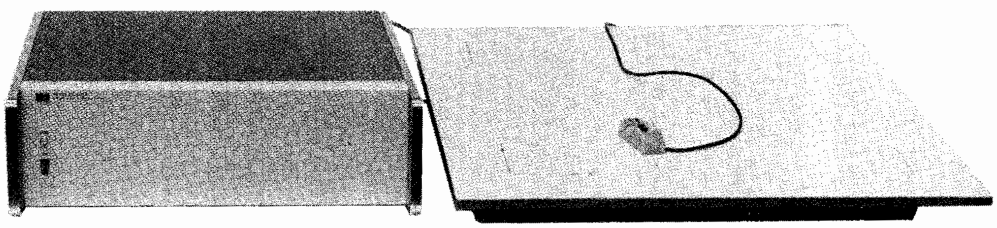
MODEL

64

HEWLETT-PACKARD
9864A DIGITIZER

PERIPHERAL MANUAL

DIGITIZER PERIPHERAL MANUAL



HEWLETT–PACKARD CALCULATOR PRODUCTS DIVISION
P.O. Box 301, Loveland, Colorado 80537, Tel. (303) 667-5000
Rue du Bois-du-Lan 7, CH-1217 Meyrin 2, Geneva, Tel. (022) 41 54 00

PREFACE

This manual contains generalized installation and operating instructions for the Model 9864A Digitizer. Since a peripheral control block (ROM) is required in order to use the digitizer with your 9800 Series Calculator, specific information on operating the digitizer (digitizer commands, electrical inspection procedure, etc.) is contained in the peripheral control block operating manual.

TABLE OF CONTENTS

TABLE OF CONTENTS

INTRODUCTION

The -hp- 9864A Digitizer quickly and accurately enters data into a 9800 Series Calculator from almost any type of graphic record. The calculator can use these data to determine lengths, integrals, average and RMS values, centroids, volumes and many other results.

A document is digitized by placing it on the digitizing surface and tracing over it with a hand-held cursor. Points can be entered one at a time under the direct control of the operator, or they may be automatically entered, at the rate at which the calculator program will accept them. The cursor for your digitizer is free from any mechanical linkages that could require adjustment or could interfere with placement of the document to be digitized.

A hold feature extends the effective size of the 17 inch by 17 inch digitizing surface to 99.99 inches, in each quadrant of the Cartesian coordinate system. With the use of proper software in the calculator, the effective size of the digitizing surface can be as large as desired.

Upon command, the digitizer can produce a wide variety of audible sounds which can be used to indicate any situation of special significance to the system operator. For instance, when digitizing around a closed curve, the digitizer can signal that the cursor has returned to the starting point.

EQUIPMENT SUPPLIED

The equipment supplied with each digitizer is listed in Table 1.

Table 1. Equipment Supplied with the digitizer.

-hp- Part No.	Quantity	Description
09864-90000	2	Digitizer Peripheral Manual
8120-1378	1	ac Power Cable
2110-0303	2	Fuse, 2 amp Slo-Blo (For 120V Operation)
2110-0312	2	Fuse, 1 amp Slo-Blo (For 230V Operation)
2140-0244	1	Spare Line Lamp
09107-90002	1	Sample Data Overlay
7120-2940	1 pkg.	Select Code Labels

The digitizer mainframe can be rack mounted by using a 5" rack mounting kit (-hp- Part No. 5060-8739). Instructions are included with the kit. When rack mounted, the digitizer fits a standard EIA 19" width mounting cabinet.

SPECIFICATIONS

The APPENDIX at the back of this manual contains a table of digitizer specifications.

INTRODUCTION

INSTRUMENT IDENTIFICATION

Your digitizer is identified by serial numbers located on the rear of the platen and on the power module on the rear of the mainframe.

SERVICE CONTRACTS

Service contracts are available for the digitizer. For further information contact your nearest -hp- Sales and Service Office; locations are listed at the back of this manual.

INITIAL INSPECTION

Your digitizer was carefully inspected both mechanically and electrically before shipment. It should be free of mars or scratches and in perfect electrical order upon receipt. Carefully inspect your digitizer for physical damage caused in transit; if there is any damage, file a claim with the carrier. If you wish to verify the electrical performance of your digitizer, use the inspection procedure provided in the operating manual supplied with the peripheral control block required for your calculator.

