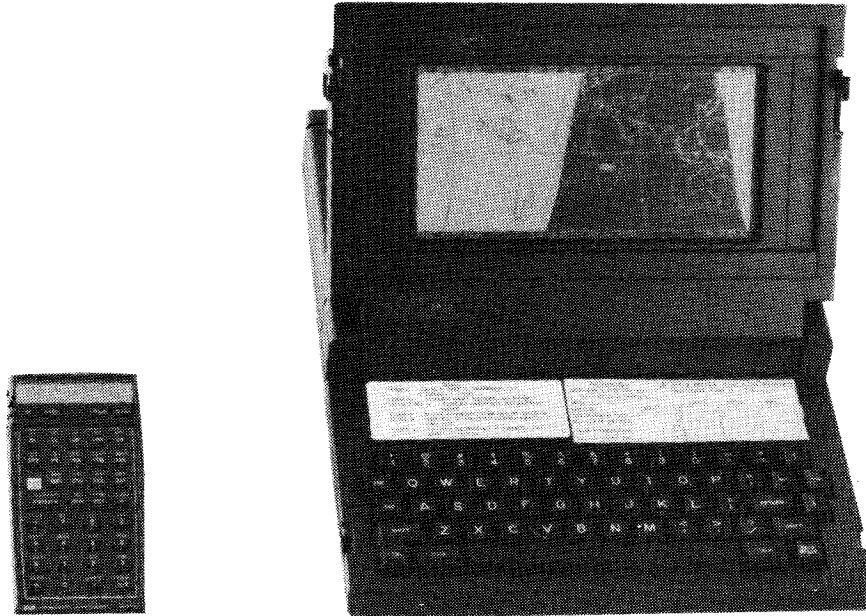


Hewlett-Packard 41 Calculator/ Shuttle Portable Onboard Computer Training Manual

HP 41/SPOC 2102



**Mission Operations Directorate
Training Division
Flight Training Branch**

November 1985

NASA

National Aeronautics and
Space Administration

Lyndon B. Johnson Space Center
Houston, Texas 77058

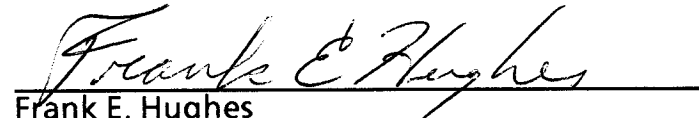
Hewlett-Packard 41 Calculator/ Shuttle Portable Onboard Computer Training Manual

HP 41/SPOC 2102

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Section 1: Introduction

The HP-41/SPOC training manual introduces the Hewlett-Packard 41 (HP-41) calculator and Shuttle Portable Onboard Computer (SPOC). The HP-41 and SPOC execute several programs which aid the crew during their onorbit activities. These handheld or panel-mounted units operate independently of the general purpose computers (GPCs); but some programs supply data for the GPCs. To receive maximum training benefit from this manual the student may desire obtaining an HP-41 calculator and, if possible, an HP32161A digital cassette drive, an HP-IL, and a SPOC.

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Setup of hardware and operation during flight are explained in detail. Brief descriptions of current HP-41 and SPOC Shuttle software programs are provided. However, the HP-41 and SPOC Flight Procedure Handbooks should be referred to for detailed information concerning the latest set of programs. There are no prerequisites to reading this training manual.

Sections 2 through 6 are written as an introduction to the HP-41 calculator. The user should become familiar with the functions and capabilities of the calculator in conjunction with the programs used in flight operations.

Sections 7 and 8 acquaint the user with the SPOC. Unlike operation of the HP-41, the user requires only a basic knowledge to run the SPOC. Therefore, less detail is given on how to operate the SPOC functions than on how the HP-41 functions.

Finally, appendices are provided as a reference for the HP-41. Of particular importance, appendix F shows the HP-41 keyboard.

Section 2: HP-41

Mention of the HP-41 calculator refers to the HP-41C, HP-41CV, or HP-41CX. The large capacity HP-41CVs are flown onboard the Space Shuttle and the lesser HP-41Cs, formerly flown, are now used for training at the Shuttle Mission Simulator (SMS). The SMS HP-41s, however, have had their memories expanded to make them equivalent to HP-41CVs. Thus, even large Shuttle programs which specifically require use of the additional HP-41CV memory may be run on the converted HP-41Cs. The greater capacity HP-41CX is not operated by the crew.

Because the HP-41 is being used by the crew as a program monitoring device rather than as a programming tool, programming aspects of the calculator will not be covered in this training manual.

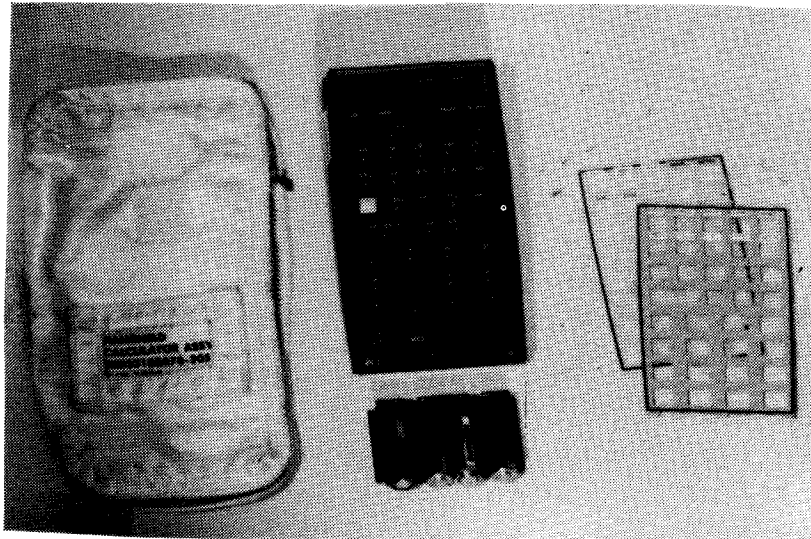


Figure 2-1.—HP-41 equipment.

Special Features

The HP-41 has a number of features that many calculators do not have.

- **Reverse Polish Notation.** Reverse Polish notation (RPN) logic is used by the HP-41 for all arithmetic expressions. It involves entering the two operands followed by the operator (+, -, ×, or ÷). Further explanation of RPN can be found in appendix A.
- **Continuous Memory.** All data, programs, and functions are maintained when the calculator is turned off.
- **Alphanumeric Capability.** The HP-41 offers both alphabetic and numeric character capability. Alphabetic characters allow for input and output of messages, prompting of data having meaningful words or sentences, and display of exact error messages.
- **Key Reassignments.** Nearly every key on the HP-41 can be reassigned to receive the function of most any other key on the keyboard. As an application, a specific phase of a program could be accessed by just pressing one key. This process allows functions to be positioned on the keyboard for quickest access. A plastic overlay with the newly defined keyboard functions is provided with each flight program and may be placed over the existing HP-41 keyboard.

- I/O Ports. The four input/output receptacles (I/O ports) in the calculator allow the user to plug in additional technical application modules, the printer, or the HP-IL (interface loop). The HP-41 will normally be configured as shown below.

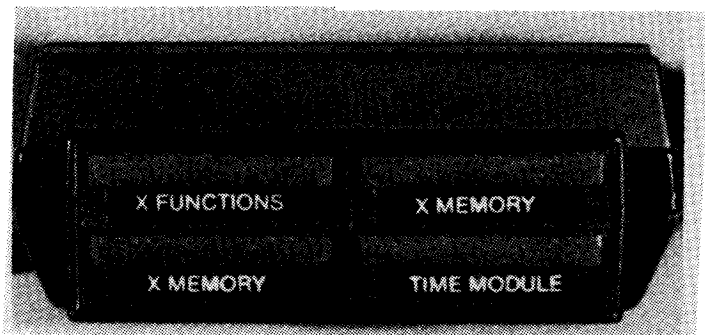


Figure 2-2.—HP-41 module configuration.

- Tones. The HP-41 is equipped with two functions that produce tones. These alarms are used in the flight programs to alert the crew to time-critical events.
- Disposable Batteries. The HP-41 runs on four 1.5-volt, size N batteries. Because it uses so little power, disposable batteries are all that are needed, since they will provide approximately 20 hours of continuous operating use. Of course, battery lifetime in the calculator depends upon how fresh they were when installed. To conserve battery power, the HP-41 automatically turns itself off after 10 minutes of inactivity.

Status Annunciators

The HP-41 displays seven visual annunciators, or key words, that indicate the present status of the calculator. The row of annunciators is located just below the alpha-numeric display. Refer to appendix F for a picture of the annunciators on the HP-41. The following is a brief explanation of each annunciator.

- BAT. The HP-41s batteries are low on power. When using alkaline batteries, 5 to 15 hours of HP-41 operating time remain.
- USER. The user mode has been selected. The keys represent user-selected functions.
- RAD/GRAD. RAD or GRAD will be displayed if the radian or gradian trigonometric mode has been selected. When operating in degrees, this field is blank. The Shuttle flight programs are written for the radian mode.
- SHIFT. The gold SHIFT key has been pressed and the gold functions above the keys are active. This may be extinguished by pressing the gold key again or executing a shifted function.
- 0 1 2 3 4. Each of these digits indicates that a flag in a program has been set. Some Shuttle flight programs use the flags to indicate the mode in which the program is currently running.
- PRGM. The program mode has been selected. It is used for writing programs.
- ALPHA. This indication means the alphabet keyboard is currently active.

Section 3: HP-41 Mode Control

The HP-41 has four operating modes, each of which activates different calculator capabilities. These four modes are normal, user, program, and alpha. The row of keys used to select these modes is located between the display and keyboard. The user, program, and alpha modes may be selected by pressing their respective keys. Normal mode is active when none of the others have been selected. Each of the four modes will be explained in this section.

Normal Mode

When the normal mode is active, the available functions are the ones printed above and on the faces of the keys. To select the function above the key, first press the SHIFT (gold) key, then press the function key. To select the function on the face of the key, simply press the key itself. The character printed in blue on the lower face of the key is only available in alpha mode and not in normal mode.

