PROGRAM DESCRIPTION I

Program Title SMOOTH

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Program Description, Equations, Variables

See the attached documentation for a description. The table of contents appears together with a summary on page 6 of the documentation.

Necessary Accessories 41 CV or quad memory module. Printer and card reader highly recommended.

Operating Limits and Warnings See program notes on page 38.

Reference(s) See references on page 7.

This program has been verified only with respect to the numerical example given in *Program Description II*. User accepts and uses this program material AT HIS OWN RISK, in reliance solely upon his own inspection of the program material and without reliance upon any representation or description concerning the program material.

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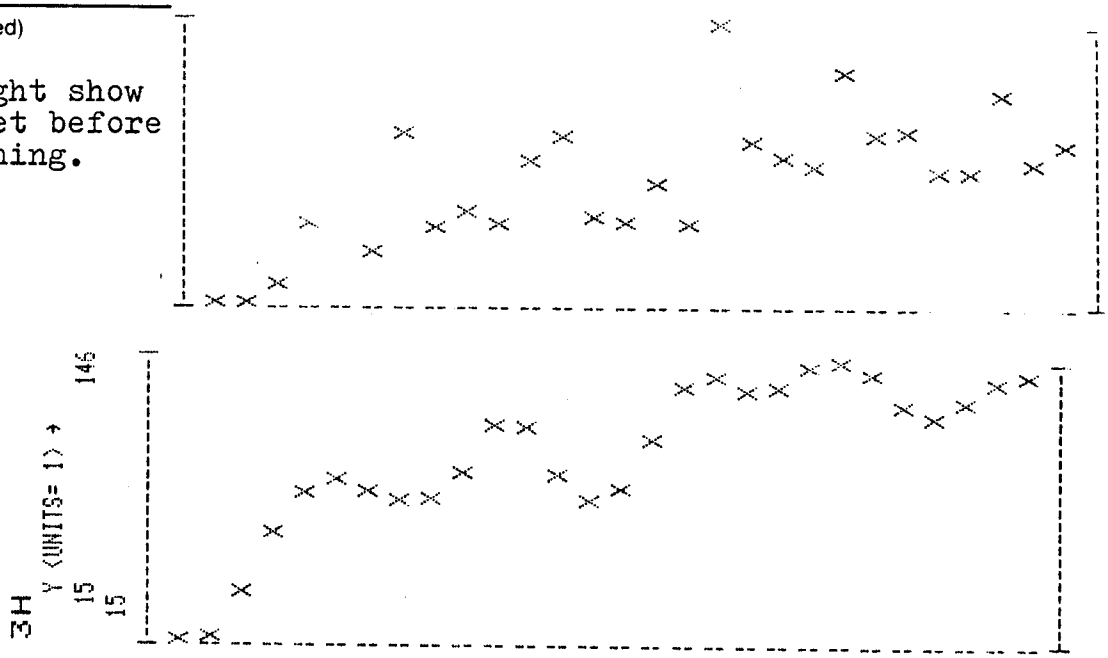
Sample Problem (Sketch if Desired)

The plots at right show a sample data set before and after smoothing.



SOLUTION:

Input	Function	Display	Comments
The sample problem above is given on pages 22-26.			

USER INSTRUCTIONS

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SIZE: (HP-41C) 136

STEP	INSTRUCTIONS	INPUT	FUNCTION	DISPLAY
	User instructions are in the attached documentation, beginning on page 14.			

REGISTERS, STATUS, FLAGS, ASSIGNMENTS

DATA REGISTERS

See pages 39-40.

STATUS

SIZE	136	TOT. REG.	319	USER MODE	
ENG		FIX	X	ON X	OFF
DEG		RAD	GRAD		

FLAGS

#	INIT S/C	SET INDICATES	CLEAR INDICATES

See pages 41-42 for a list of flags and their uses.

ASSIGNMENTS

FUNCTION	KEY	FUNCTION	KEY

None.

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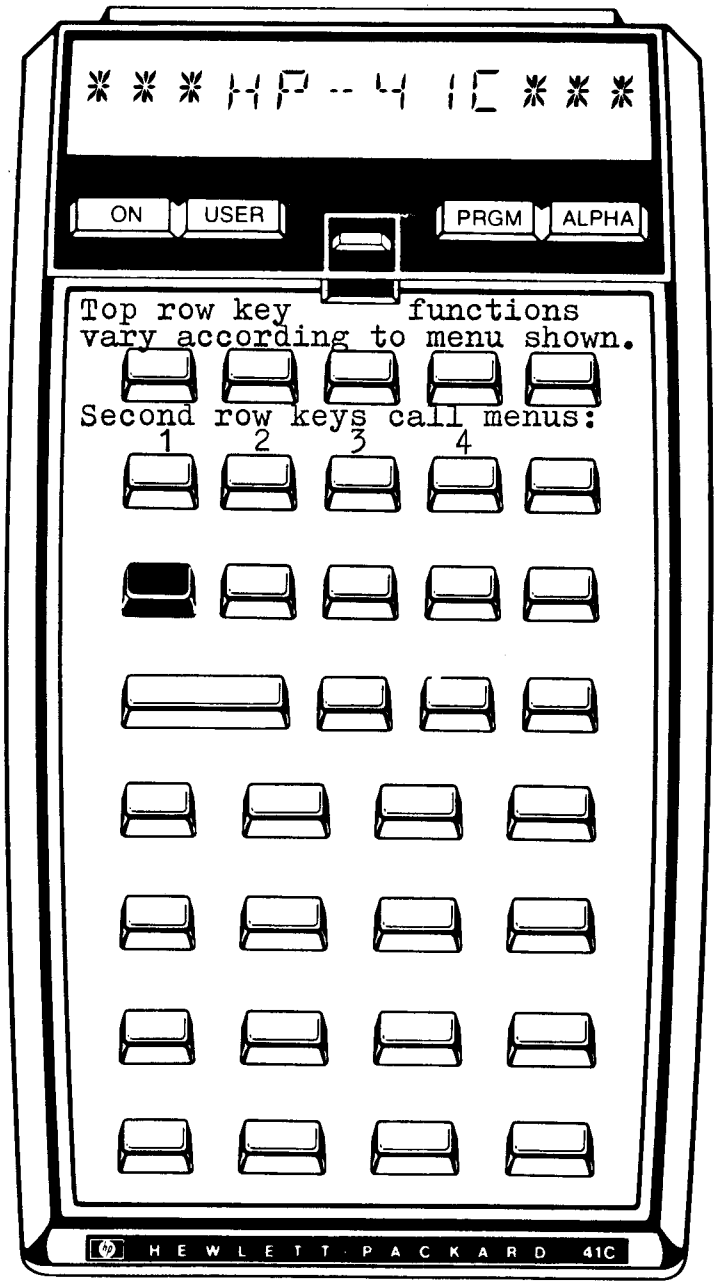
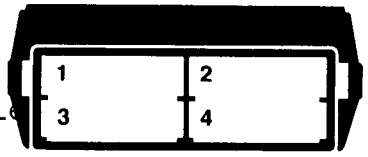
KEYBOARD CARD LABELING

KEYBOARD



SYSTEM CONFIGURATION

41CV or quad module needed



CARD

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SMOOTH

SMOOTH is a coordinated set of programs which together perform a variety of data smoothing operations. Four menus allow the user to call any of 24 operations. The menus may be deleted for added data storage and any of the programs may be executed by an XEQ statement. Furthermore, to perform a sequence of consecutive operations, such as several smoothing and printing routines, the user can set up a Batch Mode to execute a succession of programs without user intervention. I/O, limited file handling, and utility programs are included to increase the versatility of the basic smoothing programs. Application areas include virtually all enterprises which use quantitative data. Examples here are drawn from meteorology, economics, and veterinary science.

The following documentation is divided into seven sections:

For an introductory example, see page pages 22-26

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I. Introduction to Data Smoothing

A. The need for data smoothing

Data smoothing is a technique often applied to time series data to remove short term fluctuations in the data and so to allow longer term trends to become evident. While its use is not restricted to time series data, it is most relevant when the variable along the X axis increases in equal steps and a single value of a Y variable is associated with each X value. Obviously, time series data fit those specifications very well, regardless of whether the time increments are microseconds or years. The general idea which governs data smoothing is that long term trends affect adjacent or vicinal data points similarly, while events and influences unrelated to longer trends affect data points independently of each other. Most smoothing techniques use values adjacent to the value which is being smoothed in order to estimate what the value might have been if it had not been subject to influences (i.e. noise) other than the influences of the long term trend.

This documentation is not intended to present the topic of data smooothing to one unfamiliar with it. The programs are intended to be used with either of two excellent books on the subject. While the documentation will, to some extent, make it possible to use the programs without the books, the program author strongly recommends either or both of the following books. The first is somewhat more technical and complete, the second is somewhat briefer and less demanding.

Tukey, John. Exploratory Data Analysis, Addison-Wesley Publishing Company, Reading, Massachusetts, 1977.

Velleman, Paul F. and Hoaglin, David C. Applications, Basics, and Computing of Exploratory Data Analysis. Duxbury Press, Boston, Massachusetts, 1981.

B. Varieties of smoothers

Many different methods of data smoothing are available. The program package SMOOTH has includes six basic smoothing operations and several support routines. Combinations and variations raise the total of callable smoothers to nine. The references given above describe the methods in detail, explain how to judge when each may be useful, and give details on the rationale of the methods.

One commonly used smoothing technique is to take the moving

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median of a set of data points centered about the point being smoothed. Clearly, medians of three and five are simple to compute -- the sample of three or five points is centered on the point in question, and the median is found. The programs "3" and "5" find moving medians of span three and five. Moving medians of span four are trickier. For each point to be smoothed, two medians of span four are found, one span includes the point in question as its second serial value of the four, and the other span includes the point as its third value. The mean of those two values is then the smoothed value. The program "42" accomplishes such smoothing.

Another smoothing technique, Hanning, is based not on medians, but on weighted means. Each smoothed value is equal to one fourth of the sum of twice the unsmoothed point, the preceding point, and the following point. The program "H" Hanns the data. A similar technique, also based on means, involves replacing each value with the mean ofthe two flanking values. Tukey refers to that process as taking "skip means;" following his nomenclature, the symbol ">" indicates skip means.

Smoothing with "3" often leaves high spots and low spots exactly two points wide in the processed data. The program "SP" splits such points apart, treats each as an end value of a sequence, and so makes a smoother finished data set.

One rarely applies only one smoother to a data set, although occasionally one does suffice. It is more common to apply one or more smoothers repeatedly or in combination until the data are so smooth that the trends are readily evident. For example, the smoother "3" may be applied repeatedly until there is no further change, then "SP" may be applied to remove high and low spots, and finally "3" may be used again to smooth the results of the splitting. When a technique is applied repeatedly until there is no further change, its description is given by the name of the technique followed by "R," for repeated. Thus "3R" indicates that "3" is repeatedly applied until there is no further change as a result of applications.

When a series of smoothers is used, one describes the series with a character string composed of a concatenation of the descriptors of the individual smoothers. Thus, "3RS3RH" indicates repeated smoothing with "3," splitting, a second repeated application of "3," and finally an application of Hanning. SMOOTH keeps a running record of up to twelve characters to summarize the smoothing operations performed on any data set. That record is printed whenever output is

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specified.

Occasionally, even such compound smoothers do not suffice to smooth the data. It may be necessary to subtract the smoothed data from the original data, thus obtaining the "rough." The rough is then smoothed and added back to the original smooth. Such a technique is called reroughing, and is treated in the references above. SMOOTH contains data manipulation utilities to make such complex smoothing operations reasonably easy. The examples (section IV) include a suggested sequence for the use of the utilities in reroughing.

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II. Program and data organization

A. Memory structure

The data storage registers used by SMOOTH can be divided into three sections. Registers ØØ through 15 are used for pointers, printing and plotting routine requirements, scratch storage, the record of smoothers used, and descriptors of the data set. The remaining registers (12Ø additional registers in the unaltered version of SMOOTH) are divided into Bank 1 and Bank 2. All smoothing operations and most utility operations take as their input data the values in Bank 1. The smoothed output is placed in Bank 1 while the unsmoothed original data are placed in Bank 2. The prior contents of Bank 2 are lost. Therefore, following any given smoothing operation the banks are set for another operation. Furthermore, if the smoothing operation is found not to have had the desired effect, and the user wishes to restore the data from its effects, it is necessary only to switch banks to recover the data. A bank-switching program, "SW," accomplishes the change. That fundamental rule, that data are smoothed from Bank 1 back to Bank 1, with the original data ending up in Bank 2, is essential to the understanding of the flow of data in SMOOTH.

Bank 1 always starts its storage in register 16. Bank 2 starts in register 16 + N, where N is the number of data points in the data set. For example, if one is smoothing a set of 4Ø values, Bank 1 will extend from register 16 to 55, inclusive, while Bank 2 will extend from register 56 to 95.

B. I/O routines

SMOOTH has four menus, each of which presents five announced options and one implicit option to the user. The options are selected by means of keys A through E, plus one shifted key. The menus themselves can be called by pressing one of the keys F through I, or one can move from menu to menu by pressing R/S. As explained in section III-D, the menus are a convenience, not necessary to the functioning of the routines. They may be deleted to obtain extra storage space and the programs may be run by XEQ statements.

The first menu, called by pressing F, presents six programs (or program entry points) concerned with data entry and retrieval. The I/O programs all load data into or take it from Bank 1, although the printing program also prints Bank 2.

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Menu 1

Key A, under menu item "I," selects data Input. The program prompts for the number of items, then for the data values, then for information regarding the data set. Control is then returned to the user again at the I/O menu (Menu 1).

Key B selects a Card-reading program designated by the menu letter "C." The program asks how many data values are to be entered, then prompts for the card.

Key C, under the item "PR," PRints the values in Banks 1 and 2, together with the X values which correspond to the Y values in Bank 1. The X values start at whatever value has been provided, and increase by steps of 1. The shifted key "c" will perform the same function except that it will not cause printing of the Bank 2 values. See a full description in section V.

Key D, under the menu item "PL," calls a PLotting program which plots each value in Bank 1 in succession. The full plotting scale is used, so that the smallest and largest values are always plotted at the top and botton of the scale, respectively, even if smoothing has reduced the range of the data values (as it usually does).

Key E, corresponding to menu item "CW," calls a Card Writing program and allows the user to record the data in Bank 1 onto HP magnetic cards.

C. Smoothing routines

The second and third menus, which may be called by keys G and H, are used to call the smoothing routines. The second menu itself may be reached either by pressing key G from any point in the program, or by pressing R/S when Menu 1 is displayed. Each of the routines (except 3R) smooths the data in Bank 1, leaves the result in Bank 1, and places the original data into Bank 2. 3R loses the original data, but it places the smoothed data in Banks 1 and 2.

Menu 2

Key A, under menu item "3," calls the routine which performs smoothing by running medians of span 3.

Key B, corresponding to menu item "42," calls the program which performs smoothing first by running medians of 4, then recenters by running means of 2.

Key C, under "5," calls the program which smooths by runnning medians of span 5.

Key D, under the menu item "SP," SPlits apart high and low runs of length two. Such splitting is typically followed by smoothing with repeated medians of span 3 (see references), hence key d (shifted D) is provided to perform the splitting and the smoothing by 3R as one operation. Note in this case, however, that following the completion of operations Bank 2 will contain not the original data, but rather a copy of the data in Bank 1. (See section V for the reason for that.)

Key E, corresponding to menu item "H," calls the program which smooths the data by Hanning them.

Menu 3

Key A, corresponding to menu item 3R, smooths the data repeatedly by application of "3" until there is no further change in the data. Note that this program does not leave the original data in Bank 2, but leaves the smoothed data in both banks.

Key B, corresponding to menu item ">," smooths the data by applying skip means, so that each value is replaced by the mean of the adjacent values.

Key E, corresponding to menu item "EV," smooths the data set's two End Values according to the process described in section V.

D. Utilities.

Menus 3 and 4, callable by keys H and I, respectively, are used to call various utilities. Menu 3, as mentioned above, also calls some of the smoothing programs.

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Menu 3

Key C, under menu item "B," calls a Batch program which will execute a number of the smoothing programs in succession so that a compound smoothing sequence can be carried out without user intervention. Smoothing large data sets is time consuming; the batch mode can be a major convenience.

Key D, under menu item "R," Reviews, by displaying or printing, a summary of the smoothing operations which have been executed since registers 14 and 15 were cleared. Shifted D, or d, clears the two summary registers.

Menu 4

Key A, under the menu item "SW," calls a program which SWitches or interchanges the data between Banks 1 and 2.

Key B, under "CP," calls a program which CoPies the contents of Bank 1 into Bank 2. Key b (shifted B) clears Bank 2.

Key C, under menu item "+," adds the contents of Bank 2 to the contents of Bank 1 and places the result in Bank 1, leaving Bank 2 unchanged.

Key D, under "-," subtracts the contents of Bank 2 from the contents of Bank 1 and places the results in Bank 1, leaving Bank 2 unchanged. Keys C and D are used for compound smoothers which involve such processes as reroughing.

Key E, under "T," calls a program which Transforms the data in Bank 1 according to a program furnished by the user. The untransformed data are left in Bank 2.

E. Operating modes

Smooth may be operated in any of three modes. The first mode, Menu Mode, is the default mode, and is used for most operations. In Menu Mode all of the operations are selected by pressing menu keys. In Direct Execution Mode, exactly the same programs are available, but they are executed by means of XEQ statements. In Direct Execution Mode the menus are typically deleted for extra data space. Finally, there is a Batch Mode which allows successive execution of several smoothing programs.

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III. User Instructions

These instructions are prepared under the assumption that the user will be operating the program in Menu Mode, in which each program is called from a menu. When in Menu Mode the user can move about from menu to menu in either of two ways. The keys F, G, H, and I will call Menus 1, 2, 3, and 4 respectively. It is also possible to advance to the following menu, or from Menu 4 to Menu 1, by pressing R/S when any menu is displayed.

If the user is in Direct Execution Mode, when each program is called by an XEQ statement, then much of the information here still applies, but the actual method of initiating the program actions is different. The use of the Direct Execution Mode allows the user to delete the menus and so increase the storage space available for data to 80 locations per bank instead of 60. See section III-D for details on Direct Execution mode.

A. Loading and Starting Smooth

Perform master clear if all memory is to be used for smoothing, set the size equal to or smaller than 136, and then read the twelve program sides into the card reader. Pack and resize, if necessary, to 136. The only global label in the program is the initial label, "S," therefore the program can always be started or restarted by "Exec S." The program willdisplay Menu 1. Whenever restarting Smooth, as for a new data set, flags 0-4 must be cleared. Set USER mode.

B. Input and Output

1. Input.

Data are entered into Bank 1 only. If the data are required in Bank 2, then they may be moved using one of the utility programs, Switch or Copy. Data may be entered in either of two ways, manually or from a magnetic card. In order to enter data, go to Menu 1. The program SMOOTH automatically starts by going to Menu 1, but Menu 1 can also be reached by pressing key F or by repeatedly pressing key R/S when in any of the other menus.

Manual Data Entry

When in Menu 1, press A, under program "I," to enter data by hand. The display will show "N=?" In response, enter the number of data points in the sequence to be smoothed and press R/S. The display will then show "Y1=?" Enter the first datum and press R/S. The display will continue to

prompt for successive data values until all have been entered. If two successive values are the same, it is not necessary to enter the value a second time. Simply pressing R/S will enter the same value as was just entered.

If an error is made in entering data it must be manually corrected following data entry; there is no routine to remove incorrect data. When an error is made, continue entering the rest of the data, then correct it. If it is necessary to correct the data, note that each value is entered into a register which is equal to the ordinal position of the data point plus 15. Thus, for example, the tenth datum is to be found in register 25. The easiest way to correct an incorrect entry is to enter first the ordinal number of the incorrect entry (e.g. if the eleventh value is incorrect, enter 11), then 15, +, then the correct value, and finally Store Indirect Y.

When all of the data have been entered, the display will prompt with "X1=?" Enter the first X value and press R/S. The X values are those to which the Y values (the data to be smoothed) correspond. In most cases, the first X value will be 1, but in some cases it may be a given year, or some other initial time period. For example, if one were smoothing meteorological data for the years 1900 to 1950, the initial x value would be 1900. The display will then prompt "Y FIX=?" Enter the number of digits to be displayed after the decimal point when the data in banks one and two are printed out, and press R/S. The program then returns to Menu 1. (It is advisable at this time to record the data on a card by means of the Card Write program, especially if it is a large data set. See below on Card Writing.)

Magnetic Card Data Entry

To enter data from previously recorded magnetic cards, go to Menu 1 and press key B. As in the manual data entry routine, the HP-41C will prompt for the number of data values. It will then prompt for a card, and will continue the prompts until all cards have been read. It then, as in the manual entry mode, prompts for the first X value and the number of digits to the right of the decimal point when when the data are printed out.

Notes

1. CAUTION. Inadvertent operation of I (Input) or C (card input) will cause a loss of, at a minimum, the contents of the review registers. If you press either key accidentally, press one of the menu keys (F through I) when the first

prompt occurs. That will limit the damage to the loss of the review, or summary registers, 14 and 15.

2. Both of the input programs, I and C, clear registers 14 and 15, the registers that maintain the record of the smoothing operations performed. Those registers will contain empty alpha strings, not zeros. In order for one of the tests for the end of the data registers to funtion correctly, register 15 must contain alpha data. Do not change the contents of that register.

3. The values of X will increase by 1 with each line when the data are printed out. If some other increment is desired, change line 70 of the program from 1 to the desired increment value. If, for example, data are available for some phenomenon only every other year, line 70 would be changed to 2. It is also assumed that the user will want the X values to be printed out with no places to the right of the decimal point, or in FIX 0 format. If that is not the case, change line 63 of the program accordingly.

2. Output

Printing or Displaying Data

In order to print out the contents of Banks 1 and 2, press key C, under "PR" on the Menu 1. The values of X (i.e. the values to which the values in Bank 1 correspond), the values of the data in Bank 1, and those of the data in Bank 2 will all be printed if there is a printer available, and will be displayed if there is no printer. Before the data are printed or displayed, the contents of registers 14 and 15 are displayed or printed. Those registers contain a running record (up to twelve characters) of the smoothing operations which have been performed. If there is no printer, then the 41-C will stop when each value is displayed and will await the pressing of R/S before going on to the next value. When all values have been printed or shown, the program returns to Menu 1.

To print only the contents of Bank 1 and the X values, then press shifted key C, or c. The printing of Bank 2 will thereby be surpressed.

Data Plotting

Press key D in Menu 1 to plot the values in Bank 1 as a function of evenly spaced intervals on the X axis. There are no options or prompting available for this program. The full range of the printer's plotting axis is used -- the smallest value in Bank 1 is plotted at the bottom of the

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axis, and the largest is plotted at the top.
The printer's default plotting character, the small x, is used to show the points. Some other character may be preferable, such as the large X used in the accompanying examples. To load the large X, execute the following steps when the printer is attached to the 41-C. (See pages 64-66 in 82143A Printer Owner's Handbook).

```
Ø
Enter
65
BLDSPEC
34
BLDSPEC
2Ø
BLDSPEC
8
BLDSPEC
2Ø
BLDSPEC
34
BLDSPEC
65
BLDSPEC
ACSPEC
Store Ø3
```

The large X (or other character) will be kept in register 3 until that is changed manually. No other program in SMOOTH uses register 3, although it is available for use as part of a transformation program written by the user.

PL returns control to Menu 1.

Card Writing

To write a magnetic card of the data in Bank 1, press key E in Menu 1 to call program "CW," or Card Write. The machine will prompt for as many card sides as are needed to record the entire bank. CW returns control to Menu 1. When finished, it is good practice to verify the cards, but the program does not automatically call VER. VER (or any other program) may be called from any menu by the usual XEQ instruction. XEQ S will return control to Smooth.

Note: When entering data by card it is necessary to specify the number of items to be read from the card(s) in order for the Bank 1 and 2 pointers to be set correctly. Therefore, when writing data to cards it is good practice to indicate on the card the number of values recorded.

C. Data Smoothing

Six of the smoothing programs are called from Menu 2, and three are called from Menu 3. To call any of the smoothing programs simply press the key corresponding to the data smoothing method desired.

Smoothers from Menu 2

Menu 2 allows the user to call any of the five basic smoothing programs described in sections I-B and II-C. Each of the programs 3, 42, 5, SP, and H has its own calling key under its menu entry. It addition, key D may be entered in the shifted mode to provide splitting followed by repeated smoothing by application of "3" until no further change occurs (3R). To use any of these smoothers, press the appropriate key and await the beep and the return of the menu, which indicate that the smoothing operation is complete. As mentioned above, the smoothed data are placed into Bank 1; the data as they were before being smoothed are placed into Bank 2. SP followed by 3R, the combination callable by key d, does not leave the raw data in Bank 2; instead, both banks will contain the smoothed data.

The smoothing programs are time-consuming, especially with large data sets. Therefore program "SW," which interchanges, or switches, the banks, includes a beep instruction at its end. The smoothing programs all call program "SW" at their completion, hence the completion of a smoothing operation will be signaled by a beep. Note, however, that "3R" will beep at every completion of a pass of "3" and so may give premature indications of completion.

Smoothers from Menu 3

To smooth data repeatedly by application of "3" until no further change is found, press key A, under "3R," in Menu 3. As with the simple smoothers the finished data are left in Bank 1, but in contrast to the operation of the simple smoothers, Bank 2 will not contain the data as they were prior to the application of the smoother. (Each simple smoother works in effect from Bank 1 to Bank 2 and then calls "SW" to transpose banks. When more than one smoothing operation is called, as by "3R," the original data are lost as soon as the second run of the program begins to place data into Bank 2.)

To smooth by skip means, press key B, under ">" in Menu 3.

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To smooth the end values, typically done only once per data set, press key E, under menu item "EV," in Menu 3. Note that using EV does not affect the running record of the smoothers that have been applied to the data (registers 14 and 15).

Note

If a key is pressed in error, it is unwise to stop the program and assume that the data registers will be in an interpretable configuration. Once a smoothing operation has started, it is advisable to let it go to completion. If a key is pressed in error, the error may be recovered by using the "SW" program to return the original contents of Bank 1 to that bank following a smoothing operation. That technique will work for any of the five unshifted operations of Menu 2 and for ">" and "EV" in Menu 3, but it will not recover from inadvertant use of the "3R" program. It is advisable to keep card copies of important and/or long data files, partly in order to recover from such accidents.

D. Utilities

Utilities from Menu 3

Press key C, under "B" in Menu 3, to execute a previously arranged batch program.

To arrange a batch submission for SMOOTH, go to line 488 in the program mode, and insert XEQ statements following line 488, prior to the Return instruction. The numeric labels associated with the 24 routines are given in section V. They also appear below on the section on direct execution, and on the user card at the end of the documentation. Note that it will probably be necessary to reduce the number of data registers in order to insert the XEQ instructions into the program. Thus it may be advisable to delete the menus before using Batch Mode. See paragraph E, Direct Execution, of this section for instructions for the Direct Execution mode. Batch Mode will also beep the HP-41C with every completion of Switch, a utility used by every smoother. First clearing Flag 26 and including an SF 26 and BEEP at the end of the smoothers will silence the beep until the end of the batch.

Press Key D, under "R" in Menu 3, to review the smoothing steps taken since the review registers were last cleared. If the printer is connected, the results will be printed, otherwise they will be shown in the display. To clear the review registers, press Shifted D, or d, in Menu 3 to clear

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the registers. Do not store numeric information in the review registers, registers 14 and 15. To do so might cause one of the smoothing programs to malfunction, since it finds the lower end of Bank 1 by testing for alpha data.

Utilities from Menu 4

To interchange the data in the two banks, i.e. switch banks, press key A in Menu 4, under the entry "SW." The contents of the two banks are interchanged and a Beep signals completion of the change. Flag 9 is set if there is any difference in corresponding values in the banks, and is clear otherwise. The flag can be used as a quick check to see if the contents of the two banks are identical. The clear flag is used by "3R" to indicate no change was brought about by the application of "3."

Copying and Clearing.
To copy Bank 1 into Bank 2, press key B, under "CP" in Menu 4.
To clear Bank 2, press shifted key B, or key b.

Adding and Subtracting the Banks.
To add Bank 2 to Bank 1, as one might wish to do when adding a smoothed "rough" to an initial smooth, press key C, under "+" in Menu 4. The sums are placed in Bank 1; the contents of Bank 2 are unchanged.
To subtract Bank 2 from Bank 1, as one might wish to do when computing a "rough," press key D, under "-" in Menu 4. The difference, Bank 1 minus Bank 2, is placed in Bank 1; the contents of Bank 2 are unchanged.

To use any data transformation program which the user cares to supply, press key E in Menu 4, under the Menu entry "T." The user must supply a program labeled "T," which transforms a value in the X register and leaves the result in the same register. The registers Ø to 7 and 14 and 15 are available for use by T. Several of the main programs use DEG as a no-op instruction following an ISG. Therefore, if the transformation program is to use a trig mode other than degrees, it should be specified at the beginning of the program.

E. The Direct Execution Mode

Most of the program details presented throughout this documentation are fully applicable in Direct Execution Mode. The only difference is that in Direct Execution Mode the menus are not used, and are usually deleted to allow more

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data to be stored in the registers. To delete the menu sections, go to line 568 and delete the remainder of the program, by executing DEL Ø89. Then pack, and the program space saved becomes available for data. When SMOOTH is run from its beginning, however, an error message will result from the nonexistence of Label F. The program may still be used in the Direct Execution mode in spite of the error message. Any of the programs labeled from 21 to 44 may be executed. The size may now be set to 176, which allows data sets of up to 8Ø elements.

To use any of the programs in Direct Execution Mode, use XEQ, followed by the number given in the program description section, on the user card, or below. The numbers are the numbers of the labels which begin the programs. All programs end with a Return and so will simply halt upon completion. For example, in Direct Execution Mode, entering XEQ 27 will smooth the data by running medians of span three.

Label	Equivalent menu and key,		program
21	1-A	"I"	Input data by hand
22	1-B	"C"	Card input of data
23	1-C	"PR"	PRint Banks 1 and 2
24	1-c	--	Print Bank 1 only
25	1-D	"PL"	PLot Bank 1
26	1-E	"CW"	Card Write, Bank 1
27	2-A	"3"	Medians of 3
28	2-B	"42"	Medians of 4, then 2
29	2-C	"5"	Medians of 5
3Ø	2-D	"SP"	SPlit highs and lows of length 2
31	2-d	--	Same as 3Ø, but followed by 33
32	2-E	"H"	Hanning
33	3-A	"3R"	Repeated medians of 3
34	3-B	">"	Smooth by finding skip means
35	3-C	"B"	Execute Batch Mode
36	3-D	"R"	Review smoothers used
37	3-d	--	Clear the review registers
38	3-E	"EV"	Smooth the end values
39	4-A	"SW"	Switch banks
4Ø	4-B	"CP"	Copy Bank 1 to Bank 2
41	4-b	--	Clear Bank 2
42	4-C	"+"	Add Bank 2 to Bank 1
43	4-D	"-"	Subtract Bank 2 from Bank 1
44	4-E	"T"	Call transformation program

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IV. Examples

This section includes four examples of varying complexity. The first example is given in the greatest detail and is intended as an introduction to the use of the programs. The second example repeats the first, using Batch Mode. Tukey's book Exploratory Data Analysis provides the third, more complex, example. Finally, the book by Velleman and Hoaglin, A-B-Cs of EDA, provides an example of compound smoothing or reroughing.

1. Tornadoes in Texas.

This example will be given in more detail than those which follow. Each action which the user takes with respect to the 41C will be followed by two slashes (//) and the response of the 41C. the data concerning the number of Tornadoes in Texas for the years 1951 to 1978 are taken from the 1980 - 1981 Texas Almanac.

Perform master clear, set size to 136, read in the program cards, pack, and set USER mode. // 0.0000

XEQ alpha S alpha // Menu 1.

At this point any of the menu options can be selected, but since there are no data in the machine, the first task is to put data in. First, however, try using keys F, G, H, and I to display the four menus. Note also that when any menu is displayed it is possible to move to the next menu by pressing R/S.

Press F to return to Menu 1 // Menu 1

Press A, under menu "I" for input // N=?
The program is asking how many data points are in the set.

Respond: 28 R/S // Y1=?

The 41C takes and uses the number of data points, then starts to ask for the data. The first data point is to be Y1, and SMOOTH is prompting for it.

Respond: 15 R/S // Y2=?

The 41C takes 15 as its first value and keeps on asking for input until the end of the set. The values are listed on the print-out below; continue entering data until the prompting for the twenty-eighth value.

Respond (to the prompt for 28th value): 137 R/S // X1=?

When SMOOTH has the last value of the data set, which it knows because it has been keeping count of the values entered, SMOOTH asks for the first X value.

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Respond: 1951 R/S // Y FIX=?

Smooth takes 1951 as the first X value, then asks the number of decimals to use in printing the Y values.

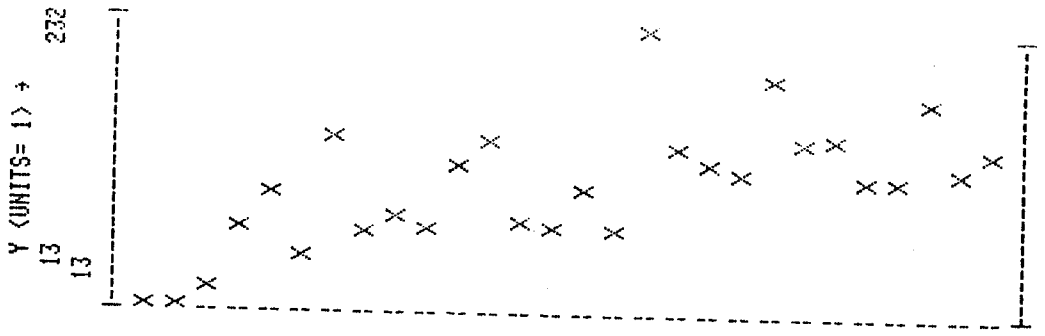
Respond: Ø R/S // Menu 1

The data are now stored, together with the values needed to describe the data. It would be a good idea to save the data on a card at this point (key E, under CW in Menu 1) but it is neither necessary nor included in this example.

Still in Menu 1, press shifted C, under "PR," to print the data in Bank 1 // The data print out as shown below, and Menu 1 returns. If there is no printer connected, the data are displayed, with a stop at each value.

```
1951: 15
1952: 13
1953: 32
1954: 77
1955: 104
1956: 56
1957: 145
1958: 74
1959: 86
1960: 77
1961: 124
1962: 143
1963: 82
1964: 78
1965: 108
1966: 77
1967: 232
1968: 139
1969: 127
1970: 121
1971: 191
1972: 144
1973: 147
1974: 116
1975: 117
1976: 176
1977: 123
1978: 137
```

Still in Menu 1, press D, under "PL," to plot the data (if there is no printer connected, skip this step and go on to the next.) // The data are plotted as below, except that the plotting character will be the small x. See instruc- tions for changing the plotting character, section III-B-2. Control returns to Menu 1. If you press ADV to move the paper out, the menu will vanish. Return to it by pressing F.



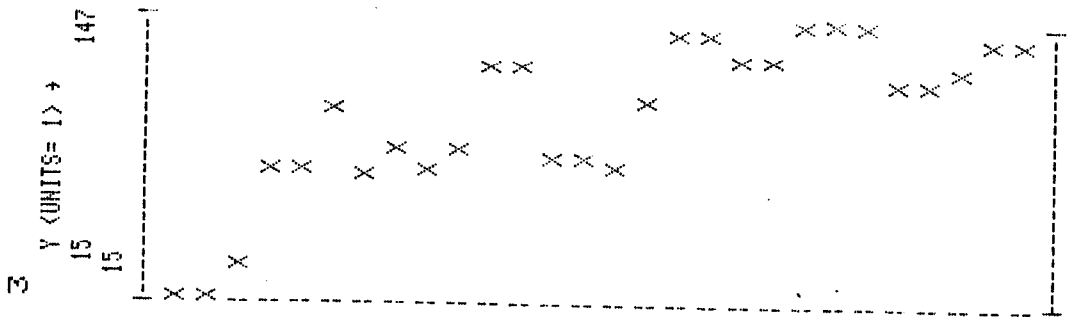
Note that only the most general upward trend in the number of tornadoes is evident. Without smoothing, the data are too disorderly to be sure whether there are other patterns.

To begin the actual smoothing, press G to go to Menu 2, where most of the smoothers may be called // Menu 2.

In Menu 2, press A, under "3," to smooth by running medians of length 3 // Calculator will Beep and show Menu 2. It would now be helpful to see the effects of the smoothing, as by another graph.

Return to Menu 1 by pressing F // Menu 1.

In Menu 1, press D, under "PL," to plot the now smoothed data // The following plot is drawn and control is returned to Menu 1.



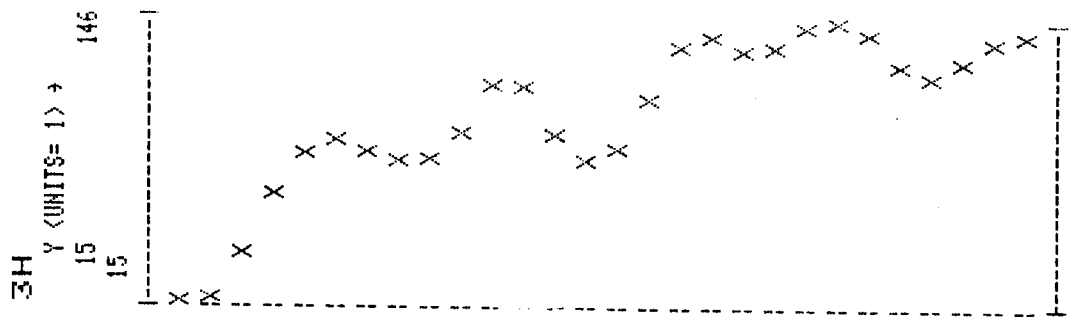
The data are much improved, just by the single application of 3, but the jerkiness of the line makes it hard to spot any patterns. Use of Hanning may help.

Press G to go to Menu 2 // Menu 2.

In Menu 2, press E, under "H," to Hann the data // Menu 2.

Press F to return to Menu 1 // Menu 1.

In Menu 1, press D, under "PL," to plot the data following the second smoother // The following plot results, and control returns to Menu 1.



Still in Menu 1, press C, under "PR," to print the data in both banks // The following printing results, and control is returned to Menu 1.

3H

1951:	15,	15
1952:	19,	15
1953:	39,	32
1954:	66,	77
1955:	84,	77
1956:	96,	104
1957:	85,	74
1958:	81,	86
1959:	82,	77
1960:	93,	86
1961:	115,	124
1962:	114,	124
1963:	93,	82
1964:	81,	82
1965:	87,	78
1966:	108,	108
1967:	131,	139
1968:	136,	139
1969:	130,	127
1970:	131,	127
1971:	141,	144
1972:	146,	147
1973:	138,	144
1974:	124,	117
1975:	119,	117
1976:	125,	123
1977:	134,	137
1978:	137,	137

Note that the contents of both Bank 1 and Bank 2 are printed, with the contents of Bank 1 coming first. Bank 1 contains the data which have been smoothed by 3 and by H, while Bank 2 contains the data which have been smoothed by 3 only. The "3H" at the top of the printings and the plots show which smoothers have been used.

Even the use of these two relatively simple smoothers have

made it much easier to find trends and patterns in the data. A periodicity of about five years emerges from the data where no such periodicity was apparent in the first plot.

2. Batch Mode

The same smoothing can be accomplished in Batch Mode by adding lines between line 488 and 489. The following short listing shows the necessary lines.

```
487 RTN
488◆LBL 35
489 XEQ 21
490 XEQ 25
491 XEQ 27
492 XEQ 32
493 XEQ 23
494 XEQ 25
495 ADV
496 ADV
497 RTN
498◆LBL 54
```

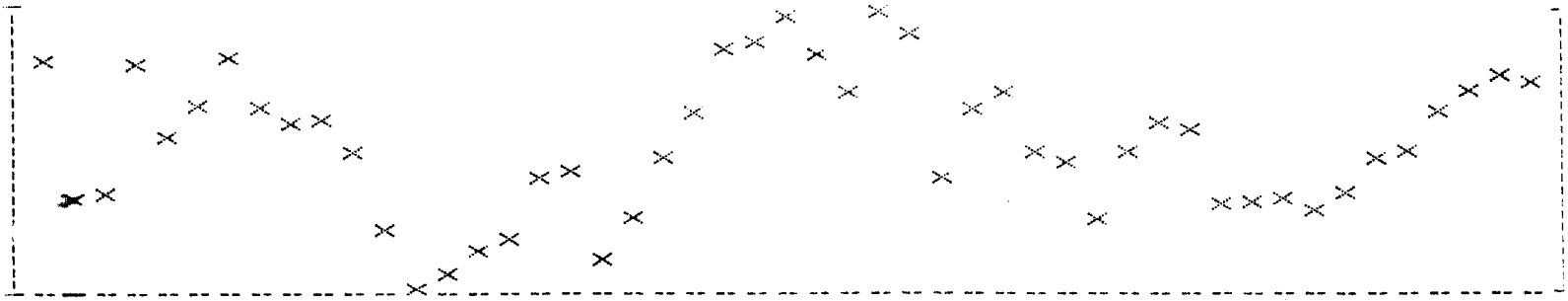
The segment calls the Input program (21), plots the data (25), smooths by 3 (27), Hanns (32), prints the data (23), and finally plots it again (25). The results were just the same as with example 1, but the process went on unattended.

3. Bituminous Coal Mined

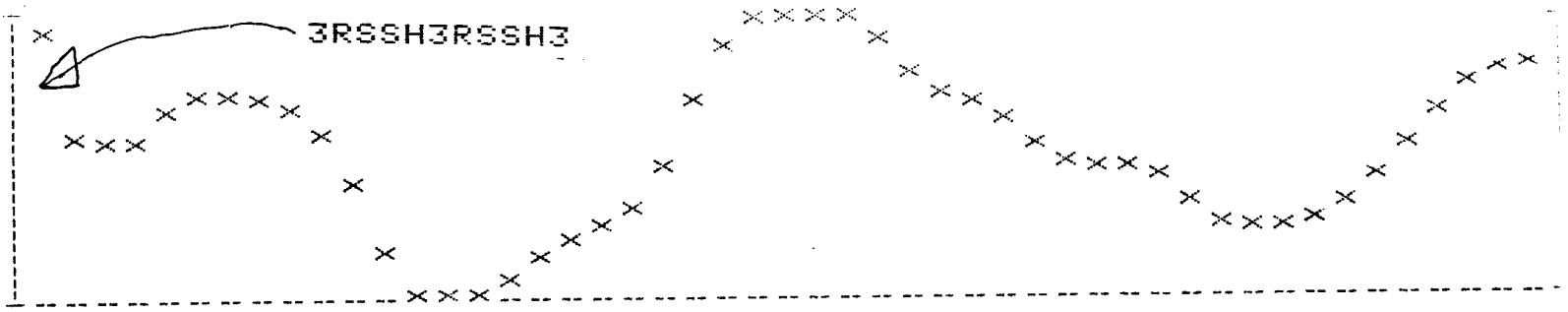
Tukey (p. 212) gives data for the years 1920-1968 for the number of tons of bituminous coal mined in the United States. While the following data and plot are not very disorderly, they can be improved by smoothing. Tukey uses an involved smoother which consists of the following: repeated smoothing by 3 until no further change occurs, splitting, splitting again, Hanning, repeated smoothing by 3 again, two more splittings, another Hanning, and, finally, another smoothing by 3. The raw data follow.

1920: 56
1921: 41[illegible]
1922: 422
1923: 565
1924: 484
1925: 520
1926: 573
1927: 518
1928: 501
1929: 505
1930: 468
1931: 382
1932: 316
1933: 334
1934: 359
1935: 372
1936: 439
1937: 446
1938: 349
1939: 395
1940: 461
1941: 511
1942: 583
1943: 590
1944: 620
1945: 578
1946: 534
1947: 631
1948: 600
1949: 438
1950: 516
1951: 534
1952: 467
1953: 457
1954: 392
1955: 467
1956: 500
1957: 493
1958: 410
1959: 412
1960: 416
1961: 403
1962: 422
1963: 459
1964: 467
1965: 512
1966: 534
1967: 552
1968: 545

Plotted, the data look as follows.



Following smoothing, the data appear as follows (note that the summary registers report all of the smoothers used in the sequence.) While the changes are not dramatic, the trends are certainly easier to see now than before smoothing.

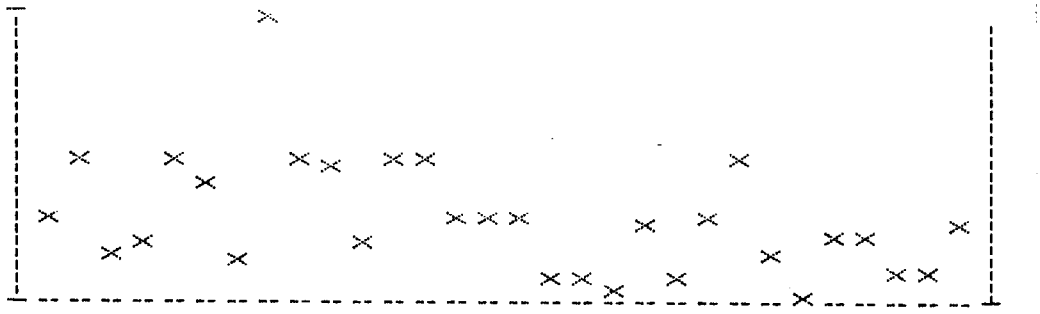


4. Cow Temperatures

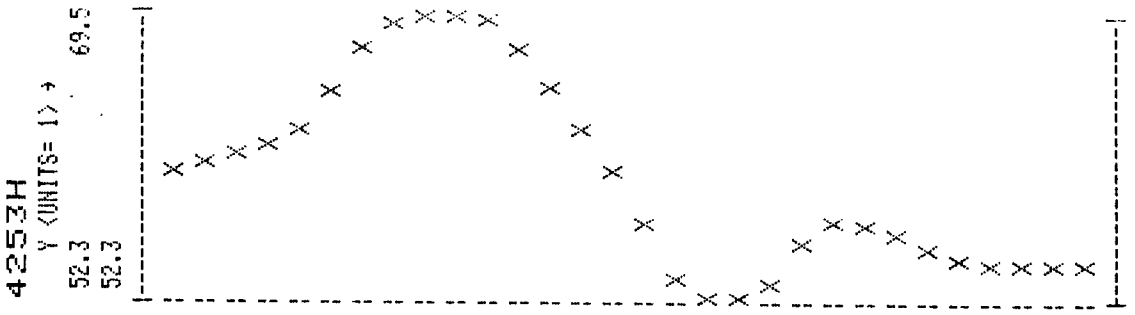
A data set from Velleman and Hoaglin (pp. 174-175) gives data obtained daily by telemetry on the internal temperature of a single cow. The entire data set covered 75 days; this fragment contains the first 30 days. The following print-out and plot show that the original data are not easy to interpret, and it is not clear that the temperatures are behaving in an orderly way. This data set illustrates the use of a compound smoother, or reroughing, even though with these data such a powerful smoother is almost excessive.

```
 1: 60.000
 2: 70.000
 3: 54.000
 4: 56.000
 5: 70.000
 6: 66.000
 7: 53.000
 8: 95.000
 9: 70.000
10: 69.000
11: 56.000
12: 70.000
13: 70.000
14: 60.000
15: 60.000
16: 60.000
17: 50.000
18: 50.000
19: 48.000
20: 59.000
21: 50.000
22: 60.000
23: 70.000
24: 54.000
25: 46.000
26: 57.000
27: 57.000
28: 51.000
29: 51.000
30: 59.
```

The plot appears as follows.



These data are smoothed well by the sequence 42, 5, 3, H. The plot below makes the regular, orderly changes over time quite obvious.



Velleman and Hoaglin, however, decide to re-rough the data, a process that involves finding the "rough," smoothing that, and adding it back to the original smooth. Since that is a fairly common procedure, the method follows in detail. Note that the utility programs of Menu 4 are used heavily.

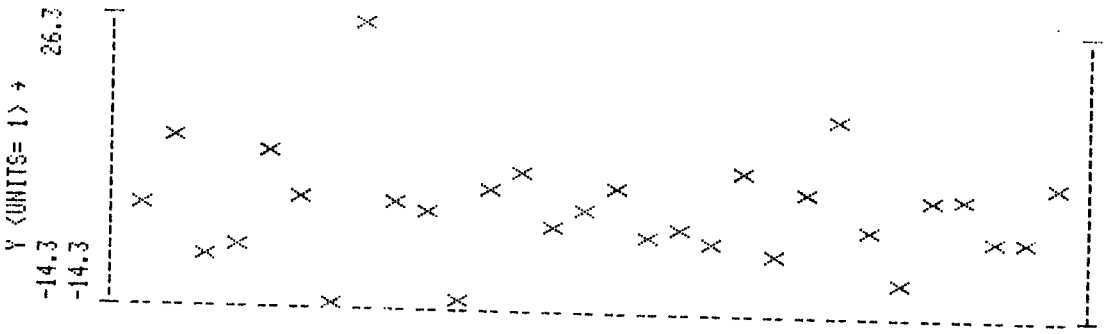
It is assumed that the data have just been smoothed and the smooth data are in Bank 1, while the contents of Bank 2 are not important. It is also assumed that the original data have been recorded on cards. Take the following steps:

Menu 1, "CW," to write the smoothed data onto cards.

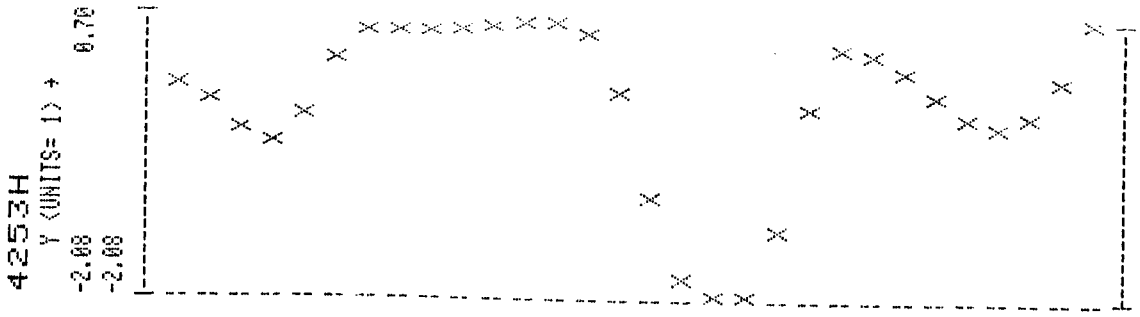
Menu 4, "SW," to switch the smoothed data to Bank 2.

Menu 1, "C," to read in cards. Read in the cards which have the original, unsmoothed data on them.

Menu 4, "-," to subtract Bank 2, the smoothed data, from Bank 1, the unsmoothed data, leaving the result, called the "rough," in Bank 1. The "rough" is the difference between the original and the smoothed data -- in essence it is what the smoothing process removed. The rough appears as follows:



The rough itself is now smoothed. Velleman and Hoaglin used the same sequence of smoothers as before, 42, 5, 3, and H. The result of the smoothing of the "rough" is shown below. The magnitude of the smoothed points is small in comparison to the values of the original smooth, but there is definitely information there, not just noise.



To complete the process of reroughing, the smoothed rough must be added back to the original smooth. To do that, take

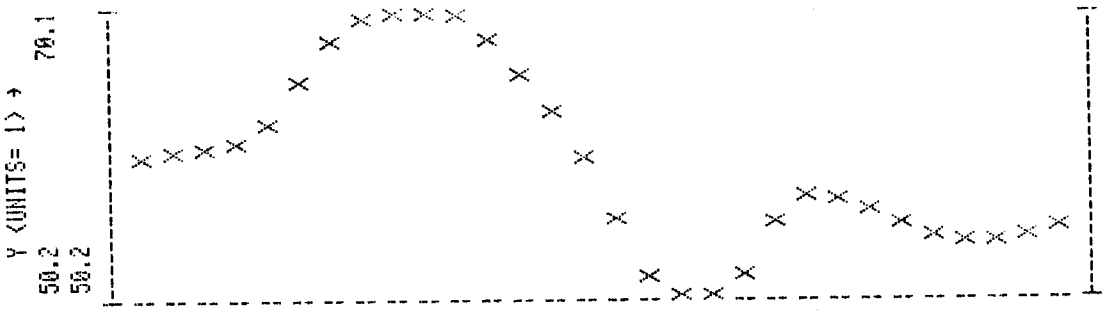
the following steps:

Menu 4, "SW," to put the smoothed "rough" into Bank 2.

Menu 1, "C," to read in the original smoothed data recorded after the first round of smoothing.

Menu 4, "+,", to add the two banks and leave the result in Bank 1.

Menu 1, "PL," to plot the final smooth.



The final smooth, shown above, is not obviously better than the initial smooth, but the excursions are slightly more apparent. As with all aspects of smoothing, the exact choices must be a matter of judgment, not rule-following. One advantage of using SMOOTH is that such choices can be tried out, and if the result is not satisfactory, an alternative course of smoothing may be tried. The author again urges users to consult the books mentioned above, in order to gain a much deeper understanding of smoothing than this brief presentation can give.

V. Program Summaries.

A. Introduction

Each of the 24 programs which may be called from the menus is described here in enough detail to indicate what it does and, in general, how it does it. The listing must be consulted for further detail, but basic information will be found here. Summary information on flags, labels, subroutines, and registers will be found in section VI. In this section a register is listed as being used only if the program changes the contents of the register.

B. Summaries of the 24 menu-callable subroutines.

The numbers (21-44) correspond to labels, letters in parentheses and quotation marks indicate the designation on the menu. E. g. "Menu 1-C" indicates that key C in Menu 1 calls the program.

21. Data input by hand ("I"). Menu 1-A. Lines 5-51.
    Subroutines called: 37
    Flags used: ØØ
    Registers used: 13, 8, 1Ø, 9, 7, 12
    Labels within program: ØØ, Ø5, 1Ø

The input program first clears the summary registers, 14 and 15, then prompts for the number of items to be smoothed. It uses the number of items to set up two pointers in registers 8 and 9 to set the beginning and ending limits to Banks 1 and 2. The program then prompts for each successive data value until all are entered, then prompts for the initial X value and the number of decimal places to be displayed with the data. Those values are stored in registers 7 and 1Ø respectively. No error correcting routines are provided.

22. Data entry from cards ("C"). Menu 1-B. Lines 3-51.

This program is the same as program 21, above, except that it starts by seting Flag ØØ. At the point where program 21 prompts for input, the setting of Flag ØØ causes program 22 to jump to label Ø5 for card input.

23. Print Banks 1 and 2 ("PR"). Menu 1-C. Lines 54-95.
    Subroutines called: 5Ø, 51
    Flags used: ØØ set supresses Bank 2 printing
    Registers used: 1Ø, 11
    Labels within program: 23, 8, 14

This segment first prints the review registers, or displays them in the absence of a printer, then prints, or displays,

the X values followed by the contents of Banks 1 and 2. Line 60 calls souroutine 50 to set pointers for the loop, while the rest of the program is a series of recalls, increments, tests for the printer, and print statements. Line 70 may be changed if the value by which X is to be incremented is not to be 1. For example, if one is smoothing measurements of Highway deterioration at one half mile intervals the initial value might correspond to the highway mile number of the measurement and the increment to 0.5. Line 63 may be changed to change the display format for X. If X is incremented in steps of .5, then FIX 1 would be appropriate. In line 91, as elsewhere throughout the program, DEG is used as a No Op instruction.

24. Print Bank 1 only. Menu 1-c. Lines 52-95.

This is identical to the above, program 23, except that the setting of flag 00 at the beginning causes the program to skip over the printing of Bank 2 values.

25. Plot the Bank 1 values ("PL"). Menu 1-D. Lines 96-143.

Subroutines called: 51
Flags used: none
Registers used: 10, 4, 2
Labels within program: 01, 06, 07

Program 25 starts by printing the review registers, then finds the minimum and maximum values in Bank 1 and stores them in registers 00 and 1. The contents of Bank 1 are then plotted using REGPLOT to obtain maximum scale. Finally, a right axis is printed.

26. Card writer ("CW"). Menu 1-E. Lines 144-147.

This short program segment writes the data from Bank 1 on magnetic cards. The pointer in register 8 is used to direct the writing. The program does not call the program VER, but it would be good practice to use it after writing the cards.

27. Smooth by medians of 3 ("3"). Menu 2-A. lines 156-183.

Subroutines called: 16, 39, 50, 52, 53
Flags used: Sets Flag 03 to indicate "long form" of subroutine 50, 02
Registers used: 10 and 11 as pointers.
Labels within program: 12 used as an entry point by the program "3R" to avoid adding a "3" to the summary each time "3R" calls "3." 4 used as loop point. 2 used as a continuation point or skipped (line 167) to exit point when

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all values have been smoothed.

The program segment "3" shares its main sections with the programs segments for Hanning and finding skip means. Only the entry points and subroutines called are different. The program steps through the data, taking three values at a time, finding the median, the weighted mean (for Hanning), or the skip mean as appropriate, and placing it into the corresponding Bank 2 register.

28. Smooth by medians of 4, then 2 ("42"). Menu 2-B. Lines 211-261.

Subroutines called: 16, 39, 5Ø, 54,55.

Flags used: Sets Flag Ø3 to indicate "long form" of subroutine 5Ø. Tests and clears flag 2 (set by the subroutine at Label 55 at last data value) to see if all data have been smoothed.

Registers used: 1Ø and 11 as pointers.

Labels within program: 13 as loop point, 15 as exit point when all values smoothed.

The program 42 first smooths the second value in Bank 1, then (Label 13) loops through the rest of the data, then smooths the next to last value, and finally exits.

29. Smooth by medians of 5 ("5"). Menu 2-C. Lines 262-295.

Subroutines called: 16, 5Ø, 52, 56
Flags used: Ø3, Ø2
Registers used: 1Ø, 11
Labels within program: 77, 76

The program 5 first smooths the next to end values by taking medians of three, then uses the subroutine at label 56 to find medians of span 5 centered at the register indicated by the value in the X register when subroutine 56 is called.

3Ø. Split highs and lows of length 2 ("SP"). Menu 2-D. Lines 298-345.

Subroutines called: 16, 4Ø, 39, 33, 57
Flags used: 29, ØØ
Registers used: 1Ø, 11, 14
Labels within program: 11, 78, 79

31. Split highs and lows of length 2, then apply "3R". Menu 2-d. Lines 296 & 297, plus all of program 3Ø.

Identical to (and part of) program 3Ø except that Flag ØØ is set to cause an excursion to program "3R" at lines 326 and 327 after the values have been split.

32. Hann the data ("H"). Menu 2-E. Lines 153-183.

This program is identical to program 27 ("3") except that it is entered three lines earlier and Flag Ø2 is set. The set condition of Flag Ø2 causes the program (lines 177 and 178) to jump to the subroutine (53) which Hanns the three values in the stack instead of finding their median.

33. Find medians of span three repeatedly until there is no further change ("3R"). Menu 3-A. Lines 382-389.

This short program segment repeatedly calls "3" until the presence of a clear flag 9 indicates that when "SW" interchanged Banks 1 and 2 after "3" found medians of span 3, there were no differences between the two banks. The program "3" is called not at its usual starting point, but at Label 12, so that repeated callings of the program will not add repeated "3"s to the summary registers. Label 8Ø is the loop point.

34. Smooth by finding skip means (">"). Menu 3-B. Lines 148-172.

This program is identical to program 27 ("3") except that it is entered eight lines earlier and Flag Ø1 is set. The set condition of Flag Ø1 causes subroutine 52 to find skip means (subroutine Ø3) instead of medians of 3.

35. Excute batch mode ("B"). Menu 3-C. Lines 488-489.

The user must insert XEQ statements between lines 488 and 489 to use the batch mode. The statements may call any of the subroutines 21 through 44. See the examples in section VII for an example of a batch program.

36. Review contents of summary registers ("R"). Menu 3-D. Lines 41Ø-413.

This program calls subroutine 51 which displays the contents of registers 14 and 15, the summary or review registers. The program is then stopped until R/S is pressed. Note that the program stops regardless of whether the printer is connected or not.

37. Clear the summary registers. Menu 3-d. Lines 4Ø5-4Ø9.

38. Smooth the end values ("EV"). Menu 3-E. Lines 438-456.

This is largely a directing and pointer-managing program. The work of the end value smoothing is done by the subroutine at label 57. End value smoothing is one of the more complex smoothing operations to program, hence the associated routines appear long, quite out of proportion to the frequency with which they are used.

39. Switch banks. ("SW"). Menu 4-A. Lines 422-437.

This is a straightforward data moving program which just sets up the pointers and interchanges the two banks. Flag Ø9 is set if any of the values in the two banks differ when they occupy the same relative position, otherwise SW leaves Flag Ø9 clear, even if it was set on entering.

4Ø. Copy Bank 1 to Bank 2 ("CP"). Menu 4-B. Lines 466-475.

This routine sets the pointers, loops through the banks, and exits.

41. Clear Bank 2. Menu 4-b. Lines 457-465.

This program, useful primarily when debugging modifications to the program, sets a pointer and packs zeros into Bank 2.

42. Add Bank 2 to Bank 1 ("+"). Menu 4-C. Lines 39Ø-4Ø4.

This program does duty for both the program to add and that to subtract the two banks. The only difference is that Flag 4 is set for adding, and clear for subtracting, in which case the sign of the value in X is changed before the addition. The contents of Bank 2 are added to or subtracted from Bank 1, with the result left in Bank 1.

43. Subtract Bank 2 from Bank 1 ("-"). Menu 4-D. Lines 392-4Ø4.

See discussion above in 42.

44. Call transformation program ("T"). Menu 4-E. Lines 476-487.

Without a user-supplied program labeled T, this routine does nothing except set up the pointers for both banks, call values out of Bank 1, try to transform them, and put them into Bank 2. It ends by calling Switch, to put the transformed data back into Bank 1. The user can supply any kind of transformation program under the label T.

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C. Summaries of subroutines used by the 24 menu-callable subroutines. Numbers indicate the labels of the subroutines.

16. Update the summary registers. Lines 372-381.

This short subroutine concatenates the contents of the alpha register to the contents of registers 14 and 15. If the resulting concatenation would have more than twelve characters, then only the first twelve are preserved.

5Ø. Set pointers, copy end values. Lines 552-568.
Subroutines called: None.
Flags used: If flag 3 is set, the "long form" is executed, otherwise the "short form."
Registers used: 8, 9, 1Ø, 11, 13.
Labels within program: None.

Subroutine 5Ø, when executed with flag 3 clear, or in the "short form," sets the pointers in registers 1Ø and 11 to be equal to those in 8 and 9, so that the original values will not be lost as the smoothing programs step through the data. The "long form" does the same thing but also copies the first and last values of Bank 1 to the same locations in Bank 2. Few of the smoothers operate on the end values; using the "long form" conveniently copies on the end values.

See Section VI-E, Utility Souroutines, for description of other subroutines in SMOOTH.

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VI. Program notes

VI-A: Miscellaneous Information

1. Most of the routines will run slowly the first time they are run after loading. As explained in the HP-41C Owner's Handbook, the GTOs and EXECs must be compiled on first execution, and SMOOTH uses many such instructions. Subsequent runs will be faster.

2. To determine whether or not Banks 1 and 2 contain the same data, run "SW," or switch, to interchange the contents of the two banks. If Flag 9 is set following the switch, then at least one value in Bank 1 is different from the value in the corresponding register in Bank 2. If, for example, it is noted that the plot of a set of data appears unchanged by a smoothing operation, then a look at Flag 9 will indicate whether or not any change took place, since all of the smoothing programs end by calling "SW."

3. Long sequences of smoothing operations can result in an overflow of the summary registers, 14 and 15. There is no warning that those registers may have overflowed. The symptom is that a full twelve characters are printed out or displayed when the registers are reviewed. Any further characters are simply ignored. If overflow becomes a problem, it is possible to note the smoothing sequence already accomplished, then clear registers 14 and 15 by means of the shifted D key (d) in Menu 3.

4. When a set of data is too long to be smoothed in one continuous operation, the data must be broken into two overlapping sets for smoothing. Because of the distortions that may be introduced at the ends of a data set, it is advisable to have the two parts of the set overlap by at least ten values if several smoothers are to be used. For example, if one is smoothing a set of 100 values, it would be a good idea to break it into two sets, one from value 1 to 65, the other from value 36 to 100. If, when re-assembling the two smoothed sets, there is not a sequence of matching values where the strings come together (e.g. values 45 to 55), then the overlap was not long enough. (It is assumed that exactly the same sequence of smoothers is applied to the two parts of the longer sequence.)

5. Two points mentioned elsewhere bear repeating. First, end value smoothing is not reflected in the summary registers, and, second, it is important to start the program with flags 0 - 4 clear.

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VI-B: Register Use

All registers numbered 16 and above are available for use as data storage registers. The registers numbered ØØ-15 have assigned uses for various of the smoothing programs. Those used are listed in this section. Note that registers 7-13 describe the data set currently in the calculator. Those registers should therefore not be used for other purposes as long as the data set may be used again. Registers ØØ through 6 may be used for scratch, as may 14 and 15, if the user observes two cautions. First, register 15 must have alphabetic information stored in it when the smoothing programs are operating, due to one of the conditional tests. Second, register 3 is used to store the plotting character. If the user is using a nonstandard plotting character, then it may be necessary to avoid using register 3, or to restore its contents before using the plotting routine. Counting registers Ø-7 and 14 and 15 there are, then, 1Ø registers available for a user program, such as a transformation program (callable by "T" from Menu 4).

Register	Use
ØØ	Contains the minimum value of Y during the plotting routine, also used as a pointer.
Ø1	Contains the maximum value of Y during the plotting routine, also used as a pointer.
Ø2	Used by plotting routine, also as a temporary pointer, as by line 352 and following.
Ø3	Special plotting character.
Ø4	Used by Praxis, when plotting the Y axis, also as another temporary pointer.
Ø5	Scratch.
Ø6	Scratch.
Ø7	Initial value of X (commonly 1), the values to which the Y values (the data being smoothed) are presumed to correspond.
Ø8	Permanent pointer for Bank 1. This pointer does not change until a new data set is loaded in or until it is changed outside of program control.
Ø9	Permanent pointer for Bank 2. As with above, this does not change.
1Ø	Working pointer for Bank 1. This pointer does change as any of the callable subroutines works through the data.

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11	Working pointer for Bank 2. As above, this pointer changes as the subroutines sweep through the data.
12	Number of decimal places to be used when printing Y.
13	N, number of points being smoothed.
14	First register of record of smoothing actions.
15	Second register of record of smoothing actions.

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VI-C: Flag Use

SMOOTH uses relatively few flags. Those that it does use, however, are checked frequently and are vital to the flow of program control. Listed below are all flag references in SMOOTH. Each reference gives the flag number, the line(s) at which it is set, the line(s) at which it is cleared, and the line(s) at which it is tested. Flags Ø and 2 each serve several purposes, depending on where in the program each is tested. Finally, the last column shows what the flag indicates when it is set.

Flag	Line at which Set	Cleared	Tested	Flag set indicates
Ø	4	25	25	Input will be from cards.
Ø	297	326	326	Splitting to be followed by 3R.
Ø	53	94	8Ø	Suppresses printing of Bank 2.
1	149	169	185	Find skip means, rather than medians or Hanning.
2	154	17Ø	157, 175 177	Perform Hanning, not medians or skip means.
2	522	278	278	End of Bank reached while finding medians of span 5.
2	546	239	239	End of data bank reached while performing 4-2 smoothing.
3	161, 214 265	557	557	When setting the bank pointers, also copy on the end values.
4	391	4Ø3	396	Add the banks, not subtract.
9	43Ø	423	387	At least one pair of corresponing values was found to differ when switching banks (clear flag indicates to 3R that further smoothing not needed.)
12	74,418	77,42Ø		Emphasized printing.
25	364	366	366	Error due to finding alpha data in register 15 and therefore indicates that the end of the data bank has been reached.
29 & 52			3Ø9, 361 521, 545	Skip next instruction.

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21 Tested in lines 66, 68, 75, 78, 84, and 87 for presence of the printer.

VI-D: Program Labels

Each of the numeric labels used in the programs is listed here, with the exception of labels 21-44, which mark the entry points of the various callable subroutines. For each label, a reference is given. The reference indicates the line which refers to the label. The references are all GTO statements unless there is an x preceding the line number, in which the referring line number holds an XEQ statement. If an x applies to more than one line, then the lines are in parentheses. For example x(56, 99, 411) indicates that a subroutine is called from lines 56, 99, and 411.

Two abbreviations are used; LP indicates a loop point, or a point to which a loop repeatedly returns, while JP indicates a jump point, or a point to which control is transferred, often as a result of a conditional test.

Label	Line	Reference	Meaning
ØØ	27	39	LP for input
Ø1	1Ø5	116	LP for finding the largest and smallest
Ø2	173	168	continuation of "3"
Ø3	196	186	JP for finding skip means of X & Z
Ø4	163	183	LP for 3, H, and >
Ø5	41	26	JP for card input
Ø6	127	131	LP for data plotting
Ø7	136	139	LP for axis-printing subroutine
Ø8	6Ø	93	LP for data printing
Ø9	536	x(53Ø,531)	Put 4 values in stack, sum the two of middle value to register ØØ
1Ø	44	4Ø	JP for reading of card
11	3Ø4	32Ø, 345 336, 332, 314	LP in program to split pairs apart
12	16Ø	152, x386	Entry point in "3," used by 3R
13	234	242	LP in 42

14	86	81	JP in printing program
15	243	240	JP in Hann for exit
16	372	x(151,159,213 264, 300, 384)	Append to the review registers
50	552	x(59, 162, 215 266, 393, 424 467, 477)	Set the bank pointers, also copy on end values if Flag 3 is set
51	414	x(56, 99, 411)	Summary register print
52	184	x(176, 272, 292 369, 524)	Skip means or medians of X, Y, &Z, depending on flag
53	202	x178	Find mean of X, 2*Y, and Z
54	490	x(225, 255 519, 548)	Find middle two of stack
55	526	x238	Heart of 42 smoothing
56	508	x277	Finds medians of span 5
57	346	x(340, 344 441,447)	Smooths the end values
76	275	283	LP for medians of span 5
77	284	279	JP for medians of span 5
78	324	310	JP for segment to split pairs
79	329	323	JP in split, when not out of data
80	385	388	LP for repeating "3" in "3R"
81	394	402	LP for "+" and "-"
82	425	435	LP for "SW," program to switch banks
83	461	464	LP for clearing Bank 2
84	468	474	LP for copying Bank 1 to Bank 2
85	478	485	LP within the transformation program.

Section VI-E: Utility Subroutines

The following subroutines are called from several places in the main program, but are not themselves callable from the menus. Subroutines 21 through 44, which make up the bulk of the program and which are callable from the menu, are described in detail in section V, and so are not treated here.

Label	Line	Returns	SRs called	Function
9	536	551	54	Back the pointer by 2, get 4 consecutive values starting there, sum the two of middle values, add result to R00.
12	160	172	50, 39 52	Smooth by "3" without appending "3" to the summary registers.
16	372	381	--	Append a record of the current action to summary registers.
50	552	558 568	--	Set the working pointers for Banks 1 & 2, copy on the end values if Flag 3 is set.
51	414	421	--	Print or view summary of operations.
52	184	195 201	--	Median of X, Y, & Z if Flag 1 is clear, mean of X & Z if set.
53	202	210	--	Find mean of X, Y, & Z, giving double weight to Y.
54	490	507	--	Place the two numerically middle values of stack in X & Y.
55	526	535	9	Find two medians of span 4 and take their mean to recenter on the point being smoothed.
56	508	525	54, 52	Find median of 5 values.
57	346	362 371	52	Smooth the end values, upper or lower, depending on sign of X.

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	COMMENTS
01◆LBL "S"	
02 GTO F	To menus.
03◆LBL 22	Card input.
04 SF 00	
05◆LBL 21	Manual input.
06 XEQ 37	
07 "N=?"	
08 PROMPT	
09 STO 13	
10 15	Set the pointers
11 +	
12 1 E-3	
13 *	
14 16	
15 +	
16 STO 08	
17 STO 10	
18 RCL 13	
19 +	
20 RCL 13	
21 1 E-3	
22 *	
23 +	
24 STO 09	
25 FS?C 00	Card or manual?
26 GTO 05	Card.
27◆LBL 00	Manual.
28 "Y"	
29 RCL 10	
30 15	
31 -	
32 FIX 0	
33 ARCL X	
34 X<>Y	
35 "⊢=?"	
36 PROMPT	
37 STO IND 10	Store each input value.
38 ISG 10	
39 GTO 00	
40 GTO 10	
41◆LBL 05	Card input starts here.
42 RCL 08	
43 XROM 30,03	
44◆LBL 10	
45 "X1=?"	Get data on the data set.
46 PROMPT	
47 STO 07	
48 "Y FIX=?"	
49 PROMPT	
50 STO 12	
51 RTN	
52◆LBL 24	Print Bank 1.
53 SF 00	
54◆LBL 23	Print both banks.
55 ADV	
56 XEQ 51	
57 RCL 07	
58 STO 00	
59 XEQ 50	Set pointers.
60◆LBL 08	
61 CLA	
62 " "	
63 FIX 0	
64 ARCL 00	
65 "⊢: "	
66 FS? 21	Flag 21 sees if printer is present.
67 ACA	
68 FS? 21	
69 CLA	
70 1	
71 ST+ 00	
72 FIX IND 12	
73 ARCL IND 10	
74 SF 12	
75 FS? 21	
76 ACA	
77 CF 12	
78 FS? 21	
79 CLA	
80 FS? 00	
81 GTO 14	
82 "⊢, "	
83 ARCL IND 11	
84 FS? 21	
85 ACA	
86◆LBL 14	
87 FC? 21	Prompt if no printer.
88 PROMPT	
89 ADV	
90 ISG 10	

Note: Refer to "HP-41C OWNER'S HANDBOOK AND PROGRAMMING GUIDE" for specific information on keystrokes. The Function Index is found at the very back of the Handbook. Refer to Appendix E in 67 or 97 "OWNER'S HANDBOOK AND PROGRAMMING GUIDE" for exact keystrokes.

PROGRAM LISTING

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```
 91 DEG
 92 ISG 11
 93 GTO 08
 94 CF 00
 95 RTN
 96*LBL 25
 97 ADV
 98 ADV
 99 XEQ 51
100 RCL 08
101 STO 10
102 RCL IND
10
103 ENTER↑
104 ENTER↑
105*LBL 01
106 RCL IND
10
107 X>Y?
108 X<>Y
109 RCL Z
110 RCL IND
10
111 X>Y?
112 X<>Y
113 RDN
114 X<>Y
115 ISG 10
116 GTO 01
117 STO 00
118 X<>Y
119 STO 01
120 RCL 00
121 STO 04
122 RCL 08
123 STO 10
124 168
125 STO 02
126 XROM "PR
AXIS"
127*LBL 06
128 RCL IND
10
129 REGPLOT
130 ISG 10
131 GTO 06
132 127
133 ACCHR
```

COMMENTS

All done?
No.
Yes.

Plot data.

Print summary registers.

Find largest and smallest values in Bank 1 to use as the upper and lower limits when plotting.

Print left axis.
Plot the points.

Plot right axis.

```
134 "-"
135 22
136*LBL 07
137 ACA
138 DSE X
139 GTO 07
140 124
141 ACCHR
142 ADV
143 RTN
144*LBL 26
145 RCL 08
146 XROM 30,
08
147 RTN
148*LBL 34
149 SF 01
150 ">"
151 XEQ 16
152 GTO 12
153*LBL 32
154 SF 02
155 "H"
156*LBL 27
157 FC? 02
158 "3"
159 XEQ 16
160*LBL 12
161 SF 03
162 XEQ 50
163*LBL 04
164 RCL IND
10
165 ISG 10
166 RCL IND
10
167 ISG 10
168 GTO 02
169 CF 01
170 CF 02
171 XEQ 39
172 RTN
173*LBL 02
174 RCL IND
10
175 FC? 02
176 XEQ 52
177 FS? 02
```

COMMENTS

Write data onto cards.

Smooth by skip means. Setting flag distinguishes this from other operations using same routine.
line 153, smoot by Hanning.
line 156, by 3.

Entry point for 3 when called by 3R.
Loop point.

Get the values to be worked on.

Clear flags, switch banks, and exit if done.
Work starts here.

Use flags to sort out what is to be done.

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PROGRAM LISTING

☐ 67 ☐ 97 ☐ 41C

```
178 XEQ 53
179 ISG 11
180 STO IND
11
181 1
182 ST- 10
183 GTO 04
184*LBL 52
185 FS? 01
186 GTO 03
187 X>Y?
188 X<>Y
189 RDN
190 X>Y?
191 X<>Y
192 R↑
193 X<Y?
194 X<>Y
195 RTN
196*LBL 03
197 RCL Z
198 +
199 2
200 /
201 RTN
202*LBL 53
203 X<>Y
204 ENTER↑
205 +
206 +
207 +
208 4
209 /
210 RTN
211*LBL 28
212 "42"
213 XEQ 16
214 SF 03
215 XEQ 50
216 ISG 10
217 ISG 11
218 STO IND
11
219 RCL IND
10
220 ST+ IND
11
221 ISG 10
```

COMMENTS

Perform smoothing operation on one triad, store its value and reset pointers, loop back.

Find median of X, Y, & Z.

Find skip means of X, Y, & Z.

Hann X, Y, & Z; i. e. find mean of X, Y, and Z, with Y counted twice.

Smooth by medians of 4, recentered with means. Reset pointers and copy on the end values.

```
222 RCL IND
10
223 ISG 10
224 RCL IND
10
225 XEQ 54
226 +
227 RCL IND
11
228 +
229 4
230 /
231 STO IND
11
232 2
233 ST- 10
234*LBL 13
235 ISG 10
236 ISG 11
237 RCL 10
238 XEQ 55
239 FS?C 02
240 GTO 15
241 STO IND
11
242 GTO 13
243*LBL 15
244 2
245 ST- 10
246 RCL IND
10
247 ISG 10
248 RCL IND
10
249 ISG 10
250 RCL IND
10
251 STO IND
11
252 ISG 10
253 RCL IND
10
254 ST+ IND
11
255 XEQ 54
256 +
257 ST+ IND
11
```

COMMENTS

Middle two values, put in X and Y.

Store smoothed next-to-end value.

Here beginneth the real work of the subroutine.
Do the actual 42 calculation.
Watch for excessively deep subroutine levels here if modifying the program.
Take care of next-to-end values.

Similar to what was done at the other end of the data set, lines 216 et cetera.

Find middle values.

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PROGRAM LISTING

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	COMMENTS
258 4	
259 ST/ IND 11	
260 XEQ 39	
261 RTN	
262*LBL 29	medians of span 5
263 "5"	
264 XEQ 16	
265 SF 03	
266 XEQ 50	set pointers
267 ISG 10	
268 ISG 11	
269 RCL IND 10	
270 ISG 10	
271 RCL IND 10	find median of 3 store it
272 XEQ 52	
273 STO IND 11	
274 ISG 11	
275*LBL 76	
276 RCL 10	
277 XEQ 56	find median of 5 points centered on register which X points to
278 FS?C 02	
279 GTO 77	
280 STO IND 11	
281 ISG 10	
282 ISG 11	
283 GTO 76	
284*LBL 77	
285 DSE 10	
286 DEG	
287 RCL IND 10	
288 ISG 10	
289 RCL IND 10	
290 ISG 10	
291 RCL IND 10	find median of X, Y, Z
292 XEQ 52	
293 STO IND 11	
294 XEQ 39	
295 RTN	
296*LBL 31	split, then 3R
297 SF 00	
298*LBL 30	split
299 "S"	
300 XEQ 16	
301 XEQ 40	
302 RCL 08	
303 STO 10	
304*LBL 11	loop point
305 RCL 10	
306 STO 11	
307 RCL IND 11	
308 ISG 10	
309 FS? 52	
310 GTO 78	
311 ISG 11	
312 RCL IND 11	
313 X=Y?	
314 GTO 11	
315 -	
316 LASTX	
317 ISG 11	
318 RCL IND 11	
319 X≠Y?	
320 GTO 11	
321 RDN	
322 ISG 11	
323 GTO 79	
324*LBL 78	here when done
325 XEQ 39	switch banks
326 FS?C 00	3R if Flag 00
327 XEQ 33	is set
328 RTN	
329*LBL 79	do the splitting
330 RCL IND 11	
331 X=Y?	
332 GTO 11	
333 -	
334 *	
335 X>0?	
336 GTO 11	
337 RCL 10	
338 STO 04	
339 CHS	
340 XEQ 57	end value smthr

Note: Refer to "HP-41C OWNER'S HANDBOOK AND PROGRAMMING GUIDE" for specific information on keystrokes. The Function Index is found at the very back of the Handbook. Refer to Appendix E in 67 or 97 "OWNER'S HANDBOOK AND PROGRAMMING GUIDE" for exact keystrokes.

PROGRAM LISTING

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	COMMENTS
341 RCL 04	
342 1	
343 +	
344 XEQ 57	end value
345 GTO 11	smoother
346*LBL 57	starts here
347 STO 02	
348 ABS	
349 RCL 13	
350 +	
351 STO 11	
352 RCL IND 02	
353 ISG 02	
354 DEG	
355 RCL IND 02	save a byte or so with 3 x
356 ENTER↑	
357 ENTER↑	
358 ST+ X	
359 +	
360 ISG 02	
361 FS? 52	acts as skip
362 RTN	instruction
363 RCL IND 02	
364 SF 25	has the pointer
365 ST+ X	reached the
366 FC?C 25	alpha data?
367 RTN	
368 -	
369 XEQ 52	
370 STO IND 11	store smoothed data value
371 RTN	add to recap
372*LBL 16	registers
373 ASTO X	
374 CLA	
375 ARCL 14	
376 ARCL 15	
377 ARCL X	
378 ASTO 14	
379 ASHF	
380 ASTO 15	
381 RTN	
382*LBL 33	repeated 3
383 "3R"	smoothing
384 XEQ 16	

	COMMENTS
385*LBL 80	loop point
386 XEQ 12	smooth by 3
387 FS? 09	any change?
388 GTO 80	yes, do it ag'n
389 RTN	no, go away
390*LBL 42	add the banks
391 SF 04	
392*LBL 43	subtract the
393 XEQ 50	banks, set
394*LBL 81	pointers
395 RCL IND 11	
396 FC? 04	
397 CHS	
398 ST+ IND 10	
399 ISG 10	
400 DEG	no op
401 ISG 11	
402 GTO 81	
403 CF 04	
404 RTN	
405*LBL 37	clear the
406 CLA	recap regis-
407 ASTO 14	ters
408 ASTO 15	
409 RTN	
410*LBL 36	review smoothers
411 XEQ 51	used so far
412 STOP	
413 RTN	
414*LBL 51	print or view
415 CLA	summary regs.
416 ARCL 14	
417 ARCL 15	
418 SF 12	
419 AVIEW	
420 CF 12	
421 RTN	
422*LBL 39	switch banks
423 CF 09	
424 XEQ 50	set pointers
425*LBL 82	heart of the
426 RCL IND 10	switching rtne
427 ENTER↑	
428 X<> IND 11	

Note: Refer to "HP-41C OWNER'S HANDBOOK AND PROGRAMMING GUIDE" for specific information on keystrokes. The Function Index is found at the very back of the Handbook. Refer to Appendix E in 67 or 97 "OWNER'S HANDBOOK AND PROGRAMMING GUIDE" for exact keystrokes.

PROGRAM LISTING

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		COMMENTS
429	X≠Y?	Flag 9 set mean
430	SF 09	the banks con-
431	STO IND	tain at least
10		one pair of
432	ISG 10	values which
433	DEG	differ from
434	ISG 11	bank to bank.
435	GTO 82	
436	BEEP	Signal done.
437	RTN	
438	✱LBL 38	End value smth.
439	XEQ 40	Copy.
440	RCL 08	Bank 1 pointer.
441	XEQ 57	Smooth end
442	STO IND	values, upper
09		or lower de-
443	RCL 09	pending on
444	1	sign.
445	−	
446	CHS	
447	XEQ 57	End values agn.
448	RCL 09	
449	RCL 13	
450	+	
451	1	
452	−	
453	X<>Y	
454	STO IND	
Y		
455	XEQ 39	Switch banks
456	RTN	and exeunt.
457	✱LBL 41	Clear Bank 2.
458	RCL 09	
459	STO 11	
460	CLX	
461	✱LBL 83	
462	STO IND	
11		
463	ISG 11	
464	GTO 83	
465	RTN	
466	✱LBL 40	Copy Bank 1
467	XEQ 50	into Bank 2.
468	✱LBL 84	Loop point.
469	RCL IND	
10		
470	STO IND	
11		

		COMMENTS
471	ISG 10	
472	DEG	
473	ISG 11	
474	GTO 84	
475	RTN	
476	✱LBL A	Come here for
477	XEQ 50	transformation
478	✱LBL 85	program.
479	RCL IND	
10		
480	XEQ "T"	User must write
481	STO IND	a transforma-
11		tion program
482	ISG 10	labeled "T."!
483	DEG	Deg is No-op
484	ISG 11	throughout.
485	GTO 85	Switch banks
486	XEQ 39	and adios.
487	RTN	
488	✱LBL 35	Batch execute
489	RTN	statements go
490	✱LBL 54	after Label 35.
491	X>Y?	Lbl 54 starts
492	X<>Y	segment to fin
493	RDN	middle two val-
494	X>Y?	ues in the
495	X<>Y	stack and place
496	RDN	them in X and
497	X>Y?	Y.
498	X<>Y	
499	RDN	
500	RDN	
501	X<Y?	
502	X<>Y	
503	RDN	
504	X<Y?	
505	X<>Y	
506	R↑	
507	RTN	
508	✱LBL 56	Find the median
509	2	of five values.
510	−	
511	STO 01	
512	RCL IND	Get four val-
01		ues to the
513	ISG 01	stack.
514	RCL IND	
01		

Note: Refer to "HP-41C OWNER'S HANDBOOK AND PROGRAMMING GUIDE" for specific information on keystrokes. The Function Index is found at the very back of the Handbook. Refer to Appendix E in 67 or 97 "OWNER'S HANDBOOK AND PROGRAMMING GUIDE" for exact keystrokes.

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```
515 ISG 01
516 RCL IND
01
517 ISG 01
518 RCL IND
01
519 XEQ 54
520 ISG 01
521 FS? 52
522 SF 02
523 RCL IND
01
524 XEQ 52
525 RTN
526*LBL 55
527 STO 01
528 CLX
529 STO 00
530 XEQ 09
531 XEQ 09
532 RCL 00
533 4
534 /
535 RTN
536*LBL 09
537 2
538 ST- 01
539 RCL IND
01
540 ISG 01
541 RCL IND
01
542 ISG 01
543 RCL IND
01
544 ISG 01
545 FS? 52
546 SF 02
547 RCL IND
01
548 XEQ 54
549 +
550 ST+ 00
551 RTN
552*LBL 50
553 RCL 08
554 STO 10
555 RCL 09
```

COMMENTS

Find the middle two.
FS? 52 is a skip.
End of data.

Find two medians of span 4 and take their mean to recenter.

Put four values in the stack, add the sum of middle two (i.e. middle in magnitude) to reg 00.

Skip.

And done.
Set the pointers.

```
556 STO 11
557 FC?C 03
558 RTN
559 1
560 -
561 RCL IND
X
562 RCL 13
563 ST+ Z
564 RDN
565 STO IND
Y
566 RCL IND
10
567 STO IND
11
568 RTN
569*LBL F
570 "I C PR
PL CW"
571 PROMPT
572 GTO G
573*LBL A
574 XEQ 21
575 GTO F
576*LBL B
577 XEQ 22
578 GTO F
579*LBL C
580 XEQ 23
581 GTO F
582*LBL c
583 XEQ 24
584 GTO F
585*LBL D
586 XEQ 25
587 GTO F
588*LBL E
589 XEQ 26
590 GTO F
591*LBL G
592 " 3 42 5
 SP H"
593 PROMPT
594 GTO H
595*LBL A
596 XEQ 27
597 GTO G
```

COMMENTS

If flag 3 is set, copy on the end values.

Menus start here. Everything from here on to the end can be deleted when operating in the direct execution mode.

Note: Refer to "HP-41C OWNER'S HANDBOOK AND PROGRAMMING GUIDE" for specific information on keystrokes. The Function Index is found at the very back of the Handbook. Refer to Appendix E in 67 or 97 "OWNER'S HANDBOOK AND PROGRAMMING GUIDE" for exact keystrokes.

PROGRAM LISTING

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```
598*LBL B
599 XEQ 28
600 GTO G
601*LBL C
602 XEQ 29
603 GTO G
604*LBL D
605 XEQ 30
606 GTO G
607*LBL d
608 XEQ 31
609 GTO G
610*LBL E
611 XEQ 3^
612 GTO G
613*LBL H
614 "3R > B
 R EV"
615 PROMPT
616 GTO I
617*LBL A
618 XEQ 33
619 GTO H
620*LBL B
621 XEQ 34
622 GTO H
623*LBL C
624 XEQ 35
625 GTO H
626*LBL D
627 XEQ 36
628 GTO H
629*LBL d
630 XEQ 37
631 GTO H
632*LBL E
633 XEQ 38
634 GTO H
635*LBL I
636 "SW CP
+ - T"
637 PROMPT
638 GTO F
639*LBL A
640 XEQ 39
641 GTO I
642*LBL B
643 XEQ 40
644 GTO I
645*LBL b
646 XEQ 41
647 GTO I
648*LBL C
649 XEQ 42
650 GTO I
651*LBL D
652 XEQ 43
653 GTO I
654*LBL E
655 XEQ 44
656 GTO I
657 END
```

COMMENTS

COMMENTS

Return to Menu 4. End.

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Note: Refer to "HP-41C OWNER'S HANDBOOK AND PROGRAMMING GUIDE" for specific information on keystrokes. The Function Index is found at the very back of the Handbook. Refer to Appendix E in 67 or 97 "OWNER'S HANDBOOK AND PROGRAMMING GUIDE" for exact keystrokes.

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Request for Comments

The author of this program would appreciate receiving comments, notification of errors, and indications of inadequacies in the documentation. A future version is planned which will use the X-funcion module and memory, as well as the tape drive. Comments will be helpful in preparing those versions.

Please send comments to:

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