INSTALLATION

POWER REQUIREMENTS

The digitizer will operate within the voltage range of 90 to 126.5 volts ac and 180 to 253 volts ac. The line frequency must be within 47 to 66 Hz. The digitizer requires a maximum of 200 voltamps.

The line voltage switch located in the power module on the rear of the mainframe selects a nominal operating voltage range of either 120V or 230V. A different fuse is required for operation in each voltage range. Information on how to set the line voltage switch and how to change fuses is presented in the following pages.

CAUTION

DO NOT APPLY AC POWER TO THE DIGITIZER UNLESS THE LINE VOLTAGE SWITCH IN THE POWER MODULE IS SET TO THE PROPER POSITION. DAMAGE TO THE DIGITIZER CAN RESULT FROM FAILURE TO OBSERVE THIS PRECAUTION.

INSTALLATION

GROUNDING REQUIREMENTS

To protect operating personnel, the NATIONAL ELECTRICAL MANUFACTURERS' ASSOCIATION (NEMA) recommends that the digitizer cabinet be grounded. The digitizer is equipped with a three-conductor power cable which, when connected to an appropriate receptacle, grounds the cabinet of the digitizer. The center pin of the power cable connector is the ground connection.

SETTING THE LINE VOLTAGE SWITCH

The line voltage switch for 120V or 230V operation can be moved only when the fuse is taken out of the power module. (The procedure for removing and replacing the fuse is given below.) With the fuse removed from the power module, and the FUSE PULL lever moved all the way to the left, use a narrow, blunt instrument (such as a small screwdriver) to slide the lever of the line voltage switch to the proper position. See Figure 1. Be sure to move the lever of the switch as far as it will go, otherwise, the FUSE PULL lever cannot be returned to its normal position.

CHANGING THE FUSE

> NOTE
>
> For 120V operation use a 2 amp Slo-Blo fuse, -hp- Part No. 2110-0303.
>
> For 230V operation use a 1 amp Slo-Blo fuse, -hp- Part No. 2110-0312.

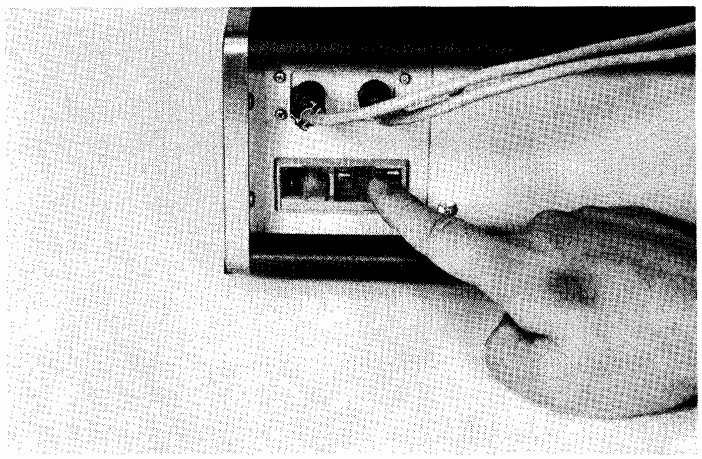
To change the fuse, refer to Figure 1 and proceed as follows:

1. Unplug the digitizer from its ac power source.
2. Remove the power cord from the power module.
3. Slide the plastic window of the power module to the left.
4. Pull the lever marked FUSE PULL. This will partially remove the fuse from the fuse clip.
5. Remove the fuse with your fingers.

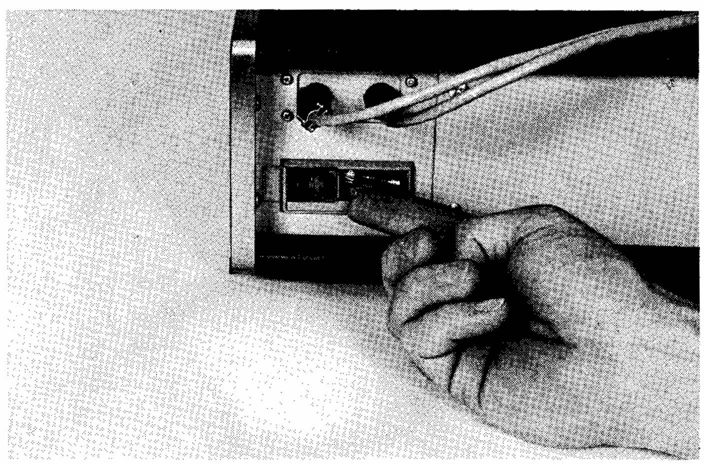
   At this point, the line voltage switch may be changed, if desired. Be sure to move the FUSE PULL lever all the way to the left before moving the switch. Also, be sure to move the switch as far as it will go.
6. Return the FUSE PULL lever to its original position.
7. Install the new fuse by pressing it firmly into the fuse clip.
8. Slide the plastic window over to the right.
9. Connect the power cord to the power module.
10. Connect the digitizer to the ac power source.