When a function key is pressed, the name of the function to be executed will appear on the display. If the key is held down for longer than about a second, NULL appears in the display, indicating that the function has been canceled. Thus, by pressing and holding a key, the function name can be observed without actually executing the function.

Example: Compute the inverse of 10. Also, notice the function name.

<u>Keystroke</u>	<u>Display</u>	
SHIFT CLX	0.0000	Clear the display. (Discussed later.)
10	10 _	
1/x	1/X 0.1000	Press and hold the 1/x key for a moment, then release. Notice that the function name remains in the display while the key is held down. The function is executed when the key is released.

Next, nullify a function by holding down the appropriate key for longer than a second.

Example: Examine the "Null" execution feature.

<u>Keystroke</u>	<u>Display</u>	
10	10 _	
1/x (hold)	1/X NULL	Press and hold 1/x until the name goes away and NULL appears. When the key is released, the function is not executed.
	10.0000	Previous contents of the display are returned.

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User Mode

The user mode allows the keys to be customized with other functions. When the USER key is pressed, USER is annunciated in the display. All keys that have not been reassigned retain their normal mode functions.

Functions are assigned using the assign (ASN) key. To assign a function to a key, follow these steps: SHIFT ASN, ALPHA, enter the name of the desired function, ALPHA, press the desired key (and SHIFT, if necessary) to be assigned. All keys may be assigned except SHIFT, ON, USER, and PRGM. To execute the newly assigned key, simply place the calculator in the user mode and press the key. All of the Shuttle flight programs must be run in

the user mode. Each program has its own keyboard overlay that designates what the reassigned keys are.

Program Mode

When the PRGM key is pressed, the calculator enters the program mode and the PRGM annunciator is displayed. Keystrokes are now recorded as program instructions. The HP-41 should not be programmed during flight, so care should be taken not to inadvertently enter the program mode. If this happens, simply press the PRGM key again, to toggle out of program mode. Programming is not covered in this training manual.

Alpha Mode

The alpha mode allows access to letters, numbers, and several special characters. When the ALPHA key is pressed, the alphabetic characters printed in blue on the lower faces of the keys become primary characters. ALPHA will annunciate, indicating the alpha mode selection.

Example: Enter the string "FUEL" in the alpha mode.

<u>Keystroke</u>	<u>Display</u>	
SHIFT CLX	0.0000	Clear the display. (Discussed later.)
ALPHA		Place the HP-41 in the alpha mode. Display may contain data from previous use.
SHIFT CLA		Clear the display. (Discussed later.)
F	F _	When a key is pressed, the letter printed in blue on the lower face of the key is displayed.
U	FU _	
E	FUE _	
L	FUEL _	
ALPHA	0.0000	Take the HP-41 out of the alpha mode. The string "FUEL" is retained in the alpha register and will appear in the display when the alpha mode is re-entered.

Example: Use the ALPHA key to enter "HP-41" in the alpha mode.

<u>Keystroke</u>	<u>Display</u>	
ALPHA	FUEL	The alpha mode is active and the string FUEL returns.
H	H _	A new string is started. The old string is automatically cleared.
P	HP _	H and P are primary characters.
SHIFT -	HP- _	- is a shifted character.
SHIFT 4	HP-4 _	4 and 1 are also shifted characters.
SHIFT 1	HP-41 _	
SHIFT CLA		Clear the display. (Discussed later.)
ALPHA	0.0000	Take the keyboard out of the alpha mode.

In addition to the blue characters on the lower faces of the keys, each key has an additional function. These functions are not printed on the keys themselves, but are diagrammed on the bottom of the HP-41 calculator and in appendix F (alpha keyboard). To select these additional functions, simply press SHIFT before pressing each key.

Section 4: HP-41 Display & Keyboard

The HP-41 has the capability to display both numeric and alphabetic characters. When the calculator is turned on, it will display what was shown before it was turned off.

Numeric Display

The numeric display is available in the normal and user modes. It can hold a maximum of ten digits, excluding the decimal point (.) and the negative sign (-). However, only eight digits are allowed for a coefficient which has a power-of-ten exponent. The two remaining digits are reserved for the exponent. To enter a number with a power-of-ten exponent, key in the number followed by EEX (enter exponent of ten). The prompt (-) will move over to the right side of the display. Key in the exponent, by entering two digits.

Example: Enter Avogadro's number (6.0225×10^{23} mol⁻¹).

<u>Keystroke</u>	<u>Display</u>	
SHIFT CLX	0.0000	Clear the display. (Discussed later.)
6.0225	6.0225 -	The HP-41 prompts for each digit.
EEX	6.0225 -	Then prompts for the exponent.
2	6.0225 2 -	
3	6.0225 23 -	Avogadro's number 6.0225×10^{23}

To key in a negative number, enter the number followed by the CHS (change sign) key. The number, preceded by a minus (-) will appear in the display. Pressing CHS again will make the number positive.

Example: Use CHS to display -30.6593.

<u>Keystroke</u>	<u>Display</u>	
SHIFT CLX	0.0000 -	Clear the display. (Discussed later.)
30.6593	30.6593 -	30.6593 is in the display.
CHS	- 30.6593 -	The number is negative
CHS	30.6593 -	The number is positive.

Alpha Display

The alpha display and keyboard can be activated by pressing the key labeled ALPHA. If any characters were previously entered into the display (while in the alpha mode), they will be shown now. Otherwise the display will be blank.

The alpha register can hold up to 24 full characters with a maximum of 12 characters being viewed in the display at any one time. While characters are being entered into the alpha display, a prompt (–) appears to the right of the last character entered. This indicates there is still room for at least one more character in the alpha register. If a string beyond 11 characters (plus the –) is entered, the HP-41 will automatically scroll the left-most characters off the screen.

Example: Enter characters into the alpha register.

<u>Keystroke</u>	<u>Display</u>	
SHIFT CLX	0.0000	Clear the display. (Discussed later.)
ALPHA		Place the HP-41 in the alpha mode. Activates the alpha keyboard.
SHIFT CLA		Clear the display. (Discussed later.)
A,B,C,D,E,F, G,H,I,J,K	ABCDEFGHIJK –	The display now contains 11 characters.
L	BCDEFGHIJKL –	Now 12 characters. The "A" has scrolled off the left side but is retained in the alpha register.
ALPHA	0.0000 –	Take the HP-41 out of the alpha mode.

Since the alpha display scrolls (or wraps) around to the left, leading characters will disappear and the display might become hard to interpret. When entering messages (such as with the alarm program) be sure that there are less than 12 characters or that the message can be interpreted after a portion of the message has scrolled by. When entering the alpha mode after the alpha register has been filled, the first 12 characters will initially be displayed. This is followed by a brief pause, after which the display will scroll left until the last character comes into view. After the message has been viewed, press the ALPHA key to exit the alpha mode.

Clearing Operations

The HP-41 has several display clearing or correcting functions that can be used to modify alphabetic or numeric data entry. These keys are explained below.

- CLX/A. In normal or user mode, pressing SHIFT CLX clears the numeric display (X-register) to zero. In the alpha mode, pressing SHIFT CLA clears the entire alpha display.
- ← (Correction). If a prompt sign appears in the display (signifying that digit entry or alpha entry has not been terminated), pressing ← deletes the right-most digit from a number being entered or the right-most character from an alpha string being entered. If no prompt sign appears (signifying that digit entry or alpha entry has been terminated), pressing ← has the same effect as pressing SHIFT CLX or SHIFT CLA. To clear the entire calculator (all programs, data key assignments, etc.) with the “master clear”, turn off the HP-41, hold down the ← key, turn the calculator back on, and release the ← key. The display will show MEMORY LOST. Any programs previously loaded into the HP-41 must now be reloaded. By the way, if MEMORY LOST appears when the HP-41 is first turned on, power to the calculator’s continuous memory was interrupted while it was off.

Display Control

Three functions, FIX, SCI, and ENG, allow the user to control the manner in which numbers appear in the HP-41 display. The HP-41 will continue to display numbers in the previously selected display control format until a new format is requested. These three functions will now be covered.

- Fixed Point Display (FIX). FIX displays numbers in a fixed decimal point format. Using the fixed point display, the number of digits after the decimal point can be specified by pressing SHIFT FIX, followed by a digit 0 through 9.

Example: Use FIX to display 2.24136 with 2, then 4 significant digits.

<u>Keystroke</u>	<u>Display</u>	
2.24136	2.24136 _	The number.
SHIFT FIX	FIX _	Display shows the function, FIX.
2 (hold)	FIX 2	This is displayed while the 2 key is briefly held down.
2 (release)	2.24	The number is rounded off to two decimal places.
SHIFT FIX 4	2.2414	Notice that the display rounds up if the next digit is 5 or greater.

- Scientific Notation Display (SCI). In scientific notation, each number is displayed with a single digit to the left of the decimal point. To the right of the decimal point are a specified number of digits (up to seven) and a power-of-ten multiplier. Scientific notation is selected by pressing shift SCI followed by a digit to specify the number of decimal places to which the number will be rounded.

Example: Use SCI to display the speed of light in scientific notation with three significant digits.

<u>Keystroke</u>	<u>Display</u>	
299792500	299,792,500 _	Speed of light.
SHIFT SCI	SCI _	The function and the prompt.
3	2.998 08	Indicates 2.998×10^8 . The display rounds up if the next digit is 5 or greater.

- Engineering Notation Display (ENG). Engineering notation is similar to scientific notation except that all exponents are shown as multiples of three (e.g., 10^3 , 10^6 , 10^{-9}). This notation is convenient for scientific and engineering calculations, where units of measure are often specified in multiples of three. Engineering notation is selected by pressing SHIFT ENG followed by a number key that specifies the number of significant digits, excluding the first one, that the number should be rounded to.

Example: Use ENG to display 1.2345×10^{-4} with five, one, then zero significant digits.

<u>Keystroke</u>	<u>Display</u>	
1.2345	1.2345 _	
EEX CHS 04	1.2345 -04	The number.
SHIFT ENG	ENG _	Display function and prompt.
5	123.450 -06	Engineering notation display. Number appears in the display rounded off to five significant digits after the omnipresent first one.
SHIFT ENG 1	120. -06	Display is rounded off to the first significant digit after the first one.
SHIFT ENG 0	100. -06	Display is rounded off to the first significant digit.

Let us continue this example by multiplying our result by 10, twice, then by reinitializing the HP-41 to a FIX 4 format:

<u>Keystroke</u>	<u>Display</u>	
10 x	1. -03	The decimal point shifts and the exponent changes.
10 x	10. -03	The decimal point shifts and the exponent remains unchanged.
SHIFT FIX 4	0.0123	The number is rounded off to four decimal places.

Special Purpose Keys

- Run/Stop (R/S). The R/S key is usually used for programming. It is utilized with flight programs to enter data into the calculator. When a program is running (PRGM annunciator is on), the R/S key will halt all execution. By pressing R/S again, the program will pick up execution right where it left off.
- Execute (XEQ). The XEQ key accesses the three HP-41 catalogs maintained in the calculator. Built-in functions, which are not printed on the keyboard, can be executed with this key. To execute a function from the display, press XEQ, ALPHA, and the function name. The function is executed upon toggling out of the alpha mode.

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Example: Compute the factorial (FACT) of 6.

Keystroke	Display	
6	6 _	The number.
XEQ	XEQ _	The HP-41 is asking, XEQ what?
ALPHA	XEQ _	Place the HP-41 in the alpha mode.
F,A,C,T	XEQ FACT _	Tell the HP-41 the factorial (FACT) function is to be executed.
ALPHA	720.0000	When the HP-41 is taken out of the alpha mode, the function in the alpha display is executed.

Notice that the content of the alpha display is not disturbed when a function is executed from the display. Also, if an attempt is made to execute (using XEQ) a

function that does not exist in the calculator (or has been misspelled), the HP-41 will display NONEXISTENT.

Appendix E contains a listing of many of the HP-41 functions. Functions dealing specifically with programming have been omitted.

- Catalog. The user can see an alphabetical listing of catalog functions by using the CATALOG key. Pressing SHIFT CATALOG followed by 1, 2, or 3 causes the display to cycle through the catalog designated. As an example, press SHIFT CATALOG, 3. The automatic listing will begin at the rate of two function names per second. Pressing any key other than ON or R/S will slow the listing, and pressing R/S will halt the listing. After the cycling has been stopped, the SST key can be used to single-step ahead. SHIFT BST can be used to back-step. The R/S key will resume cycling.
- Radians/Gradians/Degrees (RAD/GRAD/DEG). Unless specified otherwise, the HP-41 calculates angles in decimal degrees. The XEQ key can be used to select radians, gradians, or decimal degrees. If the calculator is turned off and back on, it will be in the mode previously selected.
 To select the radians mode:
 XEQ ALPHA R,A,D ALPHA
 To select the gradians mode:
 XEQ ALPHA G,R,A,D ALPHA
 To select the degrees mode:
 XEQ ALPHA D,E,G ALPHA

The RAD or GRAD annunciator will appear if the radians or gradians mode, respectively, is active. Since the HP-41 normally assumes that angles are in decimal degrees, no display annunciator will show for this case. For most flight programs, the radians mode is used and automatically selected in the programs.

Section 5: HP-41 Program Loading

Digital Cassette Drive

Programs are loaded into the HP-41 using the HP32161A digital cassette drive. This peripheral device stores and retrieves programs and data from a miniature cassette tape which can hold up to 512 records (131,072 bytes) of information. The cassette drive is connected to the HP-41 using the Hewlett-Packard Interface Loop (HP-IL). Procedures for using the digital cassette drive are covered in this section.



Figure 5-1.— HP-41 digital cassette drive.

Cassette Drive Power

Power for the digital cassette drive is provided by a rechargeable battery pack. The battery pack is located in the compartment on the bottom side of the drive. Be sure the cassette drive is turned off before removing the battery pack or connecting or disconnecting the recharger. Also, the battery pack should always be installed whenever the recharger is connected. If these precautions are not followed, the cassette drive's circuitry can be damaged.

To recharge the battery pack using ac power, first switch the cassette drive to OFF. Next, insert the ac receptacle at the rear of the cassette drive. The drive can be operated while the battery pack recharges.

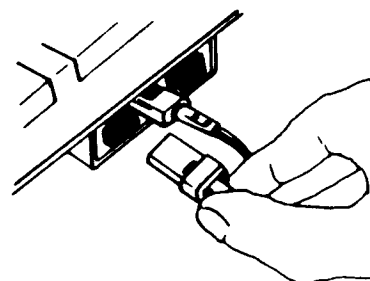


Figure 5-2.— AC receptacle insertion to the cassette drive.

Interface Connections

The digital cassette drive works in conjunction with the HP-IL. To connect the digital cassette drive to the calculator, first turn it off along with the HP-41. The HP-IL generally plugs into port 4 on the calculator (the lower right-hand port when you face the rear of the HP-41). If the time module is in port 4, it may be removed until the calculator's memory is loaded. The two lines extending from the HP-IL are then plugged into the proper ports on the back of the digital cassette drive.

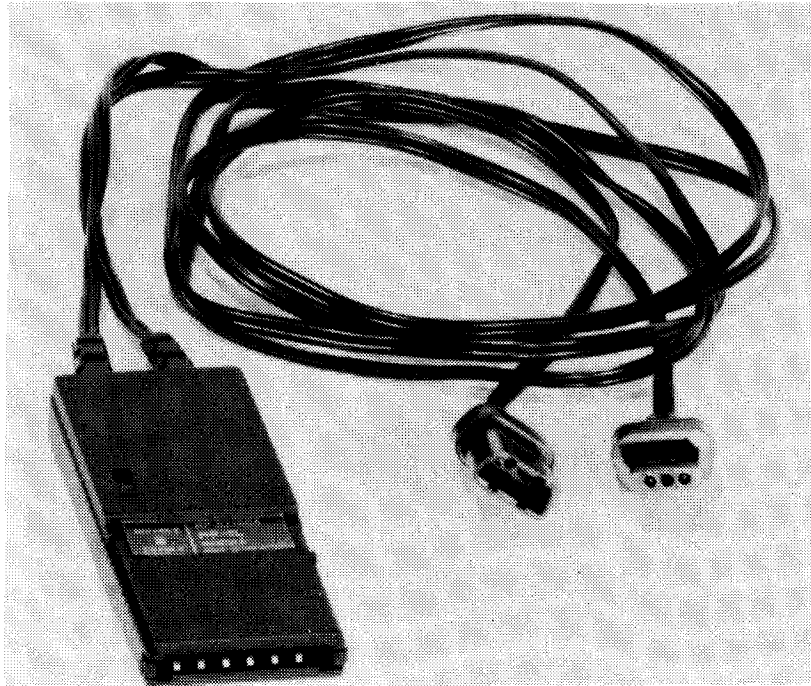


Figure 5-3.— HP-IL.

Loading the Cassette

To load the mini data cassette into the digital cassette drive, first open the cassette door by pressing the OPEN button on the front panel. Do not open the cassette door while the drive is operating or while the BUSY light is on. The cassette will not be damaged, but some information may be lost. The cassette must be loaded in only one orientation. Keep the white label facing up and the exposed tape facing into the drive. Slide the cassette into the receptacle in the door and close the door. If the tape is positioned improperly, the door will not close completely, but do not force it.

Before removing a cassette from the drive, it is good practice first to rewind the tape by pressing the REWIND button on the front panel. To remove the cassette, press the OPEN button and slide out the cassette. The cassette can be stored in its protective holder or in the storage compartment in the top of the case.

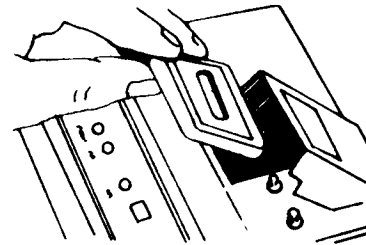


Figure 5-4.— Removing the cassette tape.

Operation Sequence

As soon as the digital cassette drive has been connected to the HP-41 via the HP-IL, and a cassette tape has been installed, the HP-41 can be switched on so that the mass storage unit can be accessed. If the power or battery lights do not come on, recharge the battery pack as described above. The system is now prepared for loading a program.

Clear the calculator memory by holding down the ← key while pressing the ON key. When both keys are released, the display should read MEMORY LOST. Next, press the ALPHA key and key in the program name; then, exit the alpha mode by pressing ALPHA again. Now load the program into the HP-41 memory by pressing XEQ, ALPHA, R, E, A, D, A, ALPHA. When the display says READY, turn the calculator and the cassette drive off, remove the HP-IL, and replace the port 4 module (if one was removed). The program is now ready to run. The read all (READA) function tells the digital cassette drive to search for the program defined in the HP-41's alpha display and load it into the HP-41 memory, reassign all keys (for the user mode), set the appropriate flags, and initialize variables. For convenience, the programs are also initialized with the user mode selected.

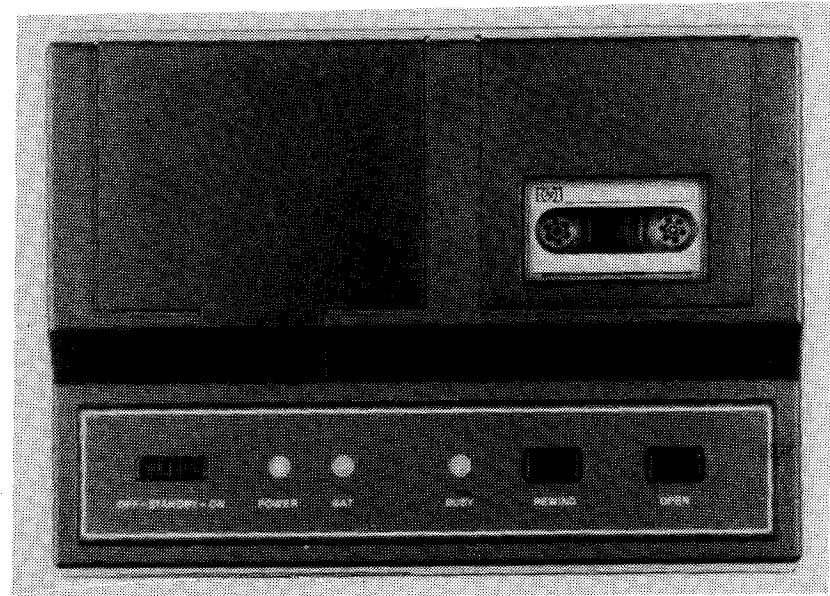


Figure 5-5. – Top view of cassette drive.

Section 6: HP-41 Flight Programs

This section contains a brief overview of each of the Shuttle flight programs used by the HP-41 calculator. For details on each program, refer to the HP-41 Flight Procedures Handbook.

It will be assumed that the programs will be loaded by the Hewlett-Packard digital cassette drive. The user should have the appropriate modules plugged into the I/O ports before loading a program. The following programs are currently used for flight applications.

Center of Gravity

16 The center of gravity (c.g.) program is used by the crew to calculate the vehicle's X and Y c.g., the deorbit propellant weight to be burned to obtain a desired X c.g., and the amount of forward reaction control system (RCS) propellant to be dumped for a desired X c.g. The program also computes the amount of OMS propellant to be crossed for a desired Y c.g., the change in velocity (ΔV) available in each pod, and the propellant required for a given ΔV .

Orbit

The orbit program provides star align and Orbiter maneuver data. The program displays the current and each subsequent star pair available for the star tracker, based on the present MET and state vector. When an attitude maneuver is requested, the program will display how long the maneuver will take (given a maneuver rate). The time of, and time to, the next sunrise or sunset can also be displayed. In addition, the map function is

available as with the observations program. A range/range rate key calculates the closing range and velocity to a target during rendezvous. Another user key utilizes a polar to rectangular coordinate transformation program, also for rendezvous.

Alarm/Hex

The alarm program allows programming of up to 120 alarm messages for crew recognition of upcoming events. In order to make the alarms easier to hear, a tone amplifier can be plugged into the back of the HP-41. The tone amp is plugged into the I/O port that usually houses the time module, which gets moved over to replace the lower extended memory module. In addition, the calculator can be configured as a stopwatch for the timing of experiments or other activities.

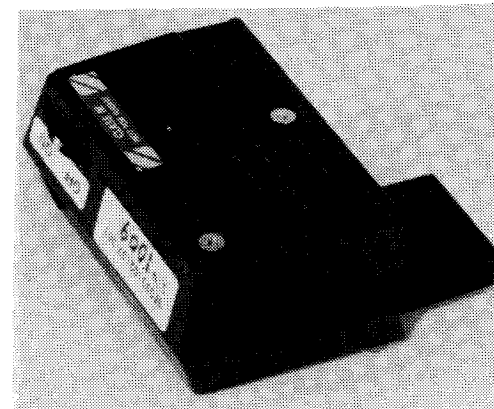


Figure 6-1.—HP-41 tone amplifier.

The hex program is automatically loaded with the alarm program and is used primarily for the CFES project. Hex computes the following numerical transformations: hexadecimal→decimal, decimal→octal, or octal→decimal.

Landing

The landing program is used only on the Shuttle training aircraft (STA) to provide basic landing data. The program calculates and outputs the following information to the crew: landing energy, speedbrake retract position, rollout prediction from touchdown to brake initiation, braking distance, and total rollout distance.

Proximity Operations

The proximity operations (PRX) program provides information concerning vehicle flyaround and station-keeping with a target satellite, sun angle data for rendezvous operations, and range/range rate data for closing on a target. Originally developed for the Spartan payload, PRX can be adapted to any rendezvous target.

Tail

The tail program computes the Orbiter tail-to-sun attitude in order to reduce vehicle cooling requirements in the event of the loss of a flash evaporator. Because the attitude can be calculated by the guidance, navigation, and control (GNC) software in operational sequence (OPS) 2, the tail program is required only in GNC OPS 3.

Section 7: Shuttle Portable Onboard Computer

The Shuttle Portable Onboard Computer (SPOC) is a microcomputer that enhances the HP-41 calculator concept. The SPOC expands this system by providing larger memory space and graphics capability. SPOC is NASA's name for the compass computer, which is manufactured by GRiD.

The SPOC was first used on STS-9 with two SPOCs being flown (one as a backup) each flight beginning with STS 51-G. The SPOCs used today have an expanded graphics screen and random access memory (RAM) over the original units, which can be flown if needed as backups.

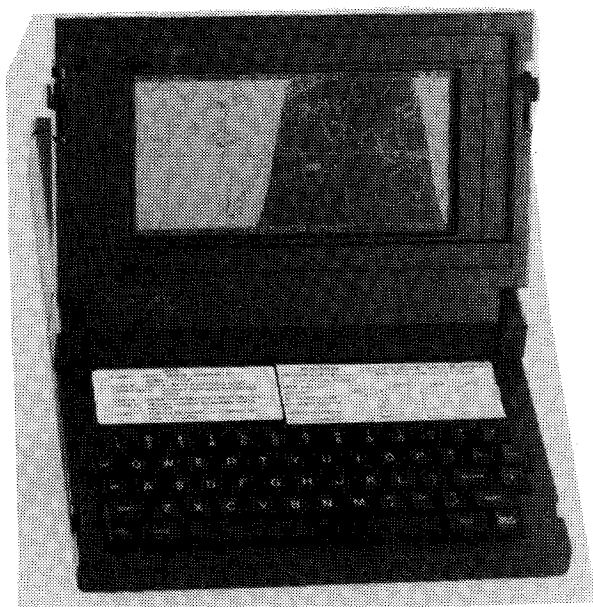


Figure 7-1.- Shuttle Portable Onboard Computer.

Hardware

The SPOC has a 384k-byte, nonvolatile bubble memory. This mass storage acts like a disk drive for use in storing programs. The SPOC directly accesses 512k bytes (256k bytes in the small-screen SPOC) of RAM for executing software. The foldup display is a high resolution electroluminescent flat panel which measures 7-9/16 by 3-3/4 inches (70 percent larger than the small-screen SPOC, which measures 4-3/4 by 3-1/2 inches).

There are four different types of keys on the SPOC: alphabetic/numeric keys, function keys for issuing commands, arrow keys for positioning the cursor, and a return key for cursor control. The memory, display, and 57-character keyboard are in a magnesium case, all of which weighs approximately 10 pounds. The unit will fit into one-half of a standard size briefcase.

The GRiD compass computer was purchased off-the-shelf and modified for cooling by replacing the built-in telephone modem with an internal fan and putting a notch in the leg for the fan's circulation. This change was necessary because the standard GRiD computer requires convective cooling, which is nonexistent in zero gravity. The lithium battery circuit that provides power for the internal clock (Greenwich mean time) was replaced with a silver oxide battery and given supplemental diodes and a fuse to ensure fail-safe operation. Also, the flown SPOCs are fitted with electromagnetic interference screens. This prevents the electromagnetic interference caused by the electroluminescent display from harming

the GPCs or other equipment onboard. When used onboard the Shuttle, the SPOC runs on phase A ac power and uses a power cable which is compatible with the Orbiter's power outlets.



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Figure 7-2.— Back side of the SPOC.

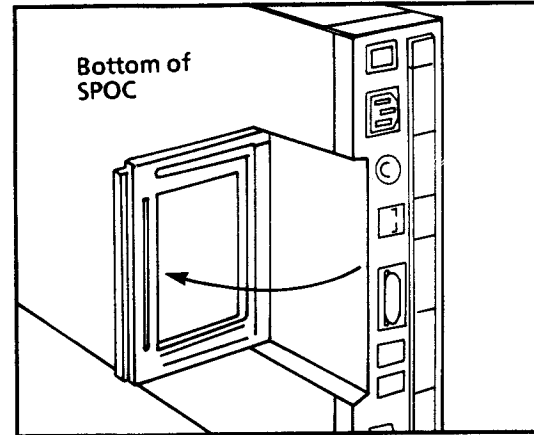
Operation

Sections 7 and 8 address use of the SPOC from an operator's perspective as opposed to that of a programmer. Thus, detail will not be given as to use of each of the keyboard functions or maintenance of the SPOC and its peripherals.

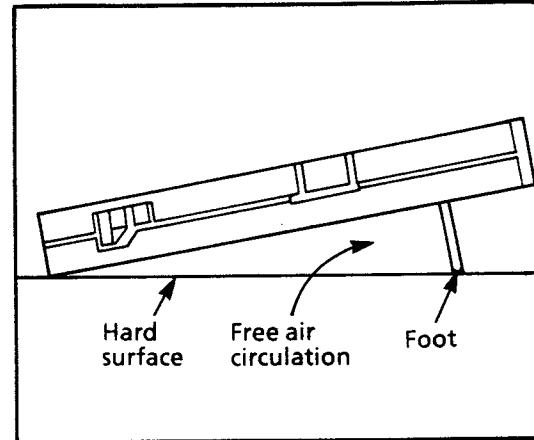
The SPOC can be turned on with a rocker switch on the back panel. Also of interest on the back panel are the power connector and fuse. The fuse may be replaced on the ground or in flight by unscrewing the old one and installing a new one.

Setup for Ground Operation

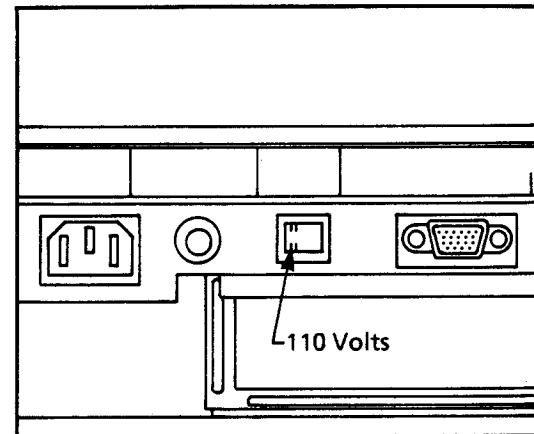
Step 1. Pull down the leg at the back of the computer until it clicks into place. This will allow for a good viewing angle and permit ventilation underneath the SPOC.



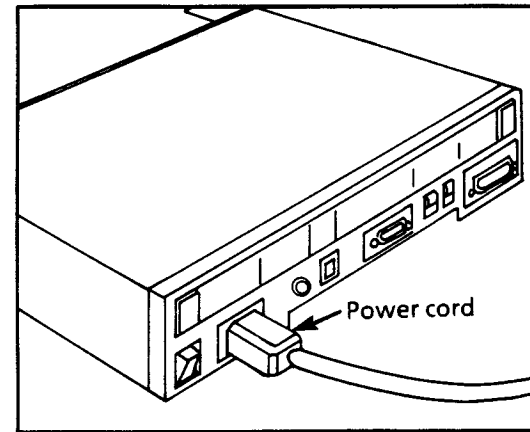
Step 2. Place the SPOC on a flat work surface. The nonflight version is not equipped with a fan for cooling. Therefore, the magnesium case provides the heat sink and requires circulation underneath.



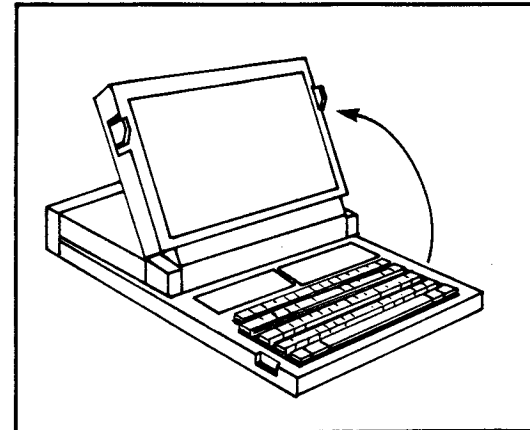
Step 3. Verify that the voltage switch is set for 110 volts.



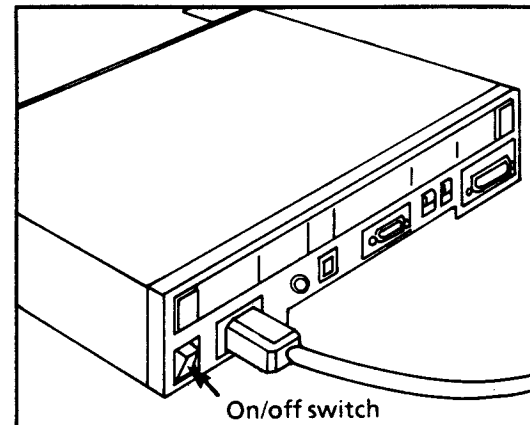
Step 4. Connect the power cable.



Step 5. The screen is locked in the frame by a latch on each side of the computer. Pull these latches forward and lift up the screen.



Step 6. Turn the power on. When you are facing the rear of the SPOC, the ON/OFF switch is on the far left side. In addition to enabling power, this switch also loads some initialization programs into random access memory (RAM). When cycling power, leave the switch off for at least 5 seconds before turning it back on. Ignoring this precaution may cause improper loading of system software.



Setup for Flight Operation

The SPOCs are stowed in a middeck locker during ascent and entry. The Post Insertion checklist calls for SPOC activation a few minutes before payload bay door opening. Panel F3 is configured so the SPOC can be attached to it using Velcro and bungee cords. For this setup, the power cord plugs into the ac utility outlet on panel F1. However, SPOC location depends on crew preference. It may be attached to any panel as long as the SPOC's 6-ft-long power cord can reach an ac utility outlet. AC 1 outlets are located on panels F1 and MO52J, AC 3 outlets are on panels A15 and MO13Q. The SPOC remains in operation until deorbit preparation.

To activate the SPOC, first set the voltage switch for 110 volts. Next, connect the power cable (which was plugged into the SPOC while stowed) to one of the ac outlets. Then, unlatch and pull up the screen. Finally, turn on the power. Because of the zero-g environment, there is no purpose in pulling down the SPOC's leg. An operations/malfunctions cue card (shown below) for the SPOC is used on orbit and can be attached with Velcro just below the SPOC's screen.

State vector addresses are the same as those used for the HP-41. These addresses are GPC software-load dependent, and thus vary from flight to flight. Notice on the cue card that the only SPOC malfunction recovery procedure is to cycle power. This clears the RAM and allows the SPOC to be reinitialized. If the SPOC will not power up, its fuse may be blown or phase A power may have failed. The crewmember may attempt to power the SPOC from another ac utility outlet.

SHUTTLE PORTABLE ONBOARD COMPUTER

ACTIVATION
 Unstow & install (pwr from AC UTIL OUTLET)
 SPOC pwr - on
 Set GMT
 Set LAUNCH TIME
 Set STATE VECTOR
 DISPLAY WORLD MAP
 To exit 'CODE-ESC'

	SET STATE VECTOR	GNC 0 GPC MEMORY		
	ENG UNITS - ITEM 26	+2	0	1 EXEC
	OPS2	OPS8	OPS3	
X				
Y				
Z				
VX				
VY				
VZ				

MALFUNCTION
 SPOC pwr - off (5 sec), then on
NOTE

'CODE-L' - select/freeze/unfreeze lat + long + f/stop
 'CODE-N' - display next ascending node
 'CODE-CTRL-N' - display current ascending node
 'CODE-F' - move forward one Earth obs site
 'CODE-R' - return to first available Earth obs site
 'CODE-S' - toggle between s/c sunrise/set and s/c noon

Section 8: Shuttle Portable Onboard Computer Flight Programs

SPOC flight software allows selection of programs from a menu format. For up-to-date detailed information on how to run each of the SPOC's programs, see the SPOC Flight Procedures Handbook. This training manual gives only an overview of the three subprograms and four primary programs.

Instructions at the bottom of the screen provide the user with the next input required. If the SPOC asks for a "CODE-X" input, where X is a specified alphanumeric key, hold the "CODE" key down while depressing "X".

Set Greenwich Mean Time

Greenwich mean time (GMT) can be updated in the SPOC's internal clock. (When external power is not supplied to the SPOC, the clock is powered by an internal battery.)

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Launch Time Update

The actual launch time can be input, if necessary, to update the prelaunch expected launch time. The launch time is stored on mass storage and used to compute MET.

State Vector Update

This allows the user to input position and velocity vectors for the true date of rotation (TDR) coordinate system. These vectors are obtained from the GPC Memory Page (utilizing the same GPC addresses and procedures as those used for the HP-41) and are written to the mass storage device for access by other programs.

World Map

The SPOC presently runs the world map as its primary program. A graphics display of a world map is overlaid with information pertaining to the Orbiter's current status with respect to the Earth. Displays on the world map are subject to revision as future changes are made to this computer program. The following information is pictured on the world map but may vary from flight to flight.

- Day/night ground terminator.
- Current and two predicted orbital groundtracks.
- Present Shuttle position (at the Shuttle bug's nose).
- Boundaries for tracking and data relay satellite (TDRS) coverage.
- Spaceflight tracking and data network (STDN) sites.
- Location of the next Earth observation site (EOS).

The following digital information is displayed along the top and bottom of the world map. These are also flight dependent.

- Current mission elapsed time (MET).
- Time to the next acquisition of signal (AOS) or loss of signal (LOS) of TDRS.
- Time to the AOS or LOS of the next STDN site, along with the code designation.
- Time to the next sunrise or sunset. User may toggle to the time to the next spacecraft noon, instead.
- Code designation of the next EOS, its MET, and the nominal camera f-stop associated with that site.

User may toggle to the following EOS information, instead.

- Current Shuttle latitude, longitude, and camera f-stop. User may select static or dynamic data. User may, instead, toggle to the longitude and MET of the next or previous ascending node.
- Time to, or since, the most recently calculated ascending node.

The world map display is shown in figure 8-1.

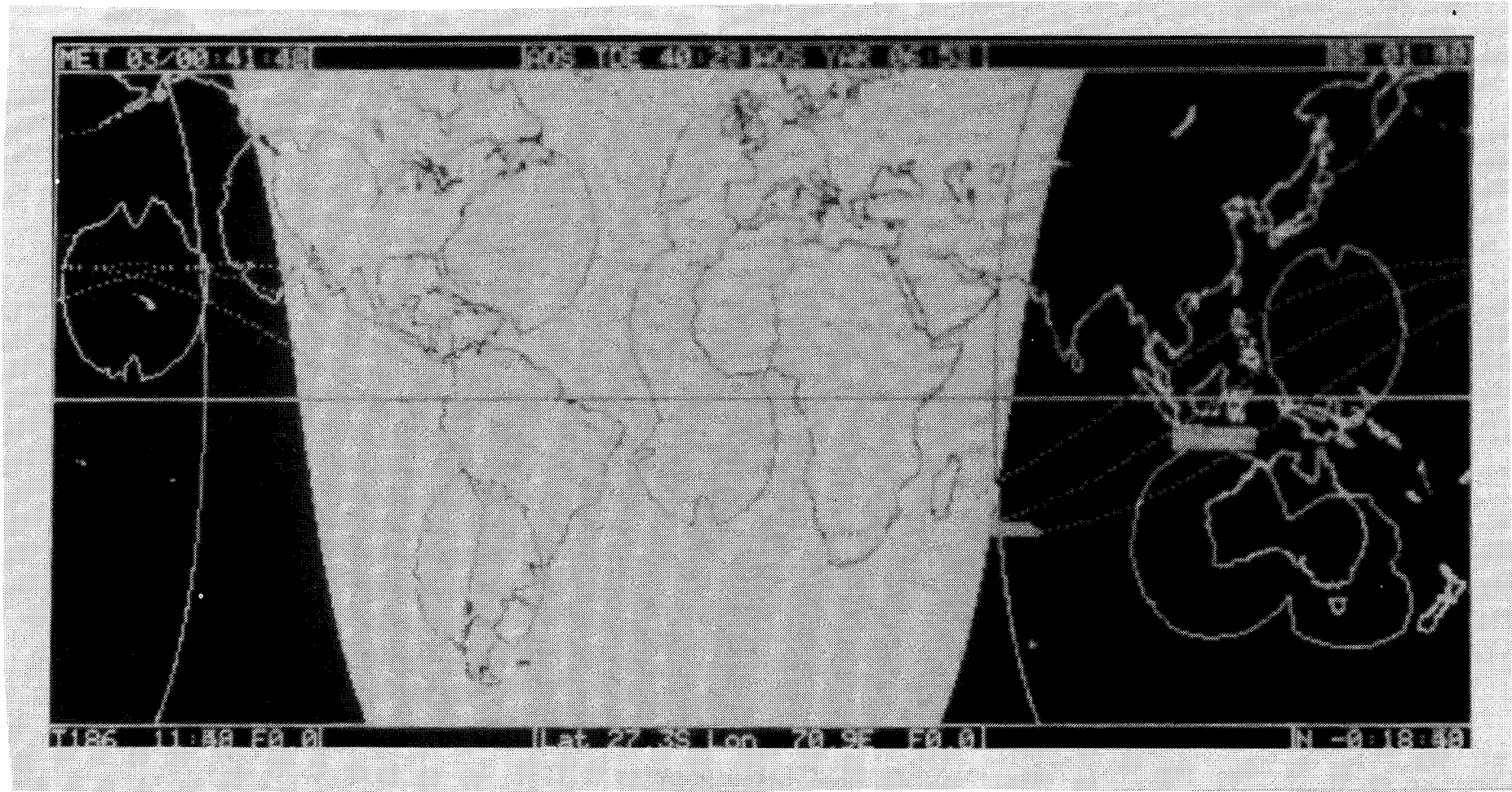


Figure 8-1.- SPOC world map display.

Deorbit

This program supplies deorbit burn information to the crew in the event of a time-critical systems failure requiring an emergency deorbit or in the case of total loss of communication with mission control. It provides more data than, and thus replaced, the former HP-41 deorbit program.

The SPOC deorbit program displays a complete landing opportunity table for selection of upcoming landing sites. Once a site has been chosen, the SPOC provides complete deorbit target information.

The deorbit program is loaded preflight, along with the world map program.

Orbital Refueling System

The orbital refueling system (ORS) program is loaded into the SPOC with the world map program prelaunch, on missions requiring it. The first flight utilizing the ORS was STS 41-G.

Crew Controlled Free Drift

The crew controlled free drift (CCFD) program can be loaded preflight along with the world map and deorbit programs, on specific flights needing it. CCFD was originally created for Spacelab 2 (STS 51-F).

Appendix A: Reverse Polish Notation

Reverse Polish notation (RPN) is a list-based logic which incorporates a last-in, first-out (LIFO) stack to handle all arithmetic expressions. The stack is used to retain intermediate values not yet processed. When an operation is requested, the two most recent entries in the stack are used. The resulting value replaces the last entry on the stack and all the other values move down one level.

The HP-41 uses a four-level stack pictured below.

The	T 0.0000
Automatic	Z 0.0000
Memory Stack	Y 0.0000
	X 0.0000

These levels are referred to as registers, with the X-register always being displayed in the normal and user modes. Each register in the stack holds a 10-digit number and its 2-digit exponent of 10. Each number, no matter how many digits it is, occupies one entire register. These registers are labeled X, Y, Z, and T. They are "stacked" like shelves, one on top of the other, with the X-register on the bottom and the T-register on top.

The contents of these registers, as well as all other information in the HP-41, are maintained by the calculator's continuous memory when it is turned off.

ENTER Key

The ENTER key is used to move numbers up the stack:

<u>Keystroke</u>	<u>Display</u>	
SHIFT CLX	0.0000	Clear the display (X-register).
3 ENTER	3.0000	3 is put into the X- and Y- registers.
2 ENTER	2.0000	2 is placed into X- and Y-, and 3 into Z-.
1 ENTER	1.0000	1 into X- and Y-, 2 into Z-, and 3 into T-.

Now notice how the stack changes after each number is entered:

<u>Keystroke</u>	<u>Display</u>	
987.3	987.3 _	The number.
ENTER	987.3000	

The stack is shown below, before and after ENTER is pressed:

Before ENTER		After ENTER	
T	3.0000	T	2.0000
Z	2.0000	Z	1.0000
Y	1.0000	Y	987.3000
X	987.3000	X	987.3000

The value in the X-register is duplicated and pushed into the Y-register. The numbers in Y- and Z- are pushed up to Z- and T-, respectively. The number in T- is lost from the top of the stack.

Now, continue by keying in a new number.

<u>Keystroke</u>	<u>Display</u>	
537.91	537.91 _	The new number in the X-register

The Enter key has separated the digits of the first number from the digits of the second number and the stack now looks like this:

T	2.0000
Z	1.0000
Y	987.3000
X	537.91 _

Manipulating the Stack

The R↓ (roll down), R↑ (roll up), and X Y (X exchange Y) functions allow the contents of the stack to be reviewed or to move data within the stack for computation at any time.

When R↓ is pressed, the stack contents shift downward one register. The value in the Y-register goes into the X-

register (and is displayed), Z- into Y-, T- into Z-, and X- into T-. Pressing R↓ another time will again roll the stack contents downward one register. Four presses of R↓ will roll the stack down four times, returning the stack contents to the original registers.

The R↑ function works the same way as R↓ except that the stack contents are rolled up instead of down. Notice that the R↑ function is not on the keyboard. It is executed from the display using the XEQ key or assigned to a key for execution in the user mode. To execute R↑ from the display, press XEQ, ALPHA, R, SHIFT↑ (the "N" key).

The X Y function exchanges the contents of the X- and Y- registers without changing the contents of the Z- and T- registers. If X↔Y is pressed with data intact from the previous example, the numbers in the X- and Y-registers will be changed.

	From	To
T	2.0000	T 2.0000
Z	1.0000	Z 1.0000
Y	987.3000	Y 537.9100
X	537.9100	X 987.3000

Try it now:

<u>Keystroke</u>	<u>Display</u>
X↔Y	987.3000

Clearing the Stack

CLST (clear stack) clears the X-, Y-, Z-, and T-registers. CLST can be executed from the display or assigned to a key.

One-number Functions and the Stack

One-number functions operate on the number in the X-register only. Examples of these are $1/x$, x^2 , and LOG. The contents of the Y-, Z-, and T-registers are not affected when a one-number function is executed.

Two-number Functions and the Stack

Two-number functions operate on the X- and Y-registers only. Examples of these are $+$, \div , and y^x . The HP-41 performs arithmetic operations by positioning the numbers in the stack the same way as would be done on paper. For instance, if 17 and 46 are to be added together, 17 is written on paper and then 46 is written underneath it like this,

$$\begin{array}{r} 17 \\ + 46 \\ \hline \end{array}$$

And then added like this,

$$\begin{array}{r} 17 \\ + 46 \\ \hline 63 \end{array}$$

The numbers are positioned the same way in the calculator, as shown here:

<u>Keystroke</u>	<u>Display</u>	
SHIFT CLX	0.0000	Clear the display (X-register).
17	17 _	17 is keyed into the X-register.
ENTER	17.0000	17 is copied from X- into Y-.
46	46 _	46 writes over 17 in the display (X-register).
+	63.0000	The result is in the X- and therefore, displayed.

Both numbers are always positioned in the calculator in the natural order first. Then the operation is executed. There is no exception to this rule. Subtraction, multiplication, and division are examples that work the same way. In each case, both numbers must be in the proper registers before the operation can be performed.

Chain Operations

Automatic movements by the stack add to the computing efficiency and ease of use of RPN. These movements automatically store intermediate results. The stack automatically "lifts" every calculated number in the stack when a new number is keyed in. The calculator knows that after it completes a calculation, any new digits that are keyed in are part of a new number. Also, the stack automatically "drops" numbers into position when two-number operations are performed.

To see how this works, solve $21 + 38 + 19 + 53 = ?$

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Keystroke	Display	
XEQ ALPHA C,L,S,T ALPHA	XEQ — XEQ — XEQ CLST — 0.0000	Clear the X-, Y-, Z-, and T-registers.
21	T 0.0000 Z 0.0000 Y 0.0000 X 21—	21 is keyed in. (Displayed)
ENTER	T 0.0000 Z 0.0000 Y 21.0000 X 21.0000	21 is copied into Y-. (Displayed)
38	T 0.0000 Z 0.0000 Y 21.0000 X 38—	38 is keyed in. (Displayed)

Keystroke	Display	
+	T 0.0000 Z 0.0000 Y 0.0000 X 59.0000	38 and 21 are added together. (Displayed)
19	T 0.0000 Z 0.0000 Y 59.0000 X 19—	19 is keyed in and 59 is automatically raised into Y-. (Displayed)
+	T 0.0000 Z 0.0000 Y 0.0000 X 78.0000	59 and 19 are added together. (Displayed)
53	T 0.0000 Z 0.0000 Y 78.0000 X 53—	53 is keyed in and 78 is automatically raised into Y-. (Displayed)
+	T 0.0000 Z 0.0000 Y 0.0000 X 131.0000	78 and 53 are added together. (Displayed)

Because operations are performed when functions are pressed, the length of such chain problems is unlimited unless a number in one of the stack registers exceeds the range of the calculator ($\pm 9.999999999 99$).

In addition to the automatic stack lift after a calculation, the stack automatically drops during calculations involving both the X- and Y-registers. It happened in the above example, but the problem will now be executed differently to see this feature more clearly:

<u>Keystroke</u>	<u>Display</u>	
XEQ	XEQ _	Clear the X-, Y-, Z-, and T-registers.
ALPHA	XEQ _	
C,L,S,T	XEQ CLST _	
ALPHA	0.0000	
21 ENTER	21.0000	The numbers are first placed into the stack (maximum of 4 at a time).
38 ENTER	38.0000	
19 ENTER	19.0000	
53	53 _	
	T 21.0000	This is how the stack first looks. (Displayed)
	Z 38.0000	
	Y 19.0000	
	53 _	
+	T 21.0000	19 and 53 are added together and the rest of the stack drops. 21 into Z- and duplicated in T-. 38 and 72 are ready to be added.
	Z 21.0000	
	Y 38.0000	
	X 72.0000	
+	T 21.0000	38 and 72 are added together and the stack drops again. Now 21 and 110 are ready to be added.
	Z 21.0000	
	Y 21.0000	
	X 110.000	
+	T 21.0000	21 and 110 are added together for the final answer and the stack continues to drop.
	Z 21.0000	
	Y 21.0000	
	X 131.000	

Notice that when the stack drops during calculations involving the X- and Y-registers, the contents of the T-register will remain unchanged.

Order of Execution

Let us look at the following example,

$$\{37 \times [(5 \div 18) + (5 \times .13)]\} \div 3.87$$

By starting at the innermost set of parentheses and working outward, just as would be done with a pencil and paper, the power and efficiency of the HP-41 calculator and RPN logic is maximized.

So, to execute this statement,

<u>Keystroke</u>	<u>Display</u>	
5 ENTER	5.0000	
18 ÷	0.2778	Result of 5 ÷ 18
5 ENTER	5.0000	
.13 ×	0.6500	Result of 5 × .13
+	0.9278	Result of (5 ÷ 18) + (5 × .13)
37 ×	34.3278	Result of 37 × (5 ÷ 18) + (5 × .13)
3.87 ÷	8.8702	Result of {37 × [(5 ÷ 18) + (5 × .13)]} ÷ 3.87

Here are the X-, Y-, Z-, and T-registers after each of the above steps have been executed. Assume the stack is initially cleared.

	5	ENTER	18	÷	5	ENTER	.13	×	+	37	×	3.87	÷
T:	0	0	0	0	0	0	0	0	0	0	0	0	0
Z:	0	0	0	0	0	0.2778	0.2778	0	0	0	0	0	0
Y:	0	5	5	0	0.2778	5	5	0.2778	0	0.9278	0	34.3278	0
X:	5	5	18	0.2778	5	5	0.13	0.6500	0.9278	37	34.3278	3.87	8.8702

Appendix B: HP-41 Maintenance and Service

Calculator Care

The HP-41 needs virtually no attention to ensure proper operation. The only requirements are as follows:

- Replace the batteries when the BAT annunciator appears in the display.
- Make sure a cap is kept on any port which is not being used. The cap prevents the contacts inside the port from becoming contaminated, which can lead to improper operation. Also, fingers or other foreign objects can alter the continuous memory or damage the port if placed inside.

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Temperature Specifications

Operating:	32 °F to 113 °F	(0 °C to 45 °C)
Storage:	-4 °F to 149 °F	(-20 °C to 65 °C)

Plug-in Extensions

All plug-in extensions should be handled with care.

- Keep the contact area free of obstructions. Should the contacts become dirty, carefully brush or blow the dirt out of the contact area. Do not use any liquid to clean the contacts or extensions.
- Store the plug-in extensions in a clean dry place. Do not place extensions in a clothes pocket unless

they are protected in their case. They could be damaged by static electricity.

- Always turn the HP-41 off before inserting or removing a plug-in extension. Failure to do so could damage both the calculator and extension.

Battery Replacement

The continuous memory of the HP-41 will normally be maintained for about 30 to 60 seconds after the batteries have been removed, provided the calculator was turned off beforehand. This should give ample time to install new ones. To replace the batteries, follow the steps below.

- 1) Turn off the calculator.
- 2) Turn the calculator over and push the lip on the battery holder toward the I/O ports. The other end of the battery pack should pop out.
- 3) Remove the batteries from the battery holder.
- 4) Look at the polarity marks on the end of the battery holder. The + and - on the battery should match the marks on the holder. Insert new batteries and carefully note the position of each battery. If any of the batteries are inserted incorrectly, the calculator will not turn on.
- 5) Insert the battery holder into the calculator such that the exposed ends of the batteries are pointing toward the I/O ports.

- 6) Push the upper edge of the battery holder into the calculator as far as it will go, then snap the lower edge of the holder into place.

If batteries are low, but immediate battery replacement is not desirable, the calculator operating time may be extended by disconnecting a peripheral. Before doing so, however, turn off power to the calculator and peripheral.

Recovery After Power Disruption

The HP-41 continuous memory circuits operate continuously – even while the calculator is turned off. Because these circuits constantly draw very low power from the batteries, they are susceptible to disruption at all times. Disruption can be caused by: inserting or removing plug-in modules or peripherals while the power is turned on, electrostatic discharge to the unit, strong magnetic fields, plugging devices into the HP-41 that are not supported by Hewlett-Packard for use with the HP-41, or other conditions that can traumatize the calculator.

Of course, all causes of disruption should be avoided. But if disruption does occur, the most common symptom is loss of keyboard control. The HP-41 has been designed to allow recovery from this condition. The procedure for resetting the calculator is to remove the battery pack, then put it back in immediately. This will reset the HP-41 without causing a memory-lost condition, unless the trauma itself was great enough to cause a memory-lost condition. Follow this procedure several times. If no response is seen, then proceed through the checklist below until recovery occurs.

- 1) Ensure that the batteries are fresh, are properly installed, and that battery contacts are not dirty.

- 2) Turn the calculator off, then back on.
- 3) While holding down the ← key, press the ON button, then release both keys. This is a “master clear” for the entire calculator.
- 4) Remove the batteries and let the continuous memory in the calculator discharge overnight. If the calculator has been cleared after the batteries are reinstalled and the HP-41 turned back on, then the display should read MEMORY LOST.
- 5) If the calculator still does not respond, service is required.

Appendix C: HP-41 Troubleshooting

	<u>Problem</u>	<u>Cause</u>	<u>Solution</u>
	1. Turn on the HP-41 and it remains blank.	Batteries are not installed properly or they are bad.	Refer to appendix B (under Battery Replacement) for installation and replacement.
	2. Loss of keyboard control.	The HP-41 possibly suffered an electrostatic disruption.	Refer to appendix B (under Recovery After Power Disruption) for steps to regain keyboard control.
	3. MEMORY LOST is displayed when the HP-41 is turned on.	All programs and data have been cleared.	Reload programs into the HP-41.
35	4. Reassigned keys do not function like they should.	The HP-41 is not in user mode.	Press the user mode key. The USER annunciator should appear in the display.
	5. NONEXISTENT appears when one of the program-assigned keys is pressed.	A module is not making contact or the program has bombed.	Check that all the modules are securely installed. If the problem still exists, the program should be reloaded.
	6. DATA ERROR appears in display and the program stops executing.	The HP-41 attempted an illegal operation. Data registers have been written over or bad data was entered.	Re-enter data and try again. If message repeats, the program should be reloaded.
	7. Program solutions do not look right.	Data registers have been written over or bad data was entered.	Re-enter data and try again. If problem persists, the program should be reloaded.

Appendix D: HP-41 Error and Status Messages

When an illegal operation is attempted on the HP-41, the operation is not performed and an error/status message appears on the display. To clear the display, press \leftarrow . If the error was caused during a running program, switching the calculator to program mode will display the program line that attempted the meaningless operation.











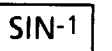

The following is a description of all error messages that might be seen on the HP-41 alphanumeric display.

<u>Display</u>	<u>Meaning</u>
ALPHA DATA	The HP-41 attempted to perform a numeric operation, such as addition or subtraction, on non-numeric data such as an Alpha string.
DATA ERROR	The HP-41 attempted to perform an illegal operation. For example, an attempt was made to execute $1/x$ where $x = 0$, or $\log x$ where $x \leq 0$.
MEMORY LOST	The continuous memory of the calculator has been cleared.
NONEXISTENT	The HP-41 has attempted to use a storage register that does not exist or is not currently allocated as a storage register. For example, an attempt was made to XEQ a function that does not exist.
NULL	Keystroke was nullified by holding the key down for longer than about a second.
OUT OF RANGE	A number has exceeded the computational or storage capability of the HP-41. The overflow limit is $\pm 9.99999999 99$.

Appendix E: HP-41 Function Index

The first column below shows the functions that can be executed by typing in characters to the HP-41. To execute the function from the display, press XEQ, ALPHA, the characters shown, then ALPHA again. The second column gives the equivalent key(s) that may be pressed to execute the function. The description column explains each function. Unless otherwise noted, all functions can be executed from the display and reassigned to other keys.

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<u>Function</u>		<u>Description</u>
<u>Display Execution</u>	<u>Keyboard Execution</u>	
		Shift key. Not assignable.
+		Addition operator.
-		Subtraction operator.
*		Multiplication operator.
/		Division operator.
1/X		Reciprocal.
10↑X		Common antilogarithm.
ABS		Absolute value.
ACOS		Arc cosine.
AON/AOFF		Alpha mode on/off. Not assignable.
ARCL		Alpha storage register recall. Function unique to the alpha mode. Requires a 2-digit, a stack indirect 2-digit, or an indirect stack address.
ASHF		Alpha shift left.
ASIN		Arc sine.
ASN		Assign. Requires function name and key location input.

<u>Function</u>		
<u>Display Execution</u>	<u>Keyboard Execution</u>	<u>Description</u>
ASTO	ASTO	Alpha store. Function unique to the alpha mode. Requires a 2-digit, a stack, an indirect 2-digit, or an indirect stack address.
ATAN	TAN ⁻¹	Arc tangent.
BEEP	BEEP	Preprogrammed multiple tone keeper.
CAT	CATALOG	Catalog list. Requires a 1-number input, or indirect address.
CHS	CHS	Change sign.
CLA	CLA	Clear alpha register. Function unique to the alpha mode.
CLD		Clear display.
CLRG		Clear all storage registers.
CLΣ	CLΣ	Clear statistics registers.
CLST		Clear automatic memory stack.
CLX	CLx/A	Clear X-register (numeric display).
	←	Correction key. Not assignable.
COS	COS	Cosine.
D-R		Degree to radians conversion.
DEC		Octal to decimal conversion.
DEG		Degrees mode.
	EEX	Enter Exponent.
ENG	ENG	Engineering notation display. Requires a 1-digit, an indirect, a 2-digit, or an indirect stack address.

<u>Function</u>		
<u>Display Execution</u>	<u>Keyboard Execution</u>	<u>Description</u>
ENTER	ENTER ↑	Enter number that is in the X-register into the Y-register.
E ↑ X	ex	Natural antilogarithm.
E ↑ X - 1		Natural antilogarithm for arguments close to zero.
FACT		Factorial.
FIX	FIX	Fix point display. Requires a 1-digit, an indirect 2-digit, or an indirect stack address.
FRC		Fractional portion of number.
GRAD		Gradian mode.
HMS		Decimal hours converted to hours, minutes, and seconds.
HMS +		Hours, minutes, seconds addition.
HMS -		Hours, minutes, seconds subtraction.
HR		Hours, minutes, and seconds converted to decimal hours.
INT		Integer portion of number.
LASTX	LASTx	Recalls the previous X-register contents to the X-register.
LN	LN	Natural logarithm.
LN1 + X		Natural logarithm for arguments close to one.
LOG	LOG	Common logarithm.
MEAN		Mean.
MOD		Module (remainder) operator.
OCT		Decimal to octal conversion.

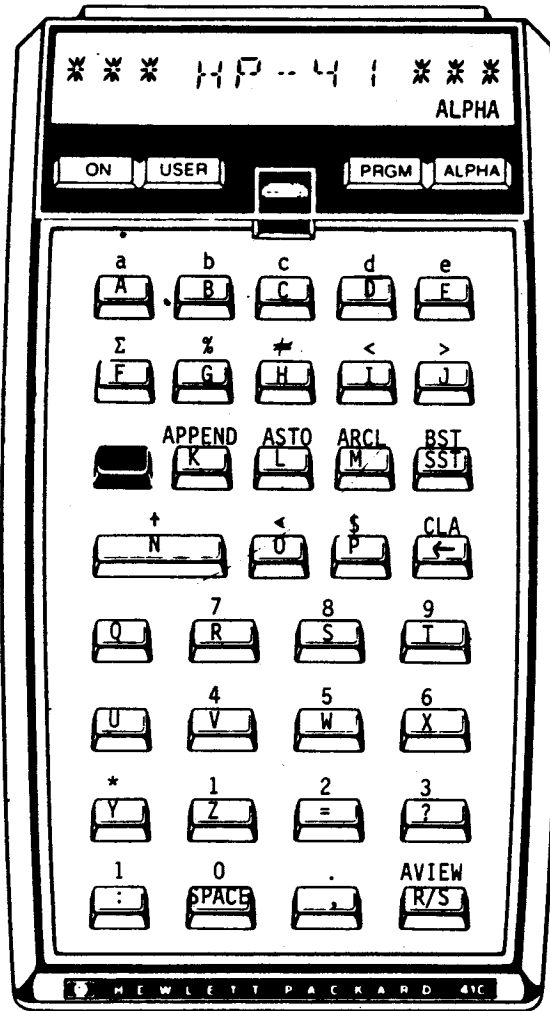
<u>Function</u>		<u>Description</u>
<u>Display Execution</u>	<u>Keyboard Execution</u>	
OFF		Calculator power off.
	<input type="button" value="ON"/>	Power on/off key. Not assignable.
ON		Power on (continuous).
P-R	<input type="button" value="P-R"/>	Polar to rectangular conversion.
%	<input type="button" value="%"/>	Percent
%CH		Percent of change.
PI	<input type="button" value="π"/>	Pi.
	<input type="button" value="PRGM"/>	Switching in and out of program mode.
R ↑		Roll up stack.
R-D		Radians to degrees conversion.
R-P	<input type="button" value="R-P"/>	Rectangular to Polar conversion.
	<input type="button" value="R/S"/>	Run/Stop. Stops a running program or starts a stopped program
RAD		Radians mode.
RCL	<input type="button" value="RCL"/>	Recall storage register. Requires a 2-digit, a stack, an indirect 2-digit, or an indirect stack address.
RDN	<input type="button" value="R↓"/>	Roll the stack down.
RND		Round.
SCI	<input type="button" value="SCI"/>	Scientific notation display. Requires a 1-digit, an indirect 2-digit, or an indirect stack address.
SDEV		Standard deviation.

	<u>Function</u>		<u>Description</u>
	<u>Display Execution</u>	<u>Keyboard Execution</u>	
	$\Sigma +$	$\Sigma +$	Accumulations for statistics.
	$\Sigma -$	$\Sigma -$	Accumulation correction.
	Σ REG		Statistical register block specification. Requires a 2-digit, an indirect 2-digit, or an indirect stack address.
	SIGN		Sign of x.
	SIN	SIN	Sine.
	SQRT	\sqrt{x}	Square root.
41	ST +	STO +	Storage register addition. Requires a 2-digit, a stack, an indirect 2-digit, or an indirect stack address.
	ST -	STO -	Storage register subtraction. Requires a 2-digit, a stack, an indirect 2-digit, or an indirect stack address.
	ST*	STO x	Storage register multiplication. Requires a 2-digit, a stack, an indirect 2-digit, or an indirect stack address.
	ST/	STO \div	Storage register division. Requires a 2-digit, a stack, an indirect 2-digit, or an indirect stack address.
	STO	STO	Store. Requires a 2-digit, a stack, an indirect 2-digit, or an indirect stack address.
	STOP	R/S	Stops program execution.
	TAN	TAN	Tangent.
	TONE		Tone. Requires a 2-digit, an indirect 2-digit, or an indirect stack address.
		USER	User mode key. Not assignable.

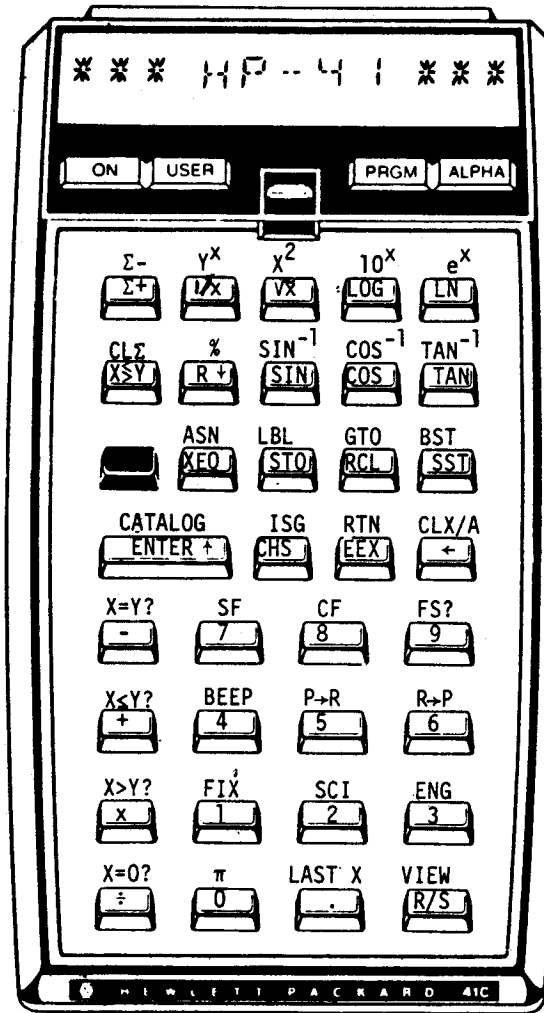
<u>Function</u>		<u>Description</u>
<u>Display Execution</u>	<u>Keyboard Execution</u>	
VIEW	VIEW	View register contents. Requires a 2-digit, a stack, an indirect 2-digit, or an indirect stack address.
XEQ	XEQ	Execute. Requires a function name or an indirect address.
X ↑ 2	x ²	Square.
Y ↑ X	y ^x	Exponential.

Appendix F: HP-41 Calculator

Alpha Mode Keyboard

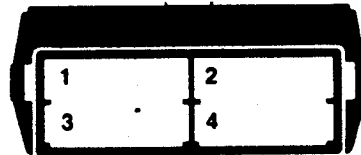


Normal Mode Keyboard

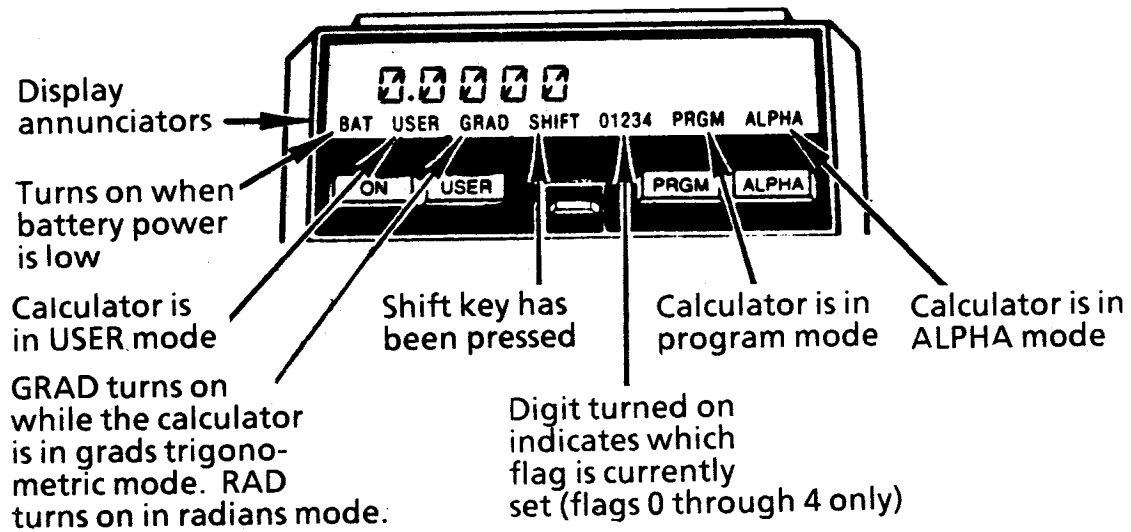


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Input/Output Port Locations



Annunciators



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End

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