, the Calculus Pac, and future revisions of the Mathematics Pac. (For more information, see "User-Defined Integrals" in Chapter 5.)

Entry Method(s)

Input	Output
1: 'integral=answer' (equation)	1:
1: :constraint: 'integral=answer' (tagged equation)	1:

Example(s)

Input	Output
'∫(L,U,TAN(A*X)^2,X)=1/A*TAN(A*X)–X' INDEF	1:
B>0: '∫(L,U,B^(A*X),X)=B^(A*X)/(A*LOG(B))' INDEF	1:

Note(s)

To tag an integral with a string, place the integral in level 2, the string in level 1, and press PRG OBJ→ →TAG.

DEFIN: Store Definite Integral

This command stores definite integrals into the user-defined integrals section of the Integral Tables in the Calculus Pac. The integrals can optionally be tagged with a string, to store variable constraint information. The integrals are stored in the global variable 'USRINTEG' in the 'SPARCOM' directory, and are accessible to the Physics Pac, the Calculus Pac, and future revisions of the Mathematics Pac. (For more information, see "User-Defined Integrals" in Chapter 5.)

Entry Method(s)

Input	Output
1: 'integral=answer' (equation)	1:
1: :constraint: 'integral=answer' (tagged equation)	1:

Example(s)

Input	Output
'∫(0,1,LOG(X)/(1+X),X)=–π^2/12' DEFIN	1:

Note(s)

To tag an integral with a string, place the integral in level 2, the string in level 1, and press PRG OBJ→ →TAG.

Chapter 10

Plotting Toolkit

The Plotting Toolkit contains commands from the Calculus Pac oriented at enhancing the graphics capabilities of your HP 48SX. The commands are organized into the Plotting Toolkit and the PLOT2, PLOT3, and DIFEQ menus.

This chapter covers:

- ❑ Using the Plotting Toolkit
- ❑ PLOT2: Sparcom PLOT2 Menu
- ❑ PLOT3: Sparcom PLOT3 Menu
- ❑ DIFEQ: Sparcom DIFEQ Menu
- ❑ GRF2: Sparcom 2D Graphics Environment
- ❑ GRF3: Sparcom 3D Graphics Environment
- ❑ PKEY: Sparcom Plotting Keys

Also included are sections on the enhanced Plot menu and a comparison chart:

- ❑ The Enhanced Plot Menu
- ❑ HP 48SX Plotting vs. Sparcom 2D & 3D Plotting

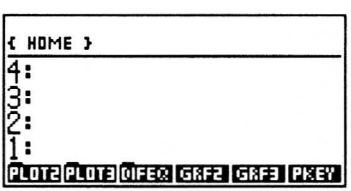
Using the Plotting Toolkit

To get to the Plotting Toolkit, follow these steps:

❶ Press [←] [LIBRARY] to display all libraries available to your HP 48SX.

❷ Find and press **CALCU** to display the Calculus Pac Library menu.

❸ Press the fourth softkey, **PLOT**, to display the Plotting Toolkit menu:



The Plotting Toolkit menu accesses the Sparcom PLOT2, PLOT3, and DIFEQ menus, the Sparcom 2D and 3D Graphics Environments, and the Sparcom Plotting Keys.

Plotting Toolkit Operations

Screen	Softkeys
Plotting Toolkit	PLOT2 PLOT3 DIFEQ GRF2 GRF3 PKEY

PLOT2: Sparcom PLOT2 Menu

See "PLOT2: Sparcom PLOT2 Menu" in Chapter 11.

PLOT3: Sparcom PLOT3 Menu

See "PLOT3: Sparcom PLOT3 Menu" in Chapter 12.

DIFEQ: Sparcom DIFEQ Menu

See "DIFEQ: Sparcom DIFEQ Menu" in Chapter 13.

GRF2: Sparcom 2D Graphics Environment

See "GRF2: Sparcom 2D Graphics Environment" in Chapter 11.

GRF3: Sparcom 3D Graphics Environment

See "GRF3: Sparcom 3D Graphics Environment" in Chapter 12.

PKEY: Sparcom Plotting Keys

This command installs or removes the Sparcom Plotting Keys. The Sparcom Plotting Keys redefine ← GRAPH, → GRAPH, ← PLOT, and → PLOT with user-key assignments to support the Sparcom 2D and 3D Graphics Environments in a transparent fashion, without inhibiting normal use of your HP 48SX. (For more information, see Chapter 11, "2D Plotting," Chapter 12, "3D Plotting," and Chapter 15 of the HP 48SX Owner's Manual, "Customizing the Calculator.")

There are two ways to install the Sparcom Plotting Keys:

- Press ← LIBRARY **CALCU** **CALCU** to access the Main menu, move the pointer to one of the three Plotting items, press ENTER to display the information screen about the Plotting item, and press ATTN to display the Sparcom PLOT2, PLOT3, or DIFEQ menus. This will automatically install the Sparcom Plotting Keys and turn on User mode. (For more information, see Chapter 1, "Main Menu.")

- Press ← LIBRARY **CALCU** **PLOT** **PKEY** to install (or remove) the Sparcom Plotting Keys. If the Sparcom Plotting Keys are *not* installed, **PKEY** will install them and turn on User mode. If the Sparcom Plotting Keys *are* installed, **PKEY** will remove them and turn off User mode.

When the Sparcom Plotting Keys are installed and User mode is turned on, the following keys are redefined:

Sparcom Plotting Keys

Key	Action
← GRAPH	Executes GRF2 to enter the Sparcom 2D Graphics Environment. (Normally executes GRAPH to enter the HP 48SX Graphics Environment.)
→ GRAPH	Executes GRF3 to enter the Sparcom 3D Graphics Environment. (Normally does nothing.)
← PLOT	Displays the enhanced Plot menu. (Normally displays the HP 48SX Plot menu.)
→ PLOT	Displays the Sparcom PLOT2 menu. (Normally displays the HP 48SX PLOTR menu.)

Entry Method(s)

Input	Output
1:	1:

Note(s)

In immediate-entry mode, ◀ GRAPH will access the Sparcom 2D Graphics Environment, ▶ GRAPH will jump the cursor to the left edge of the command line, ◀ PLOT will display the enhanced Plot menu, and ▶ PLOT will display the Sparcom PLOT2 menu.

In algebraic and program entry modes, ◀ GRAPH will echo GRF2, ▶ GRAPH will jump the cursor to the left edge of the command line, ◀ PLOT will display the enhanced Plot menu, and ▶ PLOT will display the Sparcom PLOT2 menu.

When the Sparcom Plotting Keys are installed, you will not be able to interactively edit the list of user-key assignments returned by RCLKEYS. This is because the objects assigned to keys 34.2, 34.3, 63.2, and 63.3 are system RPL objects and your HP 48SX cannot edit them directly. If you wish to edit the list of user-key assignments, you must either first remove the Sparcom Plotting Keys or you must use commands such as REPL or the Interactive Stack to *indirectly* edit the list without placing it on the command line. If you accidentally attempt to interactively edit the list of user-key assignments when the Sparcom Plotting Keys are installed, you will have to press ON–C to abort the editing operation and return to the stack. (Pressing ON–C will *not* damage user memory, but it *will* clear the stack and return to the HOME directory.)

The Calculus Pac must be installed in your HP 48SX for the Sparcom Plotting Keys to work correctly. If you remove the Calculus Pac while the Sparcom Plotting Keys are installed and your HP 48SX is in User mode, the re-defined keys will behave as if the Sparcom Plotting Keys were not installed. Upon re-installing the Calculus Pac and re-entering User mode, the re-defined keys will resume their customized functions.

The Enhanced Plot Menu

The built-in HP 48SX Plot menu—accessed by pressing [↩] [PLOT]—includes the commands necessary to access the HP 48SX PLOTR menu, set the plot type, store an equation into 'EQ', and access the Equation Catalog. The Calculus Pac enables you to *enhance* the Plot menu to include new commands to access the Sparcom PLOT2, PLOT3, and DIFEQ menus.

To enhance the Plot menu, follow these steps:

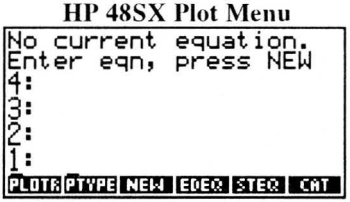
❶ Install the Sparcom Plotting Keys. (For more information, see "PKEY: Sparcom Plotting Keys.")

❷ Make sure User mode is turned on. (For more information, see Chapter 15 of the HP 48SX Owner's Manual, "Customizing the Calculator.")

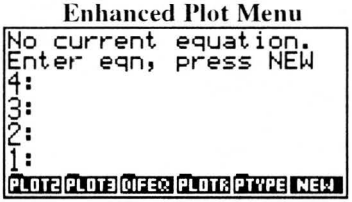
❸ Press [↩] [PLOT] to display the enhanced Plot menu.

When the enhanced Plot menu is displayed, a status message will appear, describing the current plot type and equation (displays assume 'EQ' does not exist):

HP 48SX Plot Menu



Enhanced Plot Menu



Because of the similarity between the Plot menu and the enhanced Plot menu, only the *differences* between them are summarized below. For a complete summary, see Chapter 18 of the HP 48SX Owner's Manual, "Basic Plotting and Function Analysis."

Enhanced Plot Menu Operations

Screen	Softkeys					
Plot Menu	PLOTR	PTYPE	NEW	EDEQ	STEQ	CAT
Plot Menu (Enhanced)	PLOT2	PLOT3	DIFEQ	PLOTR	PTYPE	NEW
	EDEQ	STEQ	CAT			

Key	Description
PLOT2	Displays the Sparcom PLOT2 menu for specifying the 2D plot parameters in 'PPAR' and accessing the Sparcom 2D Graphics Environment.
PLOT3	Displays the Sparcom PLOT3 menu for specifying the 3D plot parameters in 'PPAR3' and accessing the Sparcom 3D Graphics Environment.
DIFEQ	Displays the Sparcom DIFEQ menu for plotting differential equations.

HP 48SX Plotting vs. Sparcom 2D & 3D Plotting

Here is a comparison of the HP 48SX Plot application and the Sparcom 2D and 3D plotting routines.

Comparison of HP 48SX and Sparcom 2D & 3D Plotting

Feature	HP	2D	3D
Automatic plotting demonstrations	No	No	Yes
Plot parameters specified through menu(s) with status message(s)	Yes	Yes	Yes
Supported plot types:			
FUNCTION	Yes	Yes	–
CONIC	Yes	–	–
POLAR	Yes	Yes	–
PARAMETRIC	Yes	Yes	–
TRUTH	Yes	–	–
BAR	Yes	–	–
HISTOGRAM	Yes	–	–
SCATTER	Yes	–	–
FUNC3	–	–	Yes
PCURV3	–	–	Yes
PSURF3	–	–	Yes
Hidden line removal, viewing box, and xy-plane projection	–	–	Yes
Supports graphs larger than 131 x 64	Yes	Yes	Yes
Zoom operations:			
XAUTO, X, Y, XAUTO	Yes	Yes	–
Zoom box	Yes	–	–
Jump to any x-value	–	Yes	–
Center graph at cursor location	Yes	Yes	–
Display cursor coordinates	Yes	Yes	Yes
Trace mode	–	Yes	Yes

Function analysis operations:			
ROOT	Yes	Yes	–
ISECT	Yes	–	–
SLOPE	Yes	Yes	–
AREA	Yes	–	–
EXTR	Yes	Yes	–
F(X)	Yes	–	–
F'	Yes	Yes	–
NXEQ	Yes	Yes	–
Graph labeling	Yes	Yes	–
Graph tagging	–	Yes	–
Graphical editing commands:			
DOT+, DOT–, LINE	Yes	–	–
TLINE, BOX, CIRCL	Yes	–	–
MARK, REPL, SUB, DEL	Yes	–	–

Chapter 11

2D Plotting

2D plotting utilizes the Sparcom 2D Graphics Environment, which provides a powerful way to analyze and trace functions, polar plots, and parametric plots, and the Sparcom PLOT2 menu, which provides a flexible way to specify the 2D plot parameters.

This chapter covers:

- Using 2D Plotting
- PLOT2: Sparcom PLOT2 Menu
- GRF2: Sparcom 2D Graphics Environment

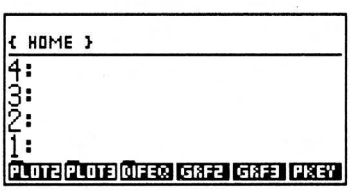
Using 2D Plotting

Both the Sparcom 2D Graphics Environment and PLOT2 menu are accessible from the Plotting Toolkit. To get to the Plotting Toolkit, follow these steps:

❶ Press [←] [LIBRARY] to display all libraries available to your HP 48SX.

❷ Find and press **CALCU** to display the Calculus Pac Library menu.

❸ Press the fourth softkey, **PLOT**, to display the Plotting Toolkit menu:



At this point, press **PLOT 2** to display the Sparcom PLOT2 menu or press **GRF 2** to enter the Sparcom 2D Graphics Environment.

PLOT2: Sparcom PLOT2 Menu

The Sparcom PLOT2 menu provides a flexible way to specify the 2D plot parameters. (Plot types other than FUNCTION, POLAR, and PARAMETRIC are not supported by the Sparcom PLOT2 menu—for other plot types, use the HP 48SX PLOTR menu.)

The Sparcom PLOT2 menu is nearly identical to the HP 48SX PLOTR menu, so you should familiarize yourself with Chapter 18 of the HP 48SX Owner's Manual, "Basic Plotting and Function Analysis," and Chapter 19, "More About Plotting and Graphics Objects."

Using the Sparcom PLOT2 Menu

There are three ways to access the Sparcom PLOT2 menu from the stack:

- Press [→] [PLOT] to display the Sparcom PLOT2 menu. (The Sparcom Plotting Keys must be installed and User mode must be turned on. For more information, see "PKEY: Sparcom Plotting Keys" in Chapter 10.)

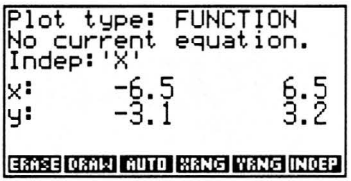
- Press [←] [PLOT] to display the enhanced Plot menu and press **PLOT2** to display the Sparcom PLOT2 menu. (The Sparcom Plotting Keys must be installed and User mode must be turned on. For more information, see "PKEY: Sparcom Plotting Keys" in Chapter 10.)

- Press [←] [LIBRARY] **CALCU** **PLOT** **PLOT2** to display the Sparcom PLOT2 menu.

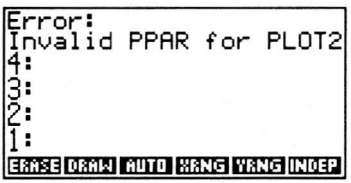
There is one way to access the Sparcom PLOT2 menu from the interactive menus:

- Press [←] [LIBRARY] **CALCU** **CALCU** to access the Main menu, move the pointer to "Plotting: 2D w/ Trace," press [ENTER] to display the information screen about 2D plotting, and press [ATTN] to display the Sparcom PLOT2 menu. (This will automatically install the Sparcom Plotting Keys and turn on User mode. For more information, see "PKEY: Sparcom Plotting Keys" in Chapter 10.)

When the Sparcom PLOT2 menu is displayed, if the plot type is FUNCTION, POLAR, or PARAMETRIC, a status message will also appear, describing the plot type, current equation(s), independent variable (with plotting range, if specified), and display ranges in the x- and y-axis directions:



However, if the plot type is *not* FUNCTION, POLAR, or PARAMETRIC, an error message will be displayed, because only those three plot types are supported by the Sparcom PLOT2 menu and 2D Graphics Environment:



If the plot type is not FUNCTION, POLAR, or PARAMETRIC, you should press NXT PTYPE and set the plot type to FUNCTION, POLAR, or PARAMETRIC. Then the status message will appear.

Because of the similarity between the Sparcom PLOT2 menu and the HP 48SX PLOTR menu, only the *differences* between them are summarized below. For a complete summary, see Chapter 18 of the HP 48SX Owner's Manual, "Basic Plotting and Function Analysis."

Sparcom PLOT2 Menu Operations

Screen	Softkeys					
Sparcom PLOT2 Menu	ERASE	DRAW	AUTO	XRNG	YRNG	INDEP
	DEPN	PTYPE	RES	CENT	SCALE	RESET
	AXES	DRAX	LABEL	*H	*W	PDIM

Key	Description
AUTO	After autoscaling, drawing the axes, and plotting the equation(s), enters the Sparcom 2D Graphics Environment. (Normally enters the HP 48SX Graphics Environment.)
DRAW	After drawing the axes and plotting the equation(s), enters the Sparcom 2D Graphics Environment. (Normally enters the HP 48SX Graphics Environment.)
PTYPE	Displays a plot type menu with only FUNCTION, POLAR, and PARAMETRIC available. (Normally all plot types are available.)

GRF2: Sparcom 2D Graphics Environment

This command invokes the Sparcom 2D Graphics Environment, which provides a powerful way to analyze and trace functions, polar plots, and parametric plots. (Plot types other than FUNCTION, POLAR, and PARAMETRIC are not supported by the Sparcom 2D Graphics Environment—for other plot types, use the HP 48SX Graphics Environment.)

The Sparcom 2D Graphics Environment is very similar to the HP 48SX Graphics Environment, so you should familiarize yourself with Chapter 18 of the HP 48SX Owner's Manual, "Basic Plotting and Function Analysis," and Chapter 19, "More About Plotting and Graphics Objects."

This section covers:

- ❑ Using the Sparcom 2D Graphics Environment
- ❑ Zoom Operations
- ❑ Jumping to Any Value of the Independent Variable
- ❑ Centering the Graph at the Cursor Coordinates
- ❑ Displaying the Cursor Coordinates
- ❑ Tracing an Equation
- ❑ Function Analysis Operations
- ❑ Tagging the Graph
- ❑ The Contents of 'PPAR'

Using the Sparcom 2D Graphics Environment

There are three ways to access the Sparcom 2D Graphics Environment:

- ❑ Plot an equation from the Sparcom PLOT2 menu with DRAW or AUTO.
- ❑ Press ← GRAPH from the stack. (The Sparcom Plotting Keys must be installed and User mode must be turned on. For more information, see "PKEY: Sparcom Plotting Keys" in Chapter 10.)
- ❑ Press ← LIBRARY CALCU PLOT GRF2.

The Sparcom 2D Graphics Environment is summarized below. (For more information, because of the similarity to the HP 48SX Graphics Environment, see Chapter 18 of the HP 48SX Owner's Manual, "Basic Plotting and Function Analysis.")

Sparcom 2D Graphics Environment Operations

Screen	Softkeys
Sparcom 2D Graphics Env.	ZOOM JUMP CENT COORD TRACE FCN TAG LABEL + - KEYS

Key	Action
CENT	Redraws the graph with the current cursor position at the center of the display, even if cursor is off-screen. If in Trace mode, the exact equation value is used.
COORD	Turns on coordinate display in the menu area. Press + or any softkey to restore the menu. The coordinates can be copied to the stack by pressing ENTER or ← ENTER.
FCN	Displays the Sparcom 2D Function Analysis Menu (subset of the HP 48SX GRAPHICS FCN menu).
JUMP	Prompts for a new value for the independent variable (x, θ, or t, depending on the plot type) and moves the cursor to that value on the current equation, redrawing the graph if necessary.
KEYS	Turns off menu to show more of the graph. Press − or any softkey to restore the menu.
LABEL	Adds axis labels to the graph.
TAG	Adds a circular tag to the graph at the cursor position.
TRACE	Toggles Trace mode on and off. In Trace mode, the cursor hugs the current equation, ◄ and ► decrease and increase the independent variable, and ▲ and ▼ switch between equations if 'EQ' contains more than one equation.
ZOOM	Displays the Sparcom 2D Zoom menu (identical to HP 48SX GRAPHICS ZOOM menu).
+ -	Toggles cursor type between dark and inverted.
ATTN	Quits to the HP 48SX stack.
ENTER	Copies the x- and y-coordinates of the cursor to the stack as a complex number. If in Trace mode, the exact equation value is used.
← ENTER	Copies a list of tagged real numbers to the stack—for functions: x and y; for polar plots: θ and r; and for parametric plots: t, x, and y. In Trace mode, the exact equation value is used.

← GRAPH	Toggles scrolling mode on and off. In scrolling mode, cursor keys scroll oversize graphs in the indicated direction.
◄ ► ▲ ▼	(Trace mode off) Move the cursor in the indicated direction. When prefixed with →, move the cursor to the edge of the screen in the indicated direction, or to the edge of PICT if already at the edge of the screen.
	(Trace mode on) ◄ and ► decrease and increase the independent variable, and ▲ and ▼ switch between equations (see TRACE). → ◄ and → ► move the cursor to the minimum and maximum value of the independent variable. → ▲ and → ▼ are non-functional.
+	Toggles coordinate display on and off (see COORD).
−	Toggles menu on and off (see KEYS).
÷	Toggles Trace mode on and off (same as TRACE).
+/-	Toggles cursor type (same as + -).
← REVIEW	Temporarily displays the PLOT2 status message, including the plot type, current equation(s), and independent variable.
STO	Copies PICT to the stack as a graphics object (GROB).
ON – MTH	Dumps the current screen to an IR printer.

Zoom Operations

From the Sparcom 2D Graphics Environment menu, press ZOOM to access the Sparcom 2D Zoom menu.

The zoom operations in the Sparcom 2D Zoom menu manipulate the viewing window by zooming in on a region for more detail or by zooming out for more information. You can zoom along the x-axis, the y-axis, or both axes.

Sparcom 2D Zoom Menu Operations

Screen	Softkeys
Zoom Menu	XAUTO X Y XY EXIT

Key	Action
EXIT	Exits the Sparcom 2D Zoom menu back to the Sparcom 2D Graphics Environment menu.
X	Prompts for x-axis zoom factor.

XAUTO	Prompts for x-axis zoom factor and autoscales y-axis.
XY	Prompts for x- and y-axis zoom factor.
Y	Prompts for y-axis zoom factor.

Jumping to Any Value of the Independent Variable

From the Sparcom 2D Graphics Environment menu, press JUMP to jump to any value of the independent variable. You will be prompted for a new value for the independent variable (X, θ, or T, depending on the plot type) and the cursor will be moved to the current equation at that value. If the current equation is undefined at that value, JUMP will do nothing. If that value is off-screen, the graph will be redrawn with the new cursor position at the center of the display.

Centering the Graph at the Cursor Coordinates

From the Sparcom 2D Graphics Environment menu, press CENT to redraw the graph with the cursor position at the center of the display. If Trace mode is on, the graph will be redrawn with the exact function value at the center of the display. If Trace mode is off, the graph will be redrawn with the pixel coordinates at the center of the display.

Displaying the Cursor Coordinates

From the Sparcom 2D Graphics Environment menu, press COORD or [+] to toggle coordinate display on and off. When on, the coordinates will be displayed in the menu area. The coordinates can be copied to the stack by pressing ENTER or [←] ENTER.

Trace Mode Off

The coordinates displayed will be the x- and y-coordinates of the center of the pixel on which the cursor is located. The coordinate labels will always be X and Y, regardless of the names of the independent and dependent variables.

Pressing ENTER will return a complex number representing the x- and y-coordinates of the center of the pixel on which the cursor is located. Pressing [←] ENTER will return the same coordinates as a list of two tagged real numbers.

Trace Mode On

The coordinates displayed will depend on the plot type:

- **FUNCTION:** The coordinates displayed will be the x-value of the cursor and F(x), the function y-value for that x-value. The coordinate

labels will be X and Y, regardless of the names of the independent and dependent variables.

- **POLAR:** The coordinates displayed will be the θ-value of the cursor and R(θ), the function r-value for that θ-value. The coordinate labels will be θ and R, regardless of the names of the independent and dependent variables.

- **PARAMETRIC:** The coordinates displayed will be the t-value of the independent variable and F(t), the function x- and y-values for that t-value. The coordinate labels will be T, X, and Y, regardless of the names of the independent and dependent variables.

Pressing ENTER will return a complex number representing the exact x- and y-coordinates of the cursor's location on the function. Pressing ← ENTER will return a list of tagged real numbers—for functions: x and y; for polar plots: θ and r; and for parametric plots: t, x, and y.

NOTE: For a function plot, toggling Trace mode on and off may change the displayed y-coordinate. This is because Trace mode always displays the *exact function value*, which may not be identical to the y-value of the closest pixel.

Tracing an Equation

From the Sparcom 2D Graphics Environment menu, press TRACE or ÷ to toggle Trace mode on and off. When on, the softkey will appear with a box.

In Trace mode, the cursor hugs the current equation, ◄ and ► decrease and increase the independent variable, and ▲ and ▼ switch between equations if 'EQ' contains more than one equation. ↵ ◄ and ↵ ► move the cursor to the minimum and maximum value of the independent variable.

NOTE: Tracing an undrawn interval of an equation will cause the equation to be filled in pixel by pixel, except in regions where the equation is undefined.

Function Analysis Operations

From the Sparcom 2D Graphics Environment menu, press FCN to access the Sparcom 2D Function Analysis menu.

The function analysis operations in the Sparcom 2D Function Analysis menu allow you to analyze the behavior and characteristics of the plotted equations.

You can find roots, extremums, slopes, and derivatives. You can also switch among multiple plotted equations. All function analysis operations work correctly whether Trace mode is on or off.

The Sparcom 2D Function Analysis menu is summarized below. (For more information, because of the similarity to the HP 48SX GRAPHICS FCN menu, see Chapter 18 of the HP 48SX Owner's Manual, "Basic Plotting and Function Analysis.")

Sparcom 2D Function Analysis Menu Operations

Screen	Softkeys
Function	ROOT EXTR SLOPE F' NXEQ EXIT

Key	Action
EXIT	Exits the Sparcom 2D Function Analysis menu back to the Sparcom 2D Graphics Environment menu.
EXTR	Moves the cursor to the nearest extremum or inflection point and displays the coordinates. The extremum is automatically copied to the stack.
F'	Calculates and plots first derivative of current equation. Prepends derivative to 'EQ', converting 'EQ' to a list if necessary. If in Trace mode, cursor switches to the derivative.
NXEQ	If 'EQ' is an equation, swaps the sides of the equation. If 'EQ' is a list, rotates the list, moving the second equation to the beginning and the first equation to the end.
ROOT	Moves the cursor to the nearest root and displays the coordinates. The root is automatically copied to the stack.
SLOPE	Calculates and displays the slope of the equation at the x-value of the cursor. If not in Trace mode, also moves the cursor to the point on the equation where the slope was calculated. The slope is automatically copied to the stack.

Tagging the Graph

From the Sparcom 2D Graphics Environment menu, press TAG to tag the graph at the current cursor location. The tag is a circular mark which can be used to circle points of interest on the graph. Unlike MARK in the HP 48SX Graphics Environment, TAG does *not* toggle the tag on and off: the tag is permanent.

The Contents of 'PPAR'

The HP 48SX Plot application and the Calculus Pac use the reserved variable 'PPAR' to store the plotting parameters for 2D plots. 'PPAR' should contain the following list of objects:

{ (x_{min}, y_{min}) (x_{max}, y_{max}) indep res axes ptype depend }

'PPAR' Contents

Item	Description	Default
(x_{min}, y_{min})	A complex number containing the coordinates of the lower left corner of the display region.	(–6.5,–3.1)
(x_{max}, y_{max})	A complex number containing the coordinates of the upper right corner of the display region.	(6.5,3.1)
indep	Independent variable. Can be a name or a list containing a name and two real numbers (the x-axis plotting range).	'X'
res	Resolution along the x-axis. A binary integer specifies the number of pixels, while a real number specifies the number of user units between points.	0
axes	A complex number containing the coordinates of the axes intersection, or a list containing the intersection and axes labels.	(0,0)
ptype	Command name specifying the plot type. Only FUNCTION, POLAR, and PARAMETRIC are supported by the Sparcom 2D Graphics Environment.	FUNCTION
depend	Dependent variable. Can be a name or a list containing the name and two real numbers (the y-axis plotting range).	'Y'

Chapter 12

3D Plotting

3D plotting utilizes the Sparcom 3D Graphics Environment, which provides a powerful way to specify, plot, and trace 3D functions, parametric curves, and parametric surfaces, and the Sparcom PLOT3 menu, which provides a flexible way to specify the 3D plot parameters.

This chapter covers:

- ❑ Using 3D Plotting
- ❑ 3D Plotting Demonstrations
- ❑ More About 3D Plotting
- ❑ PLOT3: Sparcom PLOT3 Menu
- ❑ GRF3: Sparcom 3D Graphics Environment

The programmable commands in the Sparcom PLOT3 menu and submenus are described in both "PLOT3: Sparcom PLOT3 Menu" *and* the following sections:

- ❑ DRAW3: Draw Plot (3D)
- ❑ ERASE: Erase PICT
- ❑ EYE3: Eye Point (3D)
- ❑ FUNC3: Function Plot Type (3D)
- ❑ PCURV3: Parametric Curve Plot Type (3D)
- ❑ PDIM: PICT Dimension
- ❑ PSURF3: Parametric Surface Plot Type (3D)
- ❑ STEQ: Store in EQ
- ❑ STOX: Store x-Component in EQ
- ❑ STOY: Store y-Component in EQ
- ❑ STOZ: Store z-Component in EQ
- ❑ TDOM: t-Variable Domain
- ❑ TRES: t-Variable Resolution
- ❑ TVAR: t-Variable Name
- ❑ UDOM: u-Variable Domain
- ❑ URES: u-Variable Resolution
- ❑ UVAR: u-Variable Name
- ❑ VBOX: Draw Viewing Box
- ❑ VDOM: v-Variable Domain
- ❑ VRES: v-Variable Resolution
- ❑ VVAR: v-Variable Name

- ❑ XDOM: x-Variable Domain
- ❑ XRES: x-Variable Resolution
- ❑ XRNG3: x-Axis Display Range (3D)
- ❑ XVAR: x-Variable Name
- ❑ XYPRJ: Draw xy-Plane Projection
- ❑ YDOM: y-Variable Domain
- ❑ YRES: y-Variable Resolution
- ❑ YRNG3: y-Axis Display Range (3D)
- ❑ YVAR: y-Variable Name
- ❑ ZRNG3: z-Axis Display Range (3D)

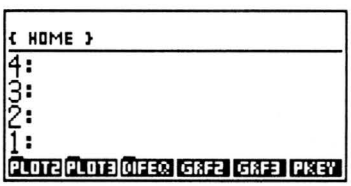
Using 3D Plotting

Both the Sparcom 3D Graphics Environment and PLOT3 menu are accessible from the Plotting Toolkit. To get to the Plotting Toolkit, follow these steps:

❶ Press [←] [LIBRARY] to display all libraries available to your HP 48SX.

❷ Find and press **CALCU** to display the Calculus Pac Library menu.

❸ Press the fourth softkey, **PLOT**, to display the Plotting Toolkit menu:



At this point, press **PLOT3** to display the Sparcom PLOT3 menu or press **GRF3** to enter the Sparcom 3D Graphics Environment.

3D Plotting Demonstrations

This section demonstrates the capabilities of the 3D plotting routines in the Calculus Pac for each of the supported plot types: 3D functions (FUNC3), parametric curves (PCURV3), and parametric surfaces (PSURF3).

This section covers:

- ❑ 3D Function Demonstration
- ❑ 3D Parametric Curve Demonstration
- ❑ 3D Parametric Surface Demonstration

3D Function Demonstration

To execute the 3D function demonstration, follow these steps:

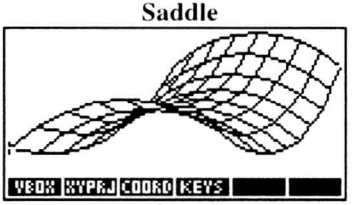
❶ (If necessary) Press ↰ LIBRARY **CALCU** **PLOT** to view Plotting Toolkit menu.

❷ (If necessary) Press **PLOT3** to display the Sparcom PLOT3 menu.

❸ (If necessary) Press **PTYPE** to display the Sparcom PLOT3 PTYPE menu.

❹ (If necessary) Press **FUNC** to set the plot type to FUNC3.

❺ Press **DEMO** to plot the demonstration equation:



$$\frac{y^2 - x^2}{5}$$

EQ: '(Y^2–X^2)/5'
PPAR3: { [–5 –5 –5] [5 5 5] [20 –30 30] 'X' 'Y' # 8d # 8d FUNC3 }

The 3D plot parameters for this plot include a modified eye point location of [20 –30 30]. All other parameters have default values.

❻ Press ATTN when you have finished examining the plot in the Sparcom 3D Graphics Environment. The Sparcom PLOT3 PTYPE menu will reappear.

3D Parametric Curve Demonstration

To execute the 3D parametric curve demonstration, follow these steps:

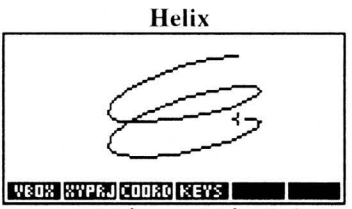
❶ (If necessary) Press ↩ LIBRARY CALCU PLOT to view Plotting Toolkit menu.

❷ (If necessary) Press PLOT3 to display the Sparcom PLOT3 menu.

❸ (If necessary) Press PTYPE to display the Sparcom PLOT3 PTYPE menu.

❹ (If necessary) Press PCURV to set the plot type to PCURV3.

❺ Press DEMO to plot the demonstration equation:



$$\sin(t)\hat{x} + \cos(t)\hat{y} + .2t\hat{z}$$

EQ: { 'SIN(T)' 'COS(T)' '.2*T' }
PPAR3: { [–1.5 –1.5 –1.5] [1.5 1.5 1.5] [20 –20 20]{ T –6.28318530718 6.28318530718 } 'Y' # 30d # 8d PCURV3 }

The 3D plot parameters for this plot include x-, y-, and z-axis display ranges of –1.5 to 1.5, a t-variable domain of -2π to $+2\pi$ to control values of the parametric variable, and a t-variable resolution of # 30d to plot the helix in finer detail. All other parameters have default values.

❻ Press ATTN when you have finished examining the plot in the Sparcom 3D Graphics Environment. The Sparcom PLOT3 PTYPE menu will reappear.

3D Parametric Surface Demonstration

To execute the 3D parametric surface demonstration, follow these steps:

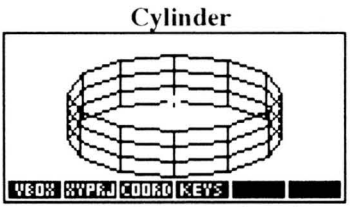
❶ (If necessary) Press ↩ LIBRARY **CALCU** **PLOT** to display the Plotting Toolkit menu.

❷ (If necessary) Press **PLOT3** to display the Sparcom PLOT3 menu.

❸ (If necessary) Press **PTYPE** to display the Sparcom PLOT3 PTYPE menu.

❹ (If necessary) Press **PSURF** to set the plot type to PSURF3.

❺ Press **DEMO** to plot the demonstration equation:



$$\sin(u)\hat{x} + \cos(u)\hat{y} + v\hat{z}$$

EQ: { 'SIN(U)' 'COS(U)' 'V' }
PPAR3: { [–1.5 –1.5 –1.5] [1.5 1.5 1.5] [0 –50 125]
{ U 0 360 } 'V' # 12d # 3d PSURF3 }

The 3D plot parameters for this plot include x-, y-, and z-axis display ranges of –1.5 to 1.5, an eye point of [0 –50 125], a u-variable domain of 0 to 360 (degrees) to control the rotation of the u-variable around the z-axis, a u-variable resolution of # 12d, and a v-variable resolution of # 3d. All other parameters have default values.

❻ Press ATTN when you have finished examining the plot in the Sparcom 3D Graphics Environment. The Sparcom PLOT3 PTYPE menu will reappear.

More About 3D Plotting

3D functions, parametric curves, and parametric surfaces are plotted in an oblique single-point perspective view with the vanishing point located along the y-axis. A fast divide-by-depth method is used to calculate the perspective, avoiding the time-consuming matrix transformations normally required for 3D plotting. The resolution of a 3D graph can be finely controlled, either as an absolute number of grid squares or line segments, or as a user unit spacing.

This section covers:

- Contents of 'EQ'
- Divide-by-Depth, Display Volume, and Eye Point
- Variable Domains vs. Display Ranges
- Controlling the Resolution
- Hidden Line Removal
- Overlaying Multiple 3D Graphs

Contents of 'EQ'

The Calculus Pac plots the equation stored in the reserved variable 'EQ'. For 3D functions, 'EQ' should contain a single expression, equation, or program, while for 3D parametric curves and surfaces, 'EQ' should contain a list of three expressions, equations, or programs, one each to represent the x-, y-, and z-components. A valid equation (or component) can be any of the following:

- **Expression:** A symbolic such as 12, 'X^2+5', or 'SIN(X)*SIN(Y)'.

- **Equation:** Two expressions separated by =, such as 'Z=12', 'Z=X^2+5', or 'Z=SIN(X)*SIN(Y)'. The left side is *always* ignored, regardless of the setting of flag –30 (Function Plotting).

- **Program:** A program that takes no values from the stack and returns exactly one value to the stack, such as « IF 'X<0' THEN '2*X' ELSE '2*Y' END ». The program should use the variables names specified by XVAR, YVAR, TVAR, UVAR, and/or VVAR.

- **Global Name:** A global name containing any of the above objects.

Throughout this chapter, the term *equation* refers to one of the above objects (for 3D functions) or to a list of three of the above objects (for 3D parametric curves and surfaces).

Divide-by-Depth, Display Volume, and Eye Point

All 3D graphs are plotted in a parallelepiped display volume, specified by x-axis, y-axis, and z-axis minimum and maximum values. The display volume is projected onto PICT (the viewing plane) with the eye point as the center of projection and a single vanishing point along the y-axis. The viewing plane is assumed to be one unit from the eye point and is always parallel to the xz-plane.

NOTE: This method prevents the eye point from being located such that $y_{min} \le y_{eye} \le y_{max}$, but this inability to "look" directly along the x-axis toward the graph can be circumvented by increasing the value of x_{eye} or z_{eye} sufficiently.

The default display volume is a 10 x 10 x 10 cube centered on the origin, and the default eye point is located at [20 –20 20]. Locating the eye point closer to the graph will increase the perspective distortion (causing lines parallel to the y-axis to noticeably converge to the vanishing point), while locating the eye point farther from the graph will decrease the perspective distortion. Increasing or decreasing x_{eye} or y_{eye} sufficiently will effectively rotate the graph about the z-axis, despite the restriction on the location of the eye point. (For more information, see "EYE3: Eye Point (3D).")

Variable Domains vs. Display Ranges

The display ranges control the dimensions of the display volume, which is always entirely contained in PICT (the viewing plane). The variable domains (which default to the display ranges) control the actual extent of the graph plotted inside the viewing volume. Therefore, while the viewing volume for a 3D function graph might be a 10 x 10 x 10 cube, the graph could be restricted to the inner 5 x 5 vertical column by specifying separate variable domains for x and y. (For more information, see "XDOM: x-Variable Domain," "YDOM: y-Variable Domain," and other related sections.)

Controlling the Resolution

The resolution along both axes of a 3D graph can be specified independently as either binary integers or real numbers. Depending on the plot type, a binary integer specifies the number of grid squares, parametric curve segments, or values of one of the parametric variables for a parametric surface, while a real number specifies the number of user units between grid lines, parametric curve points, or values of one of the parametric variables for a parametric surface. (For more information, see "XRES: x-Variable Resolution," "YRES: y-Variable Resolution," and other related sections.)

NOTE: For fastest results, plot with a coarse resolution and experiment to find the best eye point location. When you are satisfied with the view, increase the resolution for finer detail.

Hidden Line Removal

Hidden line removal is an optional setting for 3D functions and is controlled by the state of user flag 58. (Flag 58 clear means hidden line removal is active, while Flag 58 set means it is not.) By default, hidden line removal is active. To toggle hidden line removal, press **HL INE** at the Sparcom PLOT3 menu. (For more information, see "PLOT3: Sparcom PLOT3 Menu.")

WARNING: Hidden line removal applies *only* to 3D functions and not to 3D parametric curves or 3D parametric surfaces. Also, because the algorithm used to perform hidden line removal depends on the contents of PICT, before drawing a 3D function with hidden line removal, you *must* erase PICT. If you do not, the graph may be drawn incorrectly.

Overlaying Multiple 3D Graphs

Although the Sparcom PLOT2 menu and 2D Graphics Environment support multiple equations, the Sparcom PLOT3 menu and 3D Graphics Environment do not. The only way to overlay multiple 3D graphs is to store and draw one equation and then store and draw another equation, without erasing PICT between drawing operations. However, you should be aware of the following:

❶ Only the equation currently stored in 'EQ' will be traced inside the Sparcom 3D Graphics Environment—any previously drawn equation(s) will no longer be available for tracing.

❷ Hidden line removal will *not* work correctly for all 3D functions graphed subsequent to the first one, because a non-empty PICT will mislead the algorithm. Therefore, all 3D functions graphed subsequently to the first one should be drawn with hidden line removal turned off.*

* There *is* a way to display multiple 3D function graphs with hidden line removal, but it requires that you erase PICT, draw the first graph, store the first graph as a graphics object, erase PICT, draw another graph, store that graph as a graphics object, merge the two graphics objects with the command GOR, and store the resulting graphics object into PICT for display. For more information, see Chapter 19 of the HP 48SX Owner's Manual, "More About Plotting and Graphics Objects."

PLOT3: Sparcom PLOT3 Menu

The Sparcom PLOT3 menu and submenus provide a flexible way to specify the 3D plot parameters.

This section covers:

- ❑ Using the Sparcom PLOT3 Menu
- ❑ The Sparcom PLOT3 PTYPE Menu
- ❑ The Sparcom PLOT3 EQN Menu
- ❑ The Sparcom PLOT3 RNG Menu
- ❑ The Sparcom PLOT3 VAR Menu

Using the Sparcom PLOT3 Menu

There are two ways to access the Sparcom PLOT3 menu:

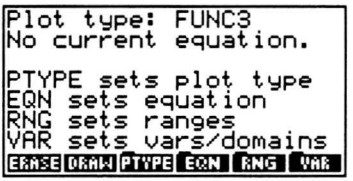
- ❑ Press ← PLOT to display the enhanced Plot menu and press **PLOT3** to display the Sparcom PLOT3 menu. (The Sparcom Plotting Keys must be installed and User mode must be turned on. For more information, see "PKEY: Sparcom Plotting Keys" in Chapter 10.)

- ❑ Press ← LIBRARY **CALCU** **PLOT** **PLOT3** to display the Sparcom PLOT3 menu.

There is one way to access the Sparcom PLOT3 menu from the interactive menus:

- ❑ Press ← LIBRARY **CALCU** **CALCU** to access the Main menu, move the pointer to "Plotting: 3D w/ Trace," press ENTER to display the information screen about 3D plotting, and press ATTN to display the Sparcom PLOT3 menu. (This will automatically install the Sparcom Plotting Keys and turn on User mode. For more information, see "PKEY: Sparcom Plotting Keys" in Chapter 10.)

When the Sparcom PLOT3 menu is displayed, a status message will appear, describing the plot type, current equation, and information about the various PLOT3 submenus (display assumes default plot type and that 'EQ' does not exist):



The Sparcom PLOT3 menu is summarized below.

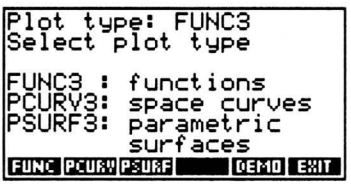
Sparcom PLOT3 Menu Operations

Screen	Softkeys
Sparcom PLOT3 Menu	ERASE DRAW3 PTYPE EQN RNG VAR VBOX XYPRJ HLINE PDIM RESET

Key	Description
DRAW	Plots the equation in the reserved variable 'EQ' in PICT (without erasing PICT), using the x-, y-, and z-axis display ranges. Automatically enters the Sparcom 3D Graphics Environment if executed from the Sparcom PLOT3 menu. ◀ DRAW3 executes STEQ. ▶ DRAW3 recalls the current equation.
ERASE	Erases PICT, leaving a blank PICT of the same size.
EQN	Displays the Sparcom PLOT3 EQN menu.
HLINE	Toggles hidden line removal for 3D functions. A box appears in the key label to indicate when hidden line removal is active.
PDIM	Changes the size of PICT. ▶ PDIM recalls the size of PICT.
PTYPE	Displays the Sparcom PLOT3 PTYPE menu.
RESET	Resets all plot parameters except the plot type, to their default values and erases PICT, restoring it to 131 x 64.
RNG	Displays the Sparcom PLOT3 RNG menu.
VAR	Displays the Sparcom PLOT3 VAR menu.
VBOX	Draws the viewing box in PICT, using the x-, y-, and z-axis display ranges.
XYPRJ	Draws the xy-plane projection in PICT, using the x- and y-axis display ranges.
◀ REVIEW	Redisplays the status message.

The Sparcom PLOT3 PTYPE Menu

Press **PTYPE** to display the Sparcom PLOT3 PTYPE menu. A status message will appear, describing the available plot types (display assumes default plot type):



The Sparcom PLOT3 PTYPE menu is summarized below.

Sparcom PLOT3 PTYPE Menu Operations

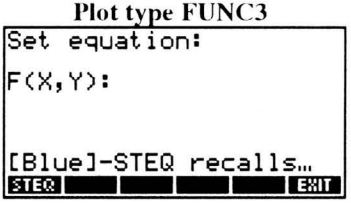
Screen	Softkeys
PTYPE Menu	FUNC PCURV PSURF DEMO EXIT

Key	Description
DEMO	Executes the demo for the current plot type.
EXIT	Exits to the Sparcom PLOT3 menu.
FUNC	Sets plot type to FUNC3 and resets variables to 'X' and 'Y'.
PCURV	Sets plot type to PCURV3 and resets first variable to 'T'.
PSURF	Sets plot type to PSURF3 and resets variables to 'U' and 'V'.
← REVIEW	Redisplays the status message.

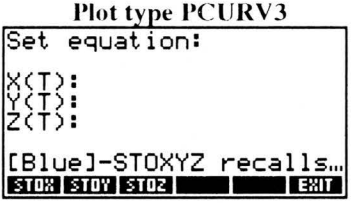
The Sparcom PLOT3 EQN Menu

Press **EQN** to display the Sparcom PLOT3 EQN menu. A status message will appear (depending on the plot type), describing the current equation (displays assume 'EQ' does not exist):

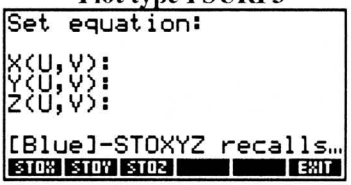
Plot type FUNC3



Plot type PCURV3



Plot type PSURF3



The Sparcom PLOT3 EQN menu is summarized below.

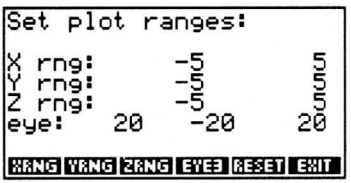
Sparcom PLOT3 EQN Menu Operations

Screen	Softkeys
EQN Menu (FUNC3)	STEQ [ ] [ ] [ ] [ ] EXIT
EQN Menu (PCURV3, PSURF3)	STOX STOY STOZ [ ] [ ] EXIT

Key	Description
EXIT	Exits to the Sparcom PLOT3 menu.
STEQ	Stores an equation from the stack into 'EQ'. ↱ STEQ recalls the current equation.
STOX	Stores an equation from the stack as the x-component of the equation in 'EQ' (as the first item in a list of three items). ↱ STOX recalls the current x-component of 'EQ'.
STOY	Stores an equation from the stack as the y-component of the equation in 'EQ' (as the second item in a list of three items). ↱ STOY recalls the current y-component of 'EQ'.
STOZ	Stores an equation from the stack as the z-component of the equation in 'EQ' (as the third item in a list of three items). ↱ STOZ recalls the current z-component of 'EQ'.
↰ REVIEW	Redisplays the status message.

The Sparcom PLOT3 RNG Menu

Press **RNG** to display the Sparcom PLOT3 RNG menu. A status message will appear, describing the current display ranges and eye point (display assumes default values):



The Sparcom PLOT3 RNG menu is summarized below.

Sparcom PLOT3 RNG Menu Operations

Screen	Softkeys
RNG Menu	XRNG YRNG ZRNG EYE3 RESET EXIT

Key	Description
EXIT	Exits to the Sparcom PLOT3 menu.
EYE3	Sets the eye point in 'PPAR3' as the vector [x_{eye} y_{eye} z_{eye}]. ↱ EYE3 recalls the current eye point.
RESET	Resets x-, y-, and z-axis display ranges and the eye point to their default values.
XRNG	Sets the x-axis display range in 'PPAR3' as part of the vectors [x_{min} y_{min} z_{min}] and [x_{max} y_{max} z_{max}]. ↱ XRNG3 recalls the current x-axis display range.
YRNG	Sets the y-axis display range in 'PPAR3' as part of the vectors [x_{min} y_{min} z_{min}] and [x_{max} y_{max} z_{max}]. ↱ YRNG3 recalls the current y-axis display range.
ZRNG	Sets the z-axis display range in 'PPAR3' as part of the vectors [x_{min} y_{min} z_{min}] and [x_{max} y_{max} z_{max}]. ↱ ZRNG3 recalls the current z-axis display range.
↰ REVIEW	Redisplays the status message.

The Sparcom PLOT3 VAR Menu

Press **VAR** to display the Sparcom PLOT3 VAR menu. A status message will appear (depending on the plot type), describing the current domains, resolutions, and variables (displays assume default values):

Plot type FUNC3

Plot type PCURV3

Plot type PSURF3

The Sparcom PLOT3 VAR menu is summarized below.

Sparcom PLOT3 VAR Menu Operations

Screen	Softkeys					
VAR Menu (FUNC3)	XDOM	YDOM	XRES	YRES	RESET	EXIT
	XVAR	YVAR				EXIT
VAR Menu (PCURV3)	TDOM	TRES	TVAR		RESET	EXIT
VAR Menu (PSURF3)	UDOM	VDOM	URES	VRES	RESET	EXIT
	UVAR	VVAR				EXIT

Key	Description
EXIT	Exits to the Sparcom PLOT3 menu.
RESET	Resets domains, resolutions, and variables to their default values.
TDOM	Sets t-variable domain in 'PPAR3' as the list { t_{var} t_{min} t_{max} }. ↵ TDOM recalls the current t-variable domain.
TRES	Sets t-variable resolution in 'PPAR3' as the binary integer or real number t_{res}. ↵ TRES recalls the current t-resolution.

TVAR	Sets t-variable name in 'PPAR3' as the name t_{var}. → TVAR recalls the current t-variable name.
UDOM	Sets u-variable domain in 'PPAR3' as the list { u_{var} u_{min} u_{max} }. → UDOM recalls the current u-variable domain.
URES	Sets u-variable resolution in 'PPAR3' as the binary integer or real number u_{res}. → URES recalls the current u-resolution.
UVAR	Sets u-variable name in 'PPAR3' as the name u_{var}. → UVAR recalls the current u-variable name.
VDOM	Sets v-variable domain in 'PPAR3' as the list { v_{var} v_{min} v_{max} }. → VDOM recalls the current v-variable domain.
VRES	Sets v-variable resolution in 'PPAR3' as the binary integer or real number v_{res}. → VRES recalls the current v-resolution.
VVAR	Sets v-variable name in 'PPAR3' as the name v_{var}. → VVAR recalls the current v-variable name.
XDOM	Sets x-variable domain in 'PPAR3' as the list { x_{var} x_{min} x_{max} }. → XDOM recalls the current x-variable domain.
XRES	Sets x-variable resolution in 'PPAR3' as the binary integer or real number x_{res}. → XRES recalls the current x-resolution.
XVAR	Sets x-variable name in 'PPAR3' as the name x_{var}. → XVAR recalls the current x-variable name.
YDOM	Sets y-variable domain in 'PPAR3' as the list { y_{var} y_{min} y_{max} }. → YDOM recalls the current y-variable domain.
YRES	Sets y-variable resolution in 'PPAR3' as the binary integer or real number y_{res}. → YRES recalls the current y-resolution.
YVAR	Sets y-variable name in 'PPAR3' as the name y_{var}. → YVAR recalls the current y-variable name.
← REVIEW	Redisplays the status message.

GRF3: Sparcom 3D Graphics Environment

This command invokes the Sparcom 3D Graphics Environment, which provides a powerful way to specify, plot, and trace 3D functions, parametric curves, and parametric surfaces.

This section covers:

- Using the Sparcom 3D Graphics Environment
- Tracing an Equation
- Drawing the Viewing Box
- Drawing the xy-Plane Projection
- Displaying the Cursor Coordinates
- The Contents of 'PPAR3'

Using the Sparcom 3D Graphics Environment

There are three ways to access the Sparcom 3D Graphics Environment:

- Plot an equation from the Sparcom PLOT3 menu with DRAW.
- Press → GRAPH from the stack. (The Sparcom Plotting Keys must be installed and User mode must be turned on. For more information, see "PKEY: Sparcom Plotting Keys" in Chapter 10.)
- Press ← LIBRARY CALCU PLOT GRF3.

The Sparcom 3D Graphics Environment is summarized below.

Sparcom 3D Graphics Environment Operations

Screen	Softkeys
Sparcom 3D Graphics Env.	VBOX XYPRJ COORD KEYS [redacted] [redacted]

Key	Action
COORD	Turns on coordinate display in the menu area. Press + or any softkey to restore the menu. The coordinates can be copied to the stack by pressing ENTER or ← ENTER.
KEYS	Turns off menu to show more of the graph. Press − or any softkey to restore the menu.

VBOX	Draws the viewing box, using the x-, y-, and z-axis display ranges.
XYPRJ	Draws the xy-plane projection, using the x- and y-axis display ranges.
◄	Decreases the first variable (x, t, or u). When prefixed with ↱, decreases to the minimum value.
►	Increases the first variable (x, t, or u, depending on the plot type). When prefixed with ↱, increases to the maximum value.
▲	Increases the second variable (y or v, depending on the plot type). When prefixed with ↱, increases to the maximum value.
▼	Decreases the second variable (y or v, depending on the plot type). When prefixed with ↱, decreases to the minimum value.
ATTN	Quits to the HP 48SX stack.
ENTER	Copies the x-, y-, and z-coordinates of the cursor to the stack as a 3D vector, using the exact equation value for the z-coordinate.
↰ ENTER	Copies a list of tagged real numbers to the stack—for 3D functions: x, y, and z; for 3D parametric curves: t, x, y, and z; and for 3D parametric surfaces: u, v, x, y, and z.
+	Toggles coordinate display in the menu area on and off. The coordinates can be copied to the stack by pressing ENTER or ↰ ENTER.
STO	Copies PICT to the stack as a graphics object (GROB).
ON–MTH	Dumps the current screen to an IR printer.

Tracing an Equation

The Sparcom 3D Graphics Environment automatically traces the plotted equation. The cursor keys move between the plotted points of the graph, which may be the intersections of the grid lines (3D functions and parametric surfaces) or the ends of the line segments (3D parametric curves). ◄ and ► decrease and increase the first variable, while ▲ and ▼ decrease and increase the second variable (except for 3D parametric curves). In all cases, prefixing a cursor key with ↱ increases or decreases the variable as far as possible in the indicated direction.

Drawing the Viewing Box

From the Sparcom 3D Graphics Environment menu, press **VBOX** to draw the viewing box, using the x-, y-, and z-axis display ranges.

Drawing the xy-Plane Projection

From the Sparcom 3D Graphics Environment menu, press **XYPRJ** to draw the xy-plane projection, using the x- and y-axis display ranges.

Displaying the Cursor Coordinates

From the Sparcom 3D Graphics Environment menu, press **COORD** or [+] to toggle coordinate display on and off. When on, the coordinates will be displayed in the menu area. The coordinates can be copied to the stack by pressing [ENTER] or [◀] [ENTER].

When coordinate display is on, pressing [NXT] will toggle between the x-, y-, and z-coordinates and either the t-coordinate for 3D parametric curves or the u- and v-coordinates for 3D parametric surfaces. For 3D functions, [NXT] is non-functional.

Pressing [ENTER] will return a 3D vector representing the exact x-, y-, and z-coordinates of the cursor's location on the function. Pressing [◀] [ENTER] will return a list of tagged real numbers—for 3D functions: x, y, and z; for 3D parametric curves: t, x, y, and z; and for 3D parametric surfaces: u, v, x, y, and z.

The Contents of 'PPAR3'

The Calculus Pac uses the global variable 'PPAR3' to store the plotting parameters for 3D plots. 'PPAR3' should contain the following list of objects:

$$\{ [x_{min}\ y_{min}\ z_{min}]\ [x_{max}\ y_{max}\ z_{max}]\ [x_{eye}\ y_{eye}\ z_{eye}]$$
$$\text{var1 var2 res1 res2 ptype } \}$$

'PPAR3' Contents

Item	Description	Default
$[x_{min}\ y_{min}\ z_{min}]$	A vector containing the coordinates of one corner of the display volume.	[–5 –5 –5]
$[x_{max}\ y_{max}\ z_{max}]$	A vector containing the coordinates of the opposite corner of the display volume.	[5 5 5]

[x_{eye} y_{eye} z_{eye}]	A vector containing the coordinates of the eye point.	[20 –20 20]
var1	First variable. Can be a name or a list containing a name and two real numbers to specify a domain.	'X' for FUNC3 'T' for PCURV3 'U' for PSURF3
var2	Second variable. Can be a name or a list containing a name and two real numbers to specify a domain.	'Y' for FUNC3 'V' for PSURF3
res1	First resolution. A real number indicates user unit resolution, while a binary integer indicates total divisions.	# 8d
res2	Second resolution. A real number indicates user unit resolution, while a binary integer indicates total divisions.	# 8d
ptype	Command name specifying the plot type. Only FUNC3, PCURV3, and PSURF3 are supported by the Sparcom 3D Graphics Environment.	FUNC3

DRAW3: Draw Plot (3D)

This command plots the equation in the reserved variable 'EQ' in PICT, using the x-, y-, and z-axis display ranges specified by XRNG3, YRNG3, and ZRNG3 and (if specified) the variable domains specified by XDOM, YDOM, TDOM, UDOM, or VDOM. When executed from the Sparcom PLOT3 menu, DRAW3 plots the equation and then enters the Sparcom 3D Graphics Environment. When executed from a program, DRAW3 plots the equation, but does *not* enter the Sparcom 3D Graphics Environment. DRAW3 does not erase PICT—to do that, execute ERASE.

DRAW3 is located in the Sparcom PLOT3 Menu.

Entry Method(s)

Input	Output
1:	1:

ERASE: Erase PICT

This command erases PICT, leaving a blank PICT of the same dimensions.

ERASE is located in the Sparcom PLOT3 Menu.

Entry Method(s)

Input	Output
1:	1:

Note(s)

This is a built-in HP 48SX command.

EYE3: Eye Point (3D)

This command specifies the eye point for the Sparcom 3D Graphics Environment. This information is stored in the global variable 'PPAR3' as the vector [x_{eye} y_{eye} z_{eye}]. The default eye point location is [20 –20 20]. (For more information, see "More About 3D Plotting.")

EYE3 is located in the Sparcom PLOT3 RNG Menu.

Entry Method(s)

Input	Output
3: x_{eye}	3:
2: y_{eye}	2:
1: z_{eye}	1:

Example(s)

Input	Output
50 –50 50 EYE3	

FUNC3: Function Plot Type (3D)

This command sets the plot type to FUNC3 for the Sparcom 3D Graphics Environment. This information is stored in the global variable 'PPAR3'. This is the default plot type. (For more information, see "More About 3D Plotting.")

FUNC3 is located in the Sparcom PLOT3 PTYPE menu.

Entry Method(s)

Input	Output
1:	1:

PCURV3: Parametric Curve Plot Type (3D)

This command sets the plot type to PCURV3 for the Sparcom 3D Graphics Environment. This information is stored in the global variable 'PPAR3'. FUNC3 is the default plot type. (For more information, see "More About 3D Plotting.")

PCURV3 is located in the Sparcom PLOT3 PTYPE menu.

Entry Method(s)

Input	Output
1:	1:

PDIM: PICT Dimension

This command replaces PICT with a blank PICT of the specified dimensions. PICT cannot be smaller than 131 pixels wide by 64 pixels high, nor larger than 2048 pixels wide.

PDIM is located in the Sparcom PLOT3 menu.

Entry Method(s)

Input	Output
2: width (binary integer) 1: height (binary integer)	2: 1:

Example(s)

Input	Output
# 262d # 128d PDIM	

Note(s)

This is a built-in HP 48SX command.

PSURF3: Parametric Surface Plot Type (3D)

This command sets the plot type to PSURF3 for the Sparcom 3D Graphics Environment. This information is stored in the global variable 'PPAR3'. FUNC3 is the default plot type. (For more information, see "More About 3D Plotting.")

PSURF3 is located in the Sparcom PLOT3 PTYPE menu.

Entry Method(s)

Input	Output
1:	1:

STEQ: Store in EQ

This command stores an equation from the stack into the reserved variable 'EQ' in the current directory. (For more information, see "More About 3D Plotting.")

STEQ is located in the Sparcom PLOT3 EQN menu (if the plot type is FUNC3) and the enhanced Plot menu.

Entry Method(s)

Input	Output
1: expression, equation, or program	1:

Example(s)

Input	Output
'SIN(X)' STEQ	
'Y=SIN(X)' STEQ	
« X SIN » STEQ	

Note(s)

This is a built-in HP 48SX command.

STOX: Store x-Component in EQ

This command stores an equation from the stack as the x-component of the equation in 'EQ' (as the first item in a list of three items) for 3D parametric curves or surfaces. If 'EQ' does not exist or is not a list of three items, it is overwritten and the y- and z-components are automatically initialized to 0. (For more information, see "More About 3D Plotting.")

STOX is located in the Sparcom PLOT3 EQN menu (if the plot type is PCURV3 or PSURF3).

Entry Method(s)

Input	Output
1: expression, equation, or program	1:

Example(s)

Input	Output
'SIN(T)' STOX	
'X=SIN(T)' STOX	
« T SIN » STOZ	

STOY: Store y-Component in EQ

This command stores an equation from the stack as the y-component of the equation in 'EQ' (as the second item in a list of three items) for 3D parametric curves and surfaces. If 'EQ' does not exist or is not a list of three items, it is overwritten and the x- and z-components are automatically initialized to 0. (For more information, see "More About 3D Plotting.")

STOY is located in the Sparcom PLOT3 EQN menu (if the plot type is PCURV3 or PSURF3).

Entry Method(s)

Input	Output
1: expression, equation, or program	1:

Example(s)

Input	Output
'COS(T)' STOY	
'Y=COS(T)' STOY	
« T COS » STOY	

STOZ: Store z-Component in EQ

This command stores an equation from the stack as the z-component of the equation in 'EQ' (as the third item in a list of three items) for 3D parametric curves and surfaces. If 'EQ' does not exist or is not a list of three items, it is overwritten and the x- and y-components are automatically initialized to 0. (For more information, see "More About 3D Plotting.")

STOZ is located in the Sparcom PLOT3 EQN menu (if the plot type is PCURV3 or PSURF3).

Entry Method(s)

Input	Output
1: expression, equation, or program	1:

Example(s)

Input	Output
'.2*T' STOZ	
'Z=.2*T' STOZ	
« .2 T * » STOZ	

TDOM: t-Variable Domain

This command specifies the t-variable domain for 3D parametric curves in the Sparcom 3D Graphics Environment. This information is stored in the global variable 'PPAR3' as t_{min} and t_{max} in the list { t_{var} t_{min} t_{max} }, which replaces the name t_{var} in 'PPAR3' if a t-variable domain is specified. The default t-variable domain is unspecified and defaults to the x-axis display range, –5 to 5. (For more information, see "More About 3D Plotting.")

TDOM is located in the Sparcom PLOT3 VAR menu (if the plot type is PCURV3.)

Entry Method(s)

Input	Output
2: t_{min} 1: t_{max}	2: 1:

Example(s)

Input	Output
–6.2831 6.2831 TDOM	

TRES: t-Variable Resolution

This command specifies the resolution of the t-variable for 3D parametric curves in the Sparcom 3D Graphics Environment. This information is stored in the global variable 'PPAR3' as a binary integer or real number. A binary integer specifies the number of parametric curve segments, while a real number specifies the number of user units between plotted values of the t-variable. The default resolution is # 8d, which represents an 8-segment parametric curve. (For more information, see "More About 3D Plotting.")

TRES is located in the Sparcom PLOT3 VAR menu (if the plot type is PCURV3).

Entry Method(s)

Input	Output
1: t_{res} (binary integer, real number)	1:

Example(s)

Input	Output
# 15d TRES	
.1 TRES	

TVAR: t-Variable Name

This command specifies the name of the t-variable for 3D parametric curves in the Sparcom 3D Graphics Environment. This information is stored in the global variable 'PPAR3' as a name. The default t-variable is 'T'. (For more information, see "More About 3D Plotting.")

TVAR is located in the Sparcom PLOT3 VAR menu (if the plot type is PCURV3).

Entry Method(s)

Input	Output
1: t_{var} (name)	1:

Example(s)

Input	Output
't' TVAR	

UDOM: u-Variable Domain

This command specifies the u-variable domain for 3D parametric surfaces in the Sparcom 3D Graphics Environment. This information is stored in the global variable 'PPAR3' as u_{min} and u_{max} in the list { u_{var} u_{min} u_{max} }, which replaces the name u_{var} in 'PPAR3' if a u-variable domain is specified. The default u-variable domain is unspecified and defaults to the x-axis display range, –5 to 5. (For more information, see "More About 3D Plotting.")

UDOM is located in the Sparcom PLOT3 VAR menu (if the plot type is PSURF3.)

Entry Method(s)

Input	Output
2: u_{min} 1: u_{max}	2: 1:

Example(s)

Input	Output
0 360 UDOM	

URES: u-Variable Resolution

This command specifies the resolution of the u-variable for 3D parametric surfaces in the Sparcom 3D Graphics Environment. This information is stored in the global variable 'PPAR3' as a binary integer or real number. A binary integer specifies the number of steps of the u-variable, while a real number specifies the number of user units between plotted values of the u-variable. The default resolution is # 8d, which represents a parametric surface with 8 steps of the u-variable. (For more information, see "More About 3D Plotting.")

URES is located in the Sparcom PLOT3 VAR menu (if the plot type is PSURF3).

Entry Method(s)

Input	Output
1: u_{res} (binary integer, real number)	1:

Example(s)

Input	Output
# 15d URES	
.1 URES	

UVAR: u-Variable Name

This command specifies the name of the u-variable for 3D parametric surfaces in the Sparcom 3D Graphics Environment. This information is stored in the global variable 'PPAR3' as a name. The default u-variable is 'U'. (For more information, see "More About 3D Plotting.")

UVAR is located in the Sparcom PLOT3 VAR menu (if the plot type is PSURF3).

Entry Method(s)

Input	Output
1: u_{var} (name)	1:

Example(s)

Input	Output
'u' UVAR	

VBOX: Draw Viewing Box

This command draws the viewing box in PICT, using the x-, y-, and z-axis display ranges specified by XRNG3, YRNG3, and ZRNG3.

VBOX is located in the Sparcom PLOT3 and 3D Graphics Environment menus.

Entry Method(s)

Input	Output
1:	1:

VDOM: v-Variable Domain

This command specifies the v-variable domain for 3D parametric surfaces in the Sparcom 3D Graphics Environment. This information is stored in the global variable 'PPAR3' as v_{min} and v_{max} in the list { v_{var} v_{min} v_{max} }, which replaces the name v_{var} in 'PPAR3' if a v-variable domain is specified. The default v-variable domain is unspecified and defaults to the y-axis display range, –5 to 5. (For more information, see "More About 3D Plotting.")

VDOM is located in the Sparcom PLOT3 VAR menu (if the plot type is PSURF3.)

Entry Method(s)

Input	Output
2: v_{min} 1: v_{max}	2: 1:

Example(s)

Input	Output
–1.5 1.5 VDOM	

VRES: v-Variable Resolution

This command specifies the resolution of the v-variable for 3D parametric surfaces in the Sparcom 3D Graphics Environment. This information is stored in the global variable 'PPAR3' as a binary integer or real number. A binary integer specifies the number of steps of the v-variable, while a real number specifies the number of user units between plotted values of the v-variable. The default resolution is # 8d, which represents a parametric surface with 8 steps of the v-variable. (For more information, see "More About 3D Plotting.")

VRES is located in the Sparcom PLOT3 VAR menu (if the plot type is PSURF3).

Entry Method(s)

Input	Output
1: v_{res} (binary integer, real number)	1:

Example(s)

Input	Output
# 15d VRES	
.1 VRES	

VVAR: v-Variable Name

This command specifies the name of the v-variable for 3D parametric surfaces in the Sparcom 3D Graphics Environment. This information is stored in the global variable 'PPAR3' as a name. The default v-variable is 'V'. (For more information, see "More About 3D Plotting.")

VVAR is located in the Sparcom PLOT3 VAR menu (if the plot type is PSURF3).

Entry Method(s)

Input	Output
1: v_{var} (name)	1:

Example(s)

Input	Output
'v' VVAR	

XDOM: x-Variable Domain

This command specifies the x-variable domain for 3D functions in the Sparcom 3D Graphics Environment. This information is stored in the global variable 'PPAR3' as x_{min} and x_{max} in the list { x_{var} x_{min} x_{max} }, which replaces the name x_{var} in 'PPAR3' if a x-variable domain is specified. The default x-variable domain is unspecified and defaults to the x-axis display range, –5 to 5. (For more information, see "More About 3D Plotting.")

XDOM is located in the Sparcom PLOT3 VAR menu (if the plot type is FUNC3.)

Entry Method(s)

Input	Output
2: x_{min} 1: x_{max}	2: 1:

Example(s)

Input	Output
–3 3 XDOM	

XRES: x-Variable Resolution

This command specifies the resolution of the x-variable for 3D functions in the Sparcom 3D Graphics Environment. This information is stored in the global variable 'PPAR3' as a binary integer or real number. A binary integer specifies the number of grid lines along the x-axis, while a real number specifies the number of user units between grid lines along the x-axis. The default resolution is # 8d, which represents a function with 8 grid lines along the x-axis. (For more information, see "More About 3D Plotting.")

XRES is located in the Sparcom PLOT3 VAR menu (if the plot type is FUNC3).

Entry Method(s)

Input	Output
1: x_{res} (binary integer, real number)	1:

Example(s)

Input	Output
# 15d XRES	
.1 XRES	

XRNG3: x-Axis Display Range (3D)

This command specifies the x-axis display range for the Sparcom 3D Graphics Environment. This information is stored in the global variable 'PPAR3' as x_{min} and x_{max} in the vectors [x_{min} y_{min} z_{min}] and [x_{max} y_{max} z_{max}]. These two vectors specify the coordinates of two opposite corners of the display volume. The default x-axis display range is –5 to 5. (For more information, see "More About 3D Plotting.")

XRNG3 is located in the Sparcom PLOT3 RNG menu.

Entry Method(s)

Input	Output
2: x_{min} 1: x_{max}	2: 1:

Example(s)

Input	Output
–5 5 XRNG	

XVAR: x-Variable Name

This command specifies the name of the x-variable for 3D functions in the Sparcom 3D Graphics Environment. This information is stored in the global variable 'PPAR3' as a name. The default x-variable is 'X'. (For more information, see "More About 3D Plotting.")

XVAR is located in the Sparcom PLOT3 VAR menu (if the plot type is FUNC3).

Entry Method(s)

Input	Output
1: x_{var} (name)	1:

Example(s)

Input	Output
'x' XVAR	

XYPRJ: Draw xy-Plane Projection

This command draws the xy-plane projection in PICT, using the x-, y-, and z-axis display ranges specified by XRNG3, YRNG3, and ZRNG3.

XYPRJ is located in the Sparcom PLOT3 and 3D Graphics Environment menus.

Entry Method(s)

Input	Output
1:	1:

YDOM: y-Variable Domain

This command specifies the y-variable domain for 3D functions in the Sparcom 3D Graphics Environment. This information is stored in the global variable 'PPAR3' as y_{min} and y_{max} in the list { y_{var} y_{min} y_{max} }, which replaces the name y_{var} in 'PPAR3' if a y-variable domain is specified. The default y-variable domain is unspecified and defaults to the y-axis display range, –5 to 5. (For more information, see "More About 3D Plotting.")

YDOM is located in the Sparcom PLOT3 VAR menu (if the plot type is FUNC3.)

Entry Method(s)

Input	Output
2: y_{min} 1: y_{max}	2: 1:

Example(s)

Input	Output
–3 3 YDOM	

YRES: y-Variable Resolution

This command specifies the resolution of the y-variable for 3D functions in the Sparcom 3D Graphics Environment. This information is stored in the global variable 'PPAR3' as a binary integer or real number. A binary integer specifies the number of grid lines along the y-axis, while a real number specifies the number of user units between grid lines along the y-axis. The default resolution is # 8d, which represents a function with 8 grid lines along the y-axis. (For more information, see "More About 3D Plotting.")

YRES is located in the Sparcom PLOT3 VAR menu (if the plot type is FUNC3).

Entry Method(s)

Input	Output
1: y_{res} (binary integer, real number)	1:

Example(s)

Input	Output
# 15d YRES	
.1 YRES	

YRNG3: y-Axis Display Range (3D)

This command specifies the y-axis display range for the Sparcom 3D Graphics Environment. This information is stored in the global variable 'PPAR3' as y_{min} and y_{max} in the vectors [x_{min} y_{min} z_{min}] and [x_{max} y_{max} z_{max}]. These two vectors specify the coordinates of two opposite corners of the display volume. The default y-axis display range is –5 to 5. (For more information, see "More About 3D Plotting.")

YRNG3 is located in the Sparcom PLOT3 RNG menu.

Entry Method(s)

Input	Output
2: y_{min} 1: y_{max}	2: 1:

Example(s)

Input	Output
–5 5 YRNG	

YVAR: y-Variable Name

This command specifies the name of the y-variable for 3D functions in the Sparcom 3D Graphics Environment. This information is stored in the global variable 'PPAR3' as a name. The default y-variable is 'Y'. (For more information, see "More About 3D Plotting.")

YVAR is located in the Sparcom PLOT3 VAR menu (if the plot type is FUNC3).

Entry Method(s)

Input	Output
1: y_{var} (name)	1:

Example(s)

Input	Output
'y' YVAR	

ZRNG3: z-Axis Display Range (3D)

This command specifies the z-axis display range for the Sparcom 3D Graphics Environment. This information is stored in the global variable 'PPAR3' as z_{min} and z_{max} in the vectors [x_{min} y_{min} z_{min}] and [x_{max} y_{max} z_{max}]. These two vectors specify the coordinates of two opposite corners of the display volume. The default z-axis display range is –5 to 5. (For more information, see "More About 3D Plotting.")

ZRNG3 is located in the Sparcom PLOT3 RNG menu.

Entry Method(s)

Input	Output
2: z_{min} 1: z_{max}	2: 1:

Example(s)

Input	Output
–5 5 ZRNG	

Chapter 13

Differential Equations Plotting

Differential equations plotting is accomplished with numerical approximation routines utilizing different variations of Euler's Method and the 4th-order Runge-Kutta method. A slope field routine is also included, to help you visualize multiple solution curves.

This chapter covers:

- Using Differential Equations Plotting
- DIFEQ: Sparcom DIFEQ Menu
- EULER: Euler's Method
- EMID: Euler's Method (Midpoint)
- EMOD: Modified Euler's Method
- RK4: Runge-Kutta Method (4th-Order)
- SLPFD: Slope Field

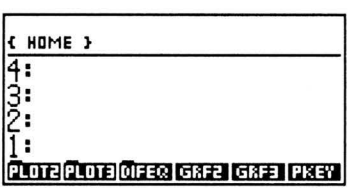
Using Differential Equations Plotting

The Sparcom DIFEQ menu is accessible from the Plotting Toolkit. To get to the Plotting Toolkit, follow these steps:

❶ Press [ON] [LIBRARY] to display all libraries available to your HP 48SX.

❷ Find and press **CALCU** to display the Calculus Pac Library menu.

❸ Press the fourth softkey, **PLOT**, to display the Plotting Toolkit menu:



At this point, press **DIFEQ** to display the Sparcom DIFEQ menu.

DIFEQ: Sparcom DIFEQ Menu

The Sparcom DIFEQ menu plots numerical approximations and slope fields for derivatives. The HP 48SX PLOTR menu or the Sparcom PLOT2 menu are used to specify the 2D plot parameters, so you should familiarize yourself with Chapter 11, "2D Plotting."

Using the Sparcom DIFEQ Menu

There are two ways to access the Sparcom DIFEQ menu from the stack:

- Press ◀ PLOT to display the enhanced Plot menu and press DIFEQ to display the Sparcom DIFEQ menu. (The Sparcom Plotting Keys must be installed and User mode must be turned on. For more information, see "PKEY: Sparcom Plotting Keys" in Chapter 10.)

- Press ◀ LIBRARY CALCU PLOT DIFEQ to display the DIFEQ menu.

There is one way to access the DIFEQ menu from the interactive menus:

- Press ◀ LIBRARY CALCU CALCU to access the Main menu, move the pointer to "Plotting: Diff. Eqns.," press ENTER to display the information screen about differential equation plotting, and press ATTN to display the Sparcom DIFEQ menu. (This will automatically install the Sparcom Plotting Keys and turn on User mode. For more information, see "PKEY: Sparcom Plotting Keys" in Chapter 10.)

The Sparcom DIFEQ menu is summarized below.

Sparcom DIFEQ Menu Operations

Screen	Softkeys
Sparcom DIFEQ Menu	EULER EMID EMOD RK4 SLPFD

Key	Description
EULER	Graphs Euler's method applied to dy/dx.
EMID	Graphs Euler's method (midpoint) applied to dy/dx.
EMOD	Graphs the modified Euler's method applied to dy/dx.
RK4	Graphs the 4th-order Runge-Kutta method applied to dy/dx.
SLPFD	Graphs the slope field of dy/dx.

EULER: Euler's Method

This command graphs the results of Euler's Method as applied to dy/dx in terms of x, y, or x and y. Euler's Method is defined by these equations:

$$\frac{dy}{dx} = f'(x,y), \text{ initial condition } f(x_0) = y_0$$

$$x_n = x_0 + nh,\ n = 0,1,2,\ldots,N,\ h \text{ is stepsize}$$

$$y_{n+1} = y_n + hf'(x_n, y_n)$$

Entry Method(s)

Input	Output
3: derivative, dy/dx	3:
2: initial condition, (x_0, y_0)	2:
1: stepsize, h (real)	1:

Example(s)

Plot the solution curve of the initial value problem $\frac{dy}{dx} = f'(x,y) = y\sin(3x)$, initial condition $f(0) = 1$, with a stepsize $h = .2$. To do this, follow these steps:

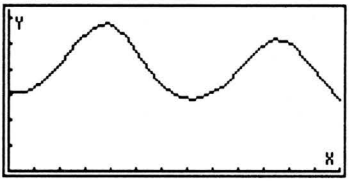
❶ Set the 2D plot parameters. To do this, press [→] [PLOT] to display the PLOTR or PLOT2 menu. Then type 0 [SPC] 4 **XRNG** to set the x-range to 0–4 and type 0 [SPC] 2 **YRNG** to set the y-range to 0–2. Press **ERASE** to erase PICT.

❷ Enter the derivative 'Y*SIN(3*X)' by typing ['] [α] Y [*] [SIN] 3 [*] [α] X [ENTER]. If necessary, press [←] [RAD] to set Radians mode.

❸ Enter the initial condition (0,1) by typing [←] [( )] 0 [←] [,] 1 [ENTER].

❹ Enter the stepsize .2 by typing .2 [ENTER].

❺ If necessary, press [→] [MENU] to return to the Sparcom DIFEQ menu and press **EULER** to plot the solution curve:



❻ Press [ATTN] when you have finished viewing the plot.

EMID: Euler's Method (Midpoint)

This command graphs the results of Euler's Method as applied to dy/dx in terms of x, y, or x and y. Euler's Method (Midpoint) is defined by these equations:

$$\frac{dy}{dx} = f'(x,y), \text{ initial condition } f(x_0) = y_0$$

$$x_n = x_0 + nh, \; n = 0,1,2,\ldots,N, \; h \text{ is stepsize}$$

$$y_{n+1} = y_n + hf'(x_n + \frac{h}{2}, y_n)$$

Entry Method(s)

Input	Output
3: derivative, dy/dx	3:
2: initial condition, (x_0, y_0)	2:
1: stepsize, h (real)	1:

Example(s)

See "EULER: Euler's Method" for an example.

EMOD: Modified Euler's Method

This command graphs the results of Euler's Method as applied to dy/dx in terms of x, y, or x and y. Modified Euler's Method is defined by these equations:

$$\frac{dy}{dx} = f'(x,y), \text{ initial condition } f(x_0) = y_0$$

$$x_n = x_0 + nh, \; n = 0,1,2,\ldots,N, \; h \text{ is stepsize}$$

$$y_{n+1} = y_n + \frac{hf'(x_n,y_n) + hf'(x_n + h, y_n)}{2}$$

Entry Method(s)

Input	Output
3: derivative, dy/dx	3:
2: initial condition, (x_0, y_0)	2:
1: stepsize, h (real)	1:

Example(s)

See "EULER: Euler's Method" for an example.

RK4: Runge-Kutta Method (4th-Order)

This command graphs the results of the 4th-order Runge-Kutta method as applied to dy/dx in terms of x, y, or x and y. The 4th-order Runge-Kutta method is defined by these equations:

$$\frac{dy}{dx} = f'(x,y), \text{ initial condition } f(x_0) = y_0$$

$$x_n = x_0 + nh, \; n = 0,1,2,\ldots,N, \; h \text{ is stepsize}$$

$$k_1 = hf'(x_n, y_n)$$

$$k_2 = hf'(x_n + \frac{h}{2}, y_n + \frac{k_1}{2})$$

$$k_3 = hf'(x_n + \frac{h}{2}, y_n + \frac{k_2}{2})$$

$$k_4 = hf'(x_n + h, y_n + k_3)$$

$$y_{n+1} = y_n + \frac{k_1}{6} + \frac{k_2}{3} + \frac{k_3}{3} + \frac{k_4}{6} + O(h^5)$$

Entry Method(s)

Input	Output
3: derivative, dy/dx	3:
2: initial condition, (x_0, y_0)	2:
1: stepsize, h (real)	1:

Example(s)

See "EULER: Euler's Method" for an example.

SLPFD: Slope Field

This command plots a set of small line segments of appropriate slope at specified lattice points, given dy/dx in terms of x, y, or x and y.

Lattice Dimensions

The default lattice structure is 12 horizontal lattice points, 6 vertical lattice points, and slope field lines 70% of the width of the lattice squares. You can override these default values by storing a list of three values in the global variable 'Lattice'—for example, storing { 12 6 .7 } would be identical to the default, while storing { 10 10 .5 } would create a 10 x 10 lattice grid with slope field lines 50% of the width of the lattice squares. The first two values in 'Lattice' must be positive integers, while the third value should range from .1 (10%) up to 1 (100%) to control the length of the slope field lines. To return to the default lattice structure, simply purge 'Lattice', using the command PURGE.

Entry Method(s)

Input	Output
1: derivative, dy/dx	1:

Example(s)

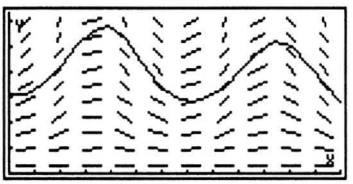
Overlay a 10 x 10 x .5 lattice slope field on the solution curve plotted in the EULER example for the equation $\frac{dy}{dx} = f'(x,y) = y\sin(3x)$. To do this, follow these steps:

❶ If necessary, set the 2D plot parameters. To do this, press [→] [PLOT] to display the PLOTR or PLOT2 menu. Then type 0 [SPC] 4 [XRNG] to set the x-range to 0–4 and type 0 [SPC] 2 [YRNG] to set the y-range to 0–2.

❷ Specify the custom lattice dimensions by typing [←] [{ }] 10 [SPC] 10 [SPC] .5 [ENTER] to put the list { 10 10 .5 } on the stack. Then type ['] [α] [α] L [←] [α] attice [ENTER] [STO] to store the list into the global variable 'Lattice' (name is case-sensitive).

❸ Enter the derivative 'Y*SIN(3*X)' by typing ['] [α] Y [*] [SIN] 3 [*] [α] X [ENTER]. If necessary, press [←] [RAD] to set Radians mode.

❹ If necessary, press [→] [MENU] to return to the Sparcom DIFEQ menu and press [SLPFD] to draw the slope field:



❺ Press [ATTN] when you have finished viewing the plot.

Chapter 14

Vector Toolkit

The Vector Toolkit organizes 25 of the programmable commands in the Calculus Pac into one menu for easy access from the stack. All of the commands are used to manipulate symbolic vectors.

This chapter covers:

- Using the Vector Toolkit
- What is a Symbolic Vector?
- VKEY: Sparcom Vector Keys
- SIMPL: Simplifying Symbolic Results
- VUNIT: Unit Vector
- VCROS: Cross Product
- VDOT: Dot Product
- VABS: Vector Length (Norm)
- GRD: Gradient
- DIV: Divergence
- CURL: Curl
- LAPL: Laplacian
- V1OP: Unary Vector Operation
- V2OP: Binary Vector Operation
- V+: Vector Addition
- V–: Vector Subtraction
- V*: Vector Multiplication
- V/: Vector Division
- VDER: Vector Derivative
- VINT: Vector Integral
- SV→: Vector to Stack
- →SV2: Stack to 2-Element Vector
- →SV3: Stack to 3-Element Vector
- VEVAL: Vector Evaluate
- V→Q: Vector to Quotient
- V→NUM: Vector Evaluate to Number
- VNEG: Vector Negate

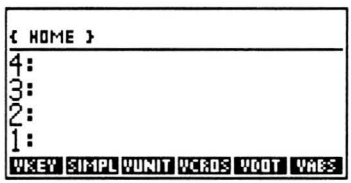
Using the Vector Toolkit

To get to the Vector Toolkit, follow these steps:

❶ Press [↩] [LIBRARY] to display all libraries available to your HP 48SX.

❷ Find and press **CALCU** to display the Calculus Pac Library menu.

❸ Press the fifth softkey, **VECT**, to display the Vector Toolkit menu:



The Vector Toolkit menu lists the 25 programmable commands used to manipulate symbolic vectors.

Vector Toolkit Operations

Screen	Softkeys					
Vector Toolkit	VKEY	SIMPL	VUNIT	VCROS	VDOT	VABS
	GRD	DIV	CURL	LAPL	V1OP	V2OP
	V+	V-	V*	V/	VDER	VINT
	SV→	→SV2	→SV3	VEVAL	V→Q	V→NU
	VNEG					

What is a Symbolic Vector?

The HP 48SX supports both real and complex vectors, but not symbolic vectors. An example of a real vector is [1 2 3], while an example of a complex vector is [(0,1) (1,2)]. However, the object [X Y Z] is not allowed by the HP 48SX. The Calculus Pac circumvents this by treating lists as symbolic vectors. An example of such a *list vector* is { X Y Z }. Hereafter, when the term *vector* is used, it refers to either a real vector, a complex vector, or a list vector. To be considered a vector, an object must satisfy the following criteria:

❶ A vector can be a real or complex array of one dimension. This eliminates *matrices*, such as [[1 2] [3 4]], which has more than one dimension. The term *two-dimensional vector* refers to a vector with two elements, such as [1 2].

❷ A vector can be a list of items without further sub-lists, such as { X Y } or { 1 2 3 4 }, but not { { X Y } { W Z } }. The latter might be a symbolic matrix, but symbolic matrices are not used or supported by the HP 48SX or the Calculus Pac.

❸ A vector must always contain at least one element. Therefore, the empty objects [ ] and { } are invalid vectors.

❹ A vector is made up of scalar components, where a *scalar* is a real number, complex number, global name, local name, symbolic expression, or unit object. Scalar components can be mixed in a vector, but if any of the components are not real numbers or complex numbers, then the vector must be a list vector, such as { X Y } or { 1 (2,3) Z 'SIN(X)' 120_ft }; otherwise, if all of the components are real numbers, the vector may be either a real vector *or* a list vector, such as [1 2] or { 1 2 }; if all the components of a vector are complex numbers, the vector may be either a complex vector *or* a list vector, such as [(3,4) (5,6)] or { (3,4) (5,6) }.

All commands in the Vector Toolkit accept vectors that satisfy these criteria. Vector Toolkit commands will return results as real or complex vectors if possible, or as list vectors if not possible. For example, adding { 1 2 3 } to { 4 5 6 } will return [5 7 9], but adding { 1 2 } to { X Y } will return { '1+X' '2+Y' }.

VKEY: Sparcom Vector Keys

This command installs or removes the Sparcom Vector Keys. The Sparcom Vector Keys are designed to support symbolic vector operations in a transparent fashion, without inhibiting normal use of your HP 48SX.

If the Sparcom Vector Keys are not installed, executing VKEY will install them, overwriting any user-key assignments for [+], [−], [*], [÷], [→][∂], [→][∫], [EVAL], [←][→Q], [→][→NUM], [←][2D], [→][3D], and [+/−], and set flag –60 (User Mode) to place your HP 48SX into User mode. (For more information, see Chapter 15 of the HP 48SX Owner's Manual, "Customizing the Calculator.") A brief message will be shown to indicate the Sparcom Vector Keys have been installed.

If the Sparcom Vector Keys are installed, executing VKEY will delete the user-key assignments for [+], [−], [*], [÷], [→][∂], [→][∫], [EVAL], [←][→Q], [→][→NUM], [←][2D], [→][3D], and [+/−], and clear flag –60 (User Mode) to remove your HP 48SX from User mode. A brief message will be shown to indicate the Sparcom Vector Keys have been removed.

When the Sparcom Vector Keys are installed and your HP 48SX is in User Mode, certain keys on your HP 48SX keyboard will be re-defined as follows:

Sparcom Vector Keys

Key	Action
[+]	V+
[−]	V–
[*]	V*
[÷]	V/
[→][∂]	VDER
[→][∫]	VINT
[EVAL]	VEVAL

Key	Action
[←][→Q]	V→Q
[→][→NUM]	V→NUM
[+/−]	VNEG
[←][2D]	SV→
	→SV2
[→][3D]	SV→
	→SV3

Entry Method(s)

Input	Output
1:	1:

Note(s)

When the Sparcom Vector Keys are installed, you will not be able to interactively edit the list of user-key assignments returned by RCLKEYS. This is because the objects assigned to keys 95.1, 85.1, 75.1, 65.1, 41.3, 42.3, 33.1, 33.2, 33.3, 53.2, 53.3, and 52.1 are system RPL objects and your HP 48SX cannot edit them directly. If you wish to edit the list of user-key assignments, you must either first remove the Sparcom Vector Keys or you must use commands such as REPL or the Interactive Stack to *indirectly* edit the list without placing it on the command line. If you accidentally attempt to interactively edit the list of user-key assignments when the Sparcom Vector Keys are installed, you will have to press ON–C to abort the editing operation and return to the stack. (Pressing ON–C will *not* damage user memory, but it *will* clear the stack and return to the HOME directory.)

The Calculus Pac must be installed in your HP 48SX for the Sparcom Vector Keys to work correctly. If you remove the Calculus Pac while the Sparcom Vector Keys are installed and your HP 48SX is in User mode, the re-defined keys will behave as if the Sparcom Vector Keys were not installed. Upon re-installing the Calculus Pac and re-entering User mode, the re-defined keys will resume their customized functions.

When the Sparcom Vector Keys are installed and your HP 48SX is in User mode, the following keys will behave slightly differently than normal:

- + will not concatenate two lists, but will attempt to add them element-wise. Also, + will not append or prepend an object to a list, but will attempt to add the object to each element of the list. (For more information, see "V+: Vector Addition.") To concatenate two lists or to append or prepend an object to a list, press → ∝ + ENTER to execute the normal + command.

- ← 2D will no longer assemble or disassemble complex numbers when flag –19 (Complex Mode Flag) is set. Instead, ← 2D will *always* assemble two real numbers or two complex numbers into a vector. (For more information, see "→SV2: Stack to 2-Element Vector.")

- EVAL will not disassemble and evaluate a list, but will attempt to evaluate it element-wise. (For more information, see "VEVAL: Vector Evaluate.") To disassemble and evaluate a list, press → ∝ EVAL ENTER to execute the normal EVAL command.

SIMPL: Symbolic Simplification

See "SIMPL: Symbolic Simplification" in Chapter 8.

VUNIT: Unit Vector

This command normalizes a vector to unit length, where unit length is determined by dividing the vector element-wise by its length (norm).

Entry Method(s)

Input	Output
1: vector	1: unit vector

Example(s)

Input	Output
[4 3] VUNIT	[.8 .6]
{ X Y Z } VUNIT	{ 'X/√(X*X+Y*Y+Z*Z)' 'Y/√(X*X+Y*Y+Z*Z)' 'Z/√(X*X+Y*Y+Z*Z)' }

VCROS: Cross Product

This command returns the cross product of two three-dimensional vectors as a three-dimensional vector. VCROS is a superset of CROSS, extended to support symbolic vectors.

Entry Method(s)

Input	Output
2: three-dimensional vector 1: three-dimensional vector	2: 1: cross product

Example(s)

Input	Output
{ X Y Z } { X Y Z } VCROS	[0 0 0]
{ X Y Z } [1 2 10] VCROS	{ 'Y*10–2*Z' 'Z–10*X' 'X*2–Y' }

VDOT: Dot Product

This command returns the numeric or symbolic dot product of two vectors of equal size. VDOT is a superset of DOT, extended to support symbolic vectors, but not symbolic matrices.

Entry Method(s)

Input	Output
2: vector 1 1: vector 2 (of same dimension)	2: 1: dot product

Example(s)

Input	Output
{ 1 2 3 } [4 5 6] VDOT	32
{ W X Y Z } { 9 8 7 1 } VDOT	'W*9+X*8+Y*7+Z'

VABS: Vector Length (Norm)

This command returns the length of a vector, which is the square root of the sum of the squares of the elements. VABS is a superset of ABS, extended to support symbolic vectors.

Entry Method(s)

Input	Output
1: vector	1: vector length

Example(s)

Input	Output
[1 2 3] VABS	3.74165738677
{ X Y Z } VABS	'√(X*X+Y*Y+Z*Z)'

GRD: Gradient

This command returns the gradient of a scalar as a three-dimensional vector. The result returned depends on the coordinate mode setting of the HP 48SX—rectangular, cylindrical, or spherical. (For more information about coordinate modes, see Chapter 12 of the HP 48SX Owner's Manual, "Vectors.")

Coordinate Variables

For the purpose of taking derivatives, the default coordinates are { X Y Z } for rectangular mode, { R T Z } for cylindrical mode, and { R T P } for spherical mode. You can override these default coordinates by storing a list of six names in the global variable 'Coords'—for example, storing { X Y Z R T P } would be identical to the default, while storing { x y z ρ θ φ } might be an alternative. If any of the coordinate variables exist in the current or parent directories, they will be evaluated to numbers in the result, so you may wish to purge the coordinate variables before executing this command. To return to the default coordinate variables, simply purge 'Coords', using the command PURGE.

Entry Method(s)

Input	Output
1: scalar	1: gradient (three-dimensional vector)

Example(s)

Input	Output
10 GRD	[0 0 0]
'X*Y' GRD	{ Y X 0 }
'R*T*Z' GRD	{ 'T*Z' 'Z' 'R*T' }

Note(s)

Second example uses XYZ mode.

Third example uses R∠Z (cylindrical) mode. Apply SIMPL to result.

All examples use default coordinate variables of { X Y Z R T P }.

DIV: Divergence

This command returns the divergence of a three-dimensional vector as a scalar. The result returned depends on the coordinate mode setting of the HP 48SX—rectangular, cylindrical, or spherical. (For more information about coordinate modes, see Chapter 12 of the HP 48SX Owner's Manual, "Vectors.")

Coordinate Variables

See "GRD: Gradient."

Entry Method(s)

Input	Output
1: three-dimensional vector	1: divergence

Example(s)

Input	Output
{ X Y Z } DIV	3
{ R T Z } DIV	'3+INV(R)'

Note(s)

Second example uses XYZ mode.

Third example uses R∠Z (cylindrical) mode. Apply SIMPL to result.

All examples use default coordinate variables of { X Y Z R T P }.

CURL: Curl

This command returns the curl of a three-dimensional vector as a three-dimensional vector. The result returned depends on the coordinate mode setting of the HP 48SX—rectangular, cylindrical, or spherical. (For more information about coordinate modes, see Chapter 12 of the HP 48SX Owner's Manual, "Vectors.")

Coordinate Variables

See "GRD: Gradient."

Entry Method(s)

Input	Output
1: three-dimensional vector	1: curl (three-dimensional vector)

Example(s)

Input	Output
[1 2 3] CURL	[0 0 0]
{ X Y Z } CURL	[0 0 0]
{ 'R*T' 'T*Z' 'R*Z' } CURL	{ '–T' '–Z' '–1+INV(R)*T*Z' }

Note(s)

Third example uses R∠Z (cylindrical) mode. Apply SIMPL to result.

All examples use default coordinate variables of { X Y Z R T P }.

LAPL: Laplacian

This command returns the Laplacian of a scalar as a scalar. (LAPL can be applied to a vector element-wise using V1 OP.) The result returned depends on the coordinate mode setting of the HP 48SX—rectangular, cylindrical, or spherical. (For more information about coordinate modes, see Chapter 12 of the HP 48SX Owner's Manual, "Vectors.")

Coordinate Variables

See "GRD: Gradient."

Entry Method(s)

Input	Output
1: scalar	1: Laplacian

Example(s)

Input	Output
10 LAPL	0
'R^2*θ^2*φ^2' LAPL	'2*COS(θ)/SIN(θ)*θ*φ^2+2*SIN(θ)^–2*θ^2+6*θ^2*φ^2+2*φ^2'

Note(s)

Second example uses Radians mode, R◿◿ (spherical) mode, and custom coordinate variables { X Y Z R θ φ }. (Enter θ by ↷ → F and φ by ↷ O → 9). Apply SIMPL to result.

V1OP: Unary Vector Operation

This command applies a unary operation to a single vector element-wise. The operation should take one argument and return one argument, which will be inserted into the appropriate place in the result vector. Any valid operation is allowed—list, program, command, or other object—provided it takes exactly one argument from the stack and returns exactly one argument to the stack.

Entry Method(s)

Input	Output
2: vector 1: operation (list,program, command)	2: 1: result vector

Example(s)

Input	Output
{ 1 2 3 } { SQ } V1OP	[1 4 9]
{ –1 –4 4 0 3 } « 2 > » V1OP	[0 0 1 0 1]

V2OP: Binary Vector Operation

This command applies a binary operation to two vectors element-wise. The operation should take two arguments and return one argument, which will be inserted into the appropriate place in the result vector. Any valid operation is allowed—list, program, command, or other object—provided it takes exactly two arguments from the stack and returns exactly one argument to the stack.

Entry Method(s)

Input	Output
3: vector 1	3:
2: vector 2	2:
1: operation (list,program, command)	1: result vector

Example(s)

Input	Output
{ 1 2 3 } [4 5 6] { + } V2OP	[5 7 9]
{ A B C } { D E F } « * » V2OP	{ 'A*D' 'B*E' 'C*F' }

Note(s)

First example is equivalent to V+.

V+: Vector Addition

This command adds a scalar or vector to another vector element-wise. V+ is a superset of +, extended to support interactions between symbolic vectors and scalars. V+ does not concatenate two lists (as does +), but rather attempts to add them element-wise. V+ does not append or prepend an object to a list (as does +), but rather attempts to add the object to each element of the list. (For more information, see "VKEY: Sparcom Vector Keys.")

Entry Method(s)

Input	Output
2: scalar or vector 1: scalar or vector (of same dimension)	2: 1: result vector

Example(s)

Input	Output
[1 2 3] { X Y Z } V+	{ '1+X' '2+Y' '3+Z' }
3 { X Y } V+	{ '3+X' '3+Y' }
{ X Y } 3 V+	{ 'X+3' 'Y+3' }
{ 10_ft 1_h } { 12_in 10_s } V+	{ 132_in 3610_s }

V–: Vector Subtraction

This command subtracts a scalar or vector from another vector or scalar element-wise. V– is a superset of –, extended to support interactions between symbolic vectors and scalars.

Entry Method(s)

Input	Output
2: scalar or vector 1: scalar or vector (of same dimension)	2: 1: result vector

Example(s)

Input	Output
[1 2 3] { X Y Z } V-	{ '1–X' '2–Y' '3–Z' }
3 { X Y } V-	{ '3–X' '3–Y' }
{ X Y } 3 V-	{ 'X–3' 'Y–3' }

V*: Vector Multiplication

This command multiplies a scalar or vector to another vector element-wise. V* is a superset of *, extended to support interactions between symbolic vectors and scalars, except that V* is meaningless for two vectors.

Entry Method(s)

Input	Output
2: scalar or vector 1: scalar or vector	2: 1: result vector

Example(s)

Input	Output
[1 2 3] 3 V*	[3 6 9]
3 { X Y } V*	{ '3*X' '3*Y' }

V/: Vector Division

This command divides a scalar or vector into another vector element-wise. V/ is a superset of /, extended to support interactions between symbolic vectors and scalars, except that V/ is meaningless for two vectors.

Entry Method(s)

Input	Output
2: scalar or vector 1: scalar or vector	2: 1: result vector

Example(s)

Input	Output
[3 6 9] 3 V/	[1 2 3]
3 { X Y } V/	{ '3/X' '3/Y' }

VDER: Vector Derivative

This command differentiates a vector element-wise with respect to the specified variable. VDER is a superset of ∂, extended to support symbolic vectors.

Entry Method(s)

Input	Output
2: vector 1: variable (name)	2: 1: result vector

Example(s)

Input	Output
[1 2 3] 'X' VDER	[0 0 0]
{ '2*X' 'X*Y' } 'X' VDER	{ 2 Y }

VINT: Vector Integral

This command integrates a vector element-wise with respect to the specified variable and over the specified interval. VINT is a superset of ∫, extended to support symbolic vectors.

Entry Method(s)

Input	Output
4: interval start (scalar)	4:
3: interval end (scalar)	3:
2: vector	2:
1: variable (name)	1: result vector

Example(s)

Input	Output
0 'π' { 'SIN(X)' 'COS(X)' } 'X' VINT	[2 0]

Note(s)

Example uses Radians mode.

SV→: Vector to Stack

This command disassembles a vector. SV→ is a superset of V→, extended to support symbolic vectors.

Entry Method(s)

Input	Output
N: ... 1: n-dimensional vector	N: scalar 1 ... 1: scalar N

Example(s)

Input	Output
[1 2 3] SV→	1 2 3
{ X Y } SV→	'X' 'Y'

→SV2: Stack to 2-Element Vector

This command assembles a two-dimensional vector. →SV2 is a superset of →V2, extended to support symbolic vectors. →SV2 does not distinguish among XYZ, R∠Z, and R∠∠ modes when assembling a symbolic vector. → SV2 does not assemble a complex number when flag –19 (Complex Mode Flag) is set; it always assembles a vector. (For more information, see "VKEY: Sparcom Vector Keys.")

Entry Method(s)

Input	Output
2: scalar 1 1: scalar 2	2: 1: two-dimensional vector

Example(s)

Input	Output
'X' 'Y' →SV2	{ X Y }
1 2 →SV2	[1 2]

→SV3: Stack to 3-Element Vector

This command assembles a three-dimensional vector. →SV3 is a superset of →V3, extended to support symbolic vectors. →SV3 does not distinguish among XYZ, R∠Z, and R∠∠ modes when assembling a symbolic vector.

Entry Method(s)

Input	Output
3: scalar 1	3:
2: scalar 2	2:
1: scalar 3	1: three-dimensional vector

Example(s)

Input	Output
'X' 'Y' 'Z' →SV2	{ X Y Z }
1 2 3 →SV2	[1 2 3]

VEVAL: Vector Evaluate

This command evaluates a vector element-wise. VEVAL is a superset of EVAL, extended to support symbolic vectors. VEVAL does not disassemble and evaluate a list (as does EVAL), but rather attempts to evaluate it element-wise.

Entry Method(s)

Input	Output
1: vector	1: result vector

Example(s)

Input	Output
{ '1+2' '2+3' } VEVAL	[3 5]
{ X Y Z } VEVAL	See Note(s)

Note(s)

The result of the second example will depend on the contents of the global variables X, Y, and Z. If none of them exist, the result will be { X Y Z }; otherwise, the result will vary.

V→Q: Vector to Quotient

This command converts a vector to a rational form element-wise. V→Q is a superset of →Q, extended to support symbolic vectors.

Entry Method(s)

Input	Output
1: vector	1: result vector

Example(s)

Input	Output
[1.5 4.8] V→Q	{ '3/2' '24/5' }

V→NUM: Vector Evaluate to Number

This command evaluates a vector into a numerical result element-wise. V→NUM is a superset of →NUM, extended to support symbolic vectors.

Entry Method(s)

Input	Output
1: vector	1: result vector

Example(s)

Input	Output
{ '1+2' '2+3' } V→NU	[3 5]
{ X Y Z } V→NU	See Note(s)

Note(s)

The result of the second example will depend on the contents of the global variables X, Y, and Z. If none of them exist, the result will be { X Y Z }; otherwise, the result will vary.

VNEG: Vector Negate

This command changes the sign of a vector element-wise. VNEG is a superset of NEG, extended to support symbolic vectors.

Entry Method(s)

Input	Output
1: vector	1: result vector

Example(s)

Input	Output
[1 2 3] VNEG	[–1 –2 –3]
{ X Y } VNEG	{ '–X' '–Y' }

Appendices and Index

Appendix A

Warranty and Service

Pocket Professional™ Support

You can get answers to your questions about using your Pocket Professional™ Pac from Sparcom. If you don't find the information in this manual or in the HP 48SX Owner's Manual, contact us in one of the following ways:

❶ E-Mail

From Internet: support@sparcom.com
From Compuserve: >Internet:support@sparcom.com
From FidoNet: To:support@sparcom.com

❷ Standard Mail

Sparcom Corporation
897 NW Grant Avenue
Corvallis, OR 97330
Attn: Technical Support Department

❸ Telephone

(503) 757–8416
9 a.m. – 5 p.m. Pacific Standard Time

❹ FAX

(503) 753–7821

Limited One-Year Warranty

What is Covered

A Pocket Professional™ Pac is warranted by Sparcom Corporation against defects in material and workmanship for one year from the date of original purchase. If you sell your application card 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 replace (at no charge) a product that proves to be defective, provided you return the product and proof of purchase, shipping prepaid, to Sparcom.

What is Not Covered

This warranty does not apply if the product has been damaged by accident or misuse or as the result of service or modification by any entity other than Sparcom Corporation.

No other 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. IN NO EVENT SHALL SPARCOM CORPORATION BE LIABLE FOR CONSEQUENTIAL DAMAGES. Products are sold on the basis of specifications applicable at the time of manufacture. Sparcom shall have no obligation to modify or update products, once sold.

If the Application Card Requires Service

Sparcom will repair an application card, or replace it with the same model or one of equal or better functionality, whether it is under warranty or not.

Service Charge

There is a fixed charge for standard out-of-warranty repairs. This charge is subject to the customer's local sales or value-added tax, wherever applicable. Application cards damaged by accident or misuse are not covered by fixed charges. These charges are individually determined based on time and material.

Shipping Instructions

If your application card requires service, ship it to the above address and:

❶ Include your return address and a description of the problem.

❷ Include a proof of purchase date if the warranty has not expired.

❸ Include a purchase order, along with a check or credit card number and expiration date (VISA or MasterCard), to cover the standard repair charge.

❹ Ship your application card, postage prepaid, in protective packaging adequate to prevent damage. Shipping damage is not covered by the warranty, so insuring the shipment is recommended.

Application cards are usually serviced and re-shipped within five working days.

Environmental Limits

The reliability of an application card depends upon the following temperature and humidity limits:

❶ Operating Temperature: 0 to 45° C (32 to 113° F).

❷ Storage Temperature: –20 to 60° C (–4 to 140° F).

❸ Operating and Storage Humidity: 90% relative humidity at 40° C (104° F) maximum.

Appendix B

Piecewise Functions

This appendix describes in detail the entry and syntax of piecewise functions. (For more information, see "Entering a Piecewise Function" in Chapter 2.)

What is a Piecewise Function?

Piecewise functions are functions that take on different functional forms (*expressions*) over different regions of the independent variable (*regions*):

$$f(x) = \begin{cases} expression\ 1 & region\ 1 \\ expression\ 2 & region\ 2 \end{cases}$$

The HP 48SX supports these types of functions by means of the IFTE command:

$$f(x) = \text{IFTE}(region\ 1, expression\ 1, expression\ 2)$$

(For more information about IFTE, see Chapter 26 of the HP 48SX Owner's Manual, "Tests and Conditional Structures.")

The Calculus Pac enables you to easily enter piecewise functions by a sequence of interactive prompts.

The input at each prompt defines a single term in the piecewise function and requires two arguments: an expression and a region. The sequence of prompts is terminated by pressing ENTER with a blank command line, and the piecewise function is then created.

The result will be an equation describing the piecewise function by means of nested IFTE commands. If PWISE was executed from the interactive menus, the result will be displayed in a result screen; otherwise, if PWISE was executed from the stack, the result will be returned to level 1.

Entry Rules

There are a few rules that must be followed to correctly specify piecewise functions:

❶ Use == in place of =. The HP 48SX uses the = operator only for assigning variables, while the == command is used to check for equality. Therefore, the region $x = 0$ should be entered as 'X==0'. See **Example 1**.

❷ To make a section of a piecewise function undefined, press [NXT] [UNDE] to enter UNDEFINED as the expression for the term, along with the corresponding region. An UNDEFINED term will automatically be appended to complete all one-term piecewise functions. (Note: UNDEFINED is simply a global name that presumably does not exist in user memory and will therefore remain unevaluated when plotting.) See **Example 2**.

❸ Always specify terms in the function in order of increasing regions. For example, specify the term for the region $x < -3$ before the term for the region $x < 3$. This is because the HP 48SX will not properly evaluate expressions like '–3<X<3', so this region must be entered as 'X<3'. However, this would incorrectly imply that the corresponding expression should be used for *all* values of X less than 3, so you must have first entered a term for the region $X \leq -3$. See **Example 3**.

❹ For regions like $x = 2,3$ the entry must be split into two separate terms because the HP 48SX will not recognize an expression like 'X==2,3'. Therefore, enter the same expression twice, for two different regions, one 'X==2' and one 'X==3'. Also, enter *more* specific terms (such 'X==2') before *less* specific terms (such as 'X≠2'). See **Example 4**.

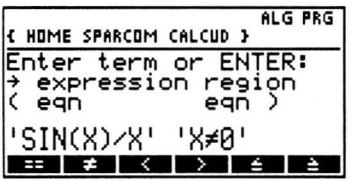
❺ The region of the final term is *always* ignored, because it is assumed that the expression of the final term governs all remaining values of the independent variable not specified by the regions of all previous terms. (Note in the generalized piecewise function shown at the beginning of this section that the second region is unnecessary and therefore ignored in the IFTE command.) For this reason, the region of the final term does not have to be strictly correct, but it must still be a valid HP 48SX equation. For example, if the first region is 'X==2' and the second region is 'X==3', the third region *should* be 'X≠2,3', but since the HP 48SX will not recognize an expression like that, it can be safely entered as 'X≠2' because it will be ignored. See **Example 4**.

Examples

Example 1: Define the piecewise function $f(x) = \begin{cases} \sin(x)/x & x \neq 0 \\ 1 & x = 0 \end{cases}$.

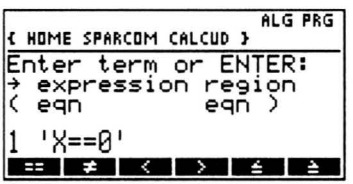
This will require two terms.

The first term consists of the expression 'SIN(X)/X' and the region 'X≠0'. Enter this information until your screen appears as follows:



Press ENTER to accept the first term. You will be prompted for another term.

The second term consists of the expression 1 and the region 'X==0'. Enter this information until your screen appears as follows.



Press ENTER to accept the second term. You will be prompted for another term.

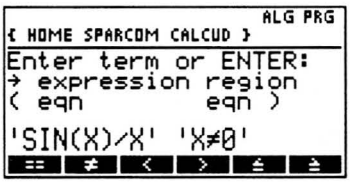
At this third prompt, press ENTER to terminate the entry, and the result will be calculated (display assumes PWISE was executed from the interactive menus):

The result can be viewed in the EquationWriter, copied to the stack, or printed on an IR printer. When you have finished viewing the result, press UP to return to the Function Library menu, MAIN to return to the Main menu, or ATTN to quit the Calculus Pac.

Example 2: Define the piecewise function $f(x) = \begin{cases} \sin(x)/x & x \neq 0 \\ undefined & x = 0 \end{cases}$.

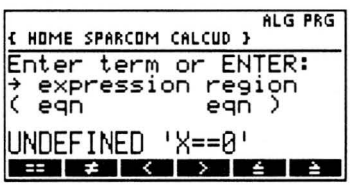
This will require either one or two terms, because if you enter only a single term, the second, UNDEFINED term will automatically be appended.

The first term consists of the expression 'SIN(X)/X' and the region 'X≠0'. Enter this information until your screen appears as follows:



Press ENTER to accept the first term. You will be prompted for another term.

At this second prompts, you can either press ENTER to terminate the entry, or enter a second term, which will consist of the expression UNDEFINED and the region 'X==0'. If you choose to enter the second term, enter this information until your screen appears as follows:



Press ENTER to accept the second term. You will be prompted for another term.

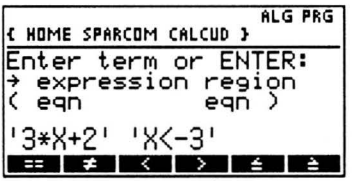
At this third prompt (or at the second prompt if you choose not to enter the second term), press ENTER to terminate the entry, and the result will be calculated (display assumes PWISE was executed from the interactive menus):

The result can be viewed in the EquationWriter, copied to the stack, or printed on an IR printer. When you have finished viewing the result, press UP to return to the Function Library menu, MAIN to return to the Main menu, or ATTN to quit the Calculus Pac.

Example 3: Define the piecewise function $f(x) = \begin{cases} 3x+2 & x < -3 \\ 2x+7 & -3 \le x \le 2 \\ 7x-2 & x > 2 \end{cases}$.

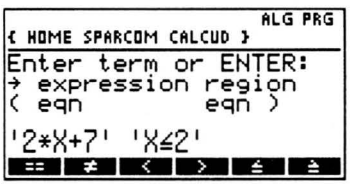
This will require three terms.

The first term consists of the expression '3*X+2' and the region 'X<–3'. Enter this information until your screen appears as follows:



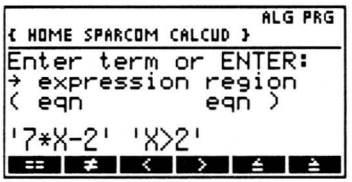
Press ENTER to accept the first term. You will be prompted for another term.

The second term consists of the expression '2*X+7' and the region 'X≤2'. Enter this information until your screen appears as follows.



Press ENTER to accept the second term. You will be prompted for another term.

The third term consists of the expression '7*X–2' and the region 'X>2'. Enter this information until your screen appears as follows.



Press ENTER to accept the third term. You will be prompted for another term.

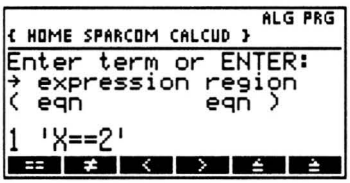
At this fourth prompt, press ENTER to terminate the entry, and the result will be calculated (display assumes PWISE was executed from the interactive menus):

The result can be viewed in the EquationWriter, copied to the stack, or printed on an IR printer. When you have finished viewing the result, press **UP** to return to the Function Library menu, **MAIN** to return to the Main menu, or ATTN to quit the Calculus Pac.

Example 4: Define the piecewise function $f(x) = \begin{cases} \dfrac{x}{(x-2)(x-3)} & x \neq 2,3 \\ 1 & x = 2,3 \end{cases}$.

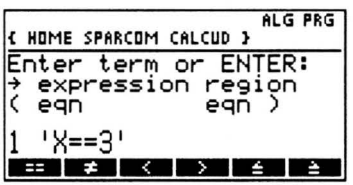
This will require three terms.

The first term consists of the expression 1 and the region 'X==2'. Enter this information until your screen appears as follows:



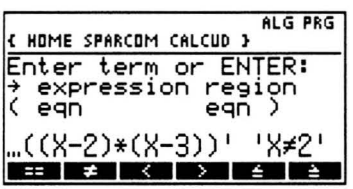
Press ENTER to accept the first term. You will be prompted for another term.

The second term consists of the expression 1 and the region 'X==3'. Enter this information until your screen appears as follows.



Press ENTER to accept the second term. You will be prompted for another term.

The third term consists of the expression 'X/((X–2)*(X–3))' and the region 'X≠2'. Enter this information until your screen appears as follows.



Press ENTER to accept the third term. You will be prompted for another term.

At this fourth prompt, press ENTER to terminate the entry, and the result will be calculated (display assumes PWISE was executed from the interactive menus):

The result can be viewed in the EquationWriter, copied to the stack, or printed on an IR printer. When you have finished viewing the result, press **UP** to return to the Function Library menu, **MAIN** to return to the Main menu, or ATTN to quit the Calculus Pac.

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