INSTALLATION

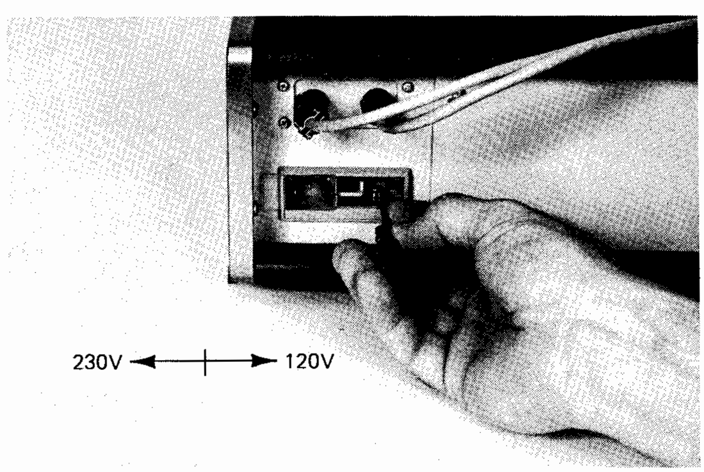
CHANGING THE FUSE (continued)



Remove the power cord, and move the window.



Pull the FUSE PULL lever to release the fuse.



Set the line voltage switch to the proper position.

Figure 1. Details of the Power Module.

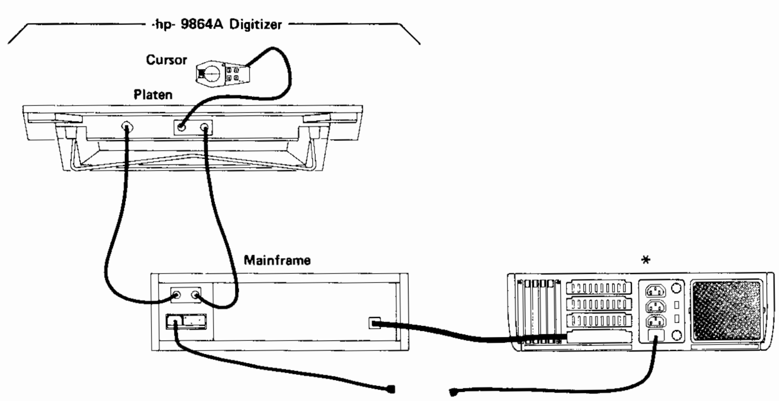
INSTALLATION

ASSEMBLY PROCEDURE

The digitizer has three elements: cursor, platen, and mainframe. Each of these three elements has at least one cable permanently attached to it. Figure 2 shows how the cables are connected, as well as how the digitizer is connected to the calculator. The digitizer can be plugged into any one of the four peripheral receptacles at the rear of the calculator.

> **CAUTION**
>
> BE SURE THAT THE CALCULATOR AND THE DIGITIZER ARE TURNED OFF WHILE CONNECTING OR DISCONNECTING ANY OF THE FOUR CABLES.

> **CAUTION**
>
> BE CAREFUL NOT TO INTERCHANGE THE CABLES WHICH CONNECT TO THE PLATEN. THE TERMINALS ARE MARKED, BUT THE CONNECTORS WILL MATE EVEN THOUGH THE CABLES ARE INCORRECTLY ROUTED.



*-hp- 9800 Series Calculator with the correct peripheral control block installed.

Figure 2. Interconnections of the Digitizer's Cables.

The plastic connectors on the cables must be handled carefully to avoid damaging them. When connecting a cable, rotate the free end of the cable until the connector keyways are aligned, then push the free end onto its mate. To disconnect a cable, use your thumb and forefinger to squeeze the ribbed portions of the connector while pulling on it gently. See Figure 3.

INSTALLATION

ASSEMBLY PROCEDURE (continued)

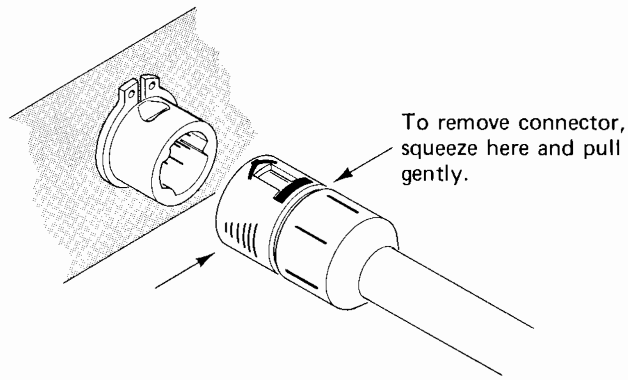


Figure 3. Details of the Connectors.

THE PERIPHERAL CONTROL BLOCK

An appropriate peripheral control block (ROM block) must be plugged into your calculator before the digitizer can be used in your 9800 System. This block provides the necessary 'hardware' to enable your calculator to control the digitizer.

Any -hp- Sales and Service Office can assist you in determining which peripheral control block is correct for your 9800 Series calculator.

DIGITIZER SELECT CODE

Since all calculator peripheral devices are connected in a 'party-line' fashion, each device must have a unique 'address' so that the calculator can specify which device should respond to each operation. The digitizer's address (or select code) consists of a one-digit number and is determined by the circuitry on the interface card. Each digitizer operation must include the correct select code, thereby instructing the proper interface card to respond to the operation while all other cards ignore it.

The digitizer may be set to any one of nine select codes by following the procedure given below. However, since each digitizer is preset to select code 9 at the factory, digitizer program information (program listings and pre-recorded programs) supplied by -hp- will specify select code 9. Therefore, to run programs supplied by -hp-, you must either reset your digitizer to select code 9 or modify each digitizer command in the program to specify the select code of your digitizer. The Digitizer Control section of your Peripheral Control Block Operating Manual describes which part of each digitizer command specifies the digitizer select code.

1. Switch the calculator and the digitizer OFF.
2. Disconnect the digitizer interface card from the calculator. Remove the four screws located on the top of the card assembly; then, turn the card over and lift off the bottom cover.

INSTALLATION

3. Locate the Select Code Switch (see Figure 4). Raise the hinged cover on the switch. Using a small, flat-blade screwdriver, carefully rotate the selector tab until it is positioned at the desired select code number (numbers are printed on the side and on the top cover of the switch). Before closing the cover, be sure the slot in the selector tab is positioned perpendicular to the length of the switch.
4. Close the switch cover and replace the interface card bottom cover. Secure the cover with the four screws which were removed in step 2.
5. Replace the Select Code Label on the digitizer mainframe with one which indicates the new select code. A package of labels is supplied with your digitizer.
6. Reconnect the interface card to the calculator and turn the calculator and digitizer ON. Verify that the desired select code is set by performing some digitizer operations (or running a digitizer program) which specify the new select code.

If you have difficulty in setting the select code, contact the nearest -hp- Sales and Service Office for assistance.

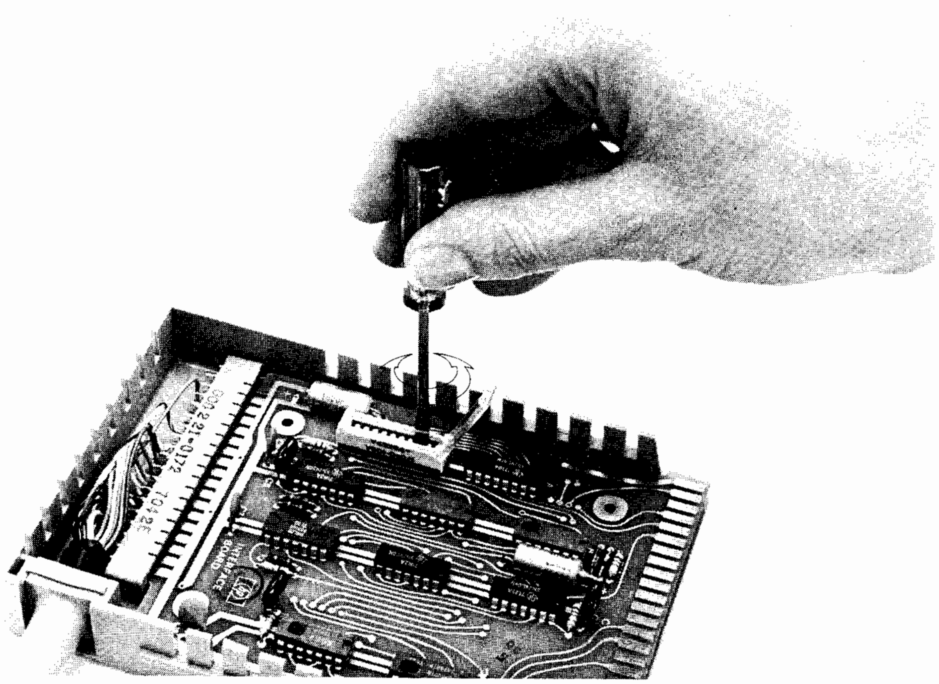


Figure 4. Setting the Digitizer Select Code.

INSTALLATION

ELECTRICAL INSPECTION

The procedure to verify your digitizer's electrical performance is contained in the operating manual supplied with the appropriate peripheral control block.

The Sample Data Overlay supplied with the digitizer is used during the electrical inspection.

CLEANING THE PLATEN AND CURSOR

When necessary for the sake of appearance, clean the platen with a soft cloth dampened with a mild detergent.

> **CAUTION**
>
> WHEN CLEANING THE PLATEN, DO NOT ALLOW ANY MOISTURE TO PENETRATE INTO THE CONNECTORS ON THE BOTTOM OF THE PLATEN.

Clean the cursor with a soft cloth that has been dampened in a mild detergent and wrung to remove excess moisture.

> **CAUTION**
>
> WHEN CLEANING THE CURSOR, DO NOT ALLOW ANY MOISTURE TO SEEP INTO THE CURSOR THROUGH THE OPENINGS FOR THE PUSH BUTTON SWITCHES, OR THROUGH THE COVER PLATE ON THE BOTTOM OF THE CURSOR.

CHANGING THE FRONT PANEL LAMP

> **WARNING**
>
> BEFORE CHANGING THE LINE LAMP, BE SURE THE DIGITIZER IS DISCONNECTED FROM THE AC POWER SOURCE.

The LINE switch on the front panel of the digitizer contains a neon light bulb. If the digitizer functions normally, but the LINE switch fails to light, the bulb is probably burned out. To change the bulb, turn the digitizer off and pull the switch lens straight out; the bulb will come out with the lens. Remove the old bulb and place the new one into the lens. Now reinstall the lens. An extra bulb, -hp- Part No. 2140-0244, is supplied with your digitizer.

NOTES

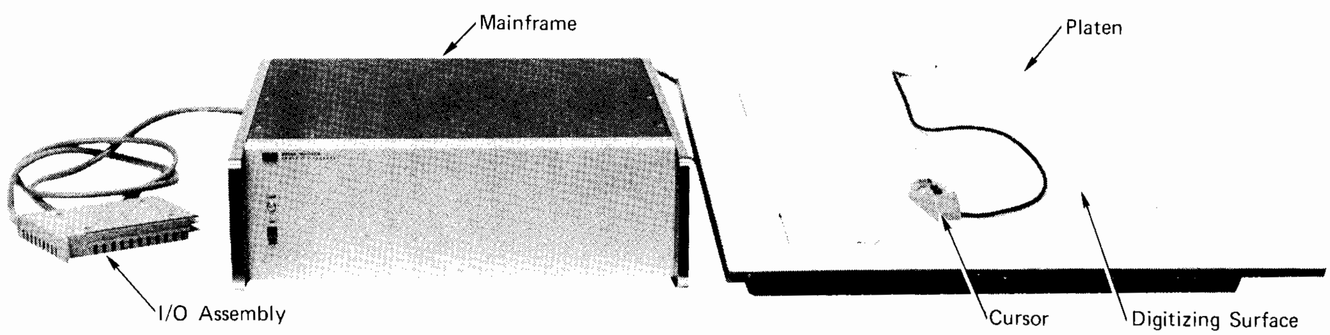


Figure 5. The 9864A Digitizer

INTRODUCTION

This chapter contains generalized operating instructions. For specific instructions for operating the digitizer with your 9800 Series calculator, refer to the operating manual for the peripheral control block which is required for your calculator.

WHAT THE DIGITIZER DOES

The digitizer enters Cartesian coordinate data from graphic records (charts, graphs, drawings, etc.) into a 9800 Series calculator. The coordinates are referenced to an origin, which is determined by the user, and entered into the calculator to the nearest hundredth of an inch (.01").

PHYSICAL DESCRIPTION

The digitizer (see Figure 5) consists of three elements: a platen with a digitizing surface, a free moving cursor, and a mainframe. The cursor and platen are connected to the mainframe by cables.

The platen has a digitizing surface that is a square area 17 inches on a side. The limits of the digitizing surface are marked on the platen. The digitizer may be used with the platen in any convenient position. The platen may sit level on the work surface, or it may be tilted by using the stand located on the underside of the platen.

THE DIGITIZING PRINCIPLE

The cursor is an electro-magnetic transmitter, operating at a low frequency. If you pick the cursor up and hold it to your ear while the digitizer is turned on, you may be able to hear a three kilohertz tone. After the digitizer has been on for a while, you will notice a slight temperature rise in the cursor, caused by the transmitting action.

> **NOTE**
>
> Due to its magnetic properties, the cursor will erase the information recorded on a calculator magnetic program card if the cursor is placed on the card.

The digitizing surface acts as a receiver for the transmissions from the cursor. The mainframe converts the received information into coordinates that describe the position of the cursor's cross hairs on the platen. Thus, conversion is not affected by the physical placement or location of the digitizing surface (e.g.; level, tilt, or orientation with respect to the points of the compass).

INTRODUCTION

THE DIGITIZING PRINCIPLE (continued)

To digitize information from a document, the document must be placed on the digitizing surface. The digitizer has two data entry modes: single and continuous. In the single mode, the cursor is moved to the desired locations and an entry is made into the calculator at each location in turn. In the continuous mode, the cursor is moved so that the cross hairs trace the line to be digitized. In either mode, a collection of coordinates is obtained that describes the line being digitized.

SCALING

Although your digitizer provides coordinates in inches only, a digitizing program can include a routine to convert data to any other unit of measure.

DOCUMENT REQUIREMENTS

Since the relationship between the cursor and the digitizing surface is purely electro-magnetic, the opacity, color, texture, and composition of the document being digitized have no effect on the digitizing process. The only requirements are that the material be:

1. no thicker than .025 inches,
2. able to lie flat on the digitizing surface,
3. non-magnetizable, and
4. that the lines or figures on the document be visible to the operator so that he can follow them with the cross hairs.

The method used to generate the information on the document (ballpoint pen, pencil, felt tip pen, heat sensitive chart paper, light sensitive chart paper, etc.) will have no effect on the digitizing process.

DIGITIZER CONTROL

LOCATIONS OF THE CONTROLS

The LINE switch on the mainframe controls the application of ac power to the digitizer. The LINE switch lens is illuminated when power is applied to the insturment.

With the exception of the LINE switch on the mainframe, the controls of the digitizer are located on the cursor.

DIGITIZER CONTROL

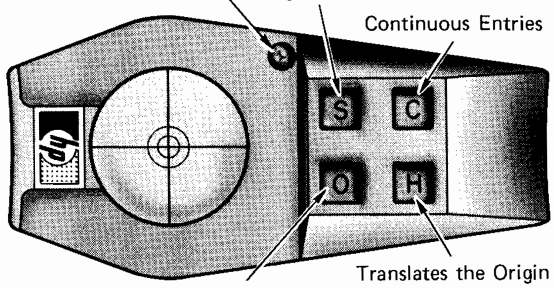


Figure 6. The Cursor for the 9864A Digitizer

HANDLING THE CURSOR

Either of the following things constitute improper cursor motion, unless it occurs while 'hold' (described later) is in effect: tilting or raising the cursor more than .040 inches above the digitizing surface; or sliding the cursor outside the digitizing area. If you move the cursor improperly, there will be an audible tone, lasting approximately three quarters of a second, and the sample light will go out; these things indicate that the origin has been lost. The origin must be re-established before any further entries can be made.

SETTING THE ORIGIN [O]

[O] is used to set the origin. The origin is set by placing the cross hairs of the cursor over the point that is to be the origin, and then pressing [O]. The origin may be set anywhere on the digitizing surface. Once the origin is set the sample light on the cursor will come on.

Setting an origin cancels the hold feature, which is described later.

LOCATING THE X AND Y AXES

When the digitizer is first turned on, it does not assume any particular point to be the origin. When a point on the digitizing surface is specified as the origin a set of X and Y axes is defined. The labeling of the axes, and the assignment of the positive and negative directions along the axes, are automatic and are always done in the same way with respect to the digitizing surface; the positive X and Y directions on the digitizing surface are marked with arrows.

DIGITIZER CONTROL

CONDITIONS FOR DATA ENTRY

The coordinates of the cursor cross hairs are entered into the calculator when two conditions are satisfied. First, the calculator must request the data.* Second, the operator must instruct the digitizer to make the entry. It is necessary for the calculator to request the coordinates because programs must be written so that each program expects the data at specific places in the program. It is reasonable for the operator to have some control over the entry process because he is the means by which the cursor is moved across the document, and he may desire that only certain points be entered.

Any transfer of information from the digitizer to another peripheral must take place under control of the calculator. It is not possible, for instance, to transfer data from the digitizer directly to the plotter, without those peripherals being controlled by the calculator.

DATA ENTRY MODES

The operator can make his entries in either of two modes: single or continuous.

In the 'single' (discrete) mode, the calculator requests coordinates, but the operator must initiate each entry by giving the digitizer a command. This action is repeated for each point digitized in the single mode. The single mode is useful when digitizing a figure composed of straight line segments, as only the verticies of the figure will be entered. It can also be used to digitize selected points along a curved line.

In the 'continuous' mode the digitizer makes every entry as soon as the calculator requests it. The continuous mode is useful when digitizing a figure composed of curved lines since the operator can simply trace around the figure. In the continuous mode of operation the operator must be careful how he moves the cursor, as any extraneous movement of the cursor will result in the entry of erroneous coordinates.

SINGLE MODE

S

After a data request has been given from the calculator, pressing [S] will enter the current coordinates of the cursor cross hairs. [S] must be released and another data request received before another entry can be made. However, the next data request will be recognized even though [S] is still held down from the previous entry.

Each time that [S] is used to make an entry the sample light on the cursor will blink.

*Specific data request commands for your 9800 System are defined by the particular peripheral control block which is plugged into your calculator; thus the general term 'data request' will be used to represent a calculator-to-digitizer command for requesting data.

DIGITIZER CONTROL

CONTINUOUS MODE

[C]

When the digitizer is placed in the continuous mode, a data request (by itself) will cause data entries to be made into the calculator. The digitizer is placed in the continuous mode by pressing [C]. After pressing [C] the digitizer remains in the continuous mode until [C] is pressed again.

> NOTE
>
> If, while taking data in the continuous mode, you accidentally press [O], the digitizer will cease to sample. The continuous entry mode will have to be re-established by pressing [C]. However, since [O] was pressed, the origin will no longer be the same point that it was, and must be re-established before continuing to sample.

The digitizer may be placed in the continuous mode before or after a data request is given. Also, the digitizer will recognize a data request which precedes the selection of the continuous mode; then, when [C] is pressed, an entry is made immediately.

If, during the execution of a program, the digitizer is making entries in the continuous mode, the sample light on the cursor will blink continuously. If the entry rate is fairly slow (less than five a second) the sample light will blink at the actual sample rate. If the sample rate is higher than about five samples a second, the sample light will blink at its most rapid rate of around five blinks per second.

The digitizer will never be in the continuous mode just after application of ac power.

> IMPORTANT NOTE
>
> DO NOT PRESS [S] WHILE SAMPLING IN THE CONTINUOUS MODE. PRESSING [S] WHILE SAMPLING IN THE CONTINUOUS MODE CAN CAUSE ERRONEOUS ENTRIES.

SAMPLE RATE

In the single mode, the rate at which samples are taken depends upon how often the calculator requests data, and upon how often the operator initiates each entry.

In the continuous mode, the sample rate is a function of the rate at which the calculator requests data. The exact rate depends upon the amount of activity the calculator must perform between entries, including the time taken for actions of any other peripherals in the system.

DIGITIZER CONTROL

THE HOLD FEATURE

The digitizer is equipped with a 'hold' feature that permits easy handling of documents larger than the digitizing surface. The hold feature enables the operator to translate (shift) the origin in any direction. Translation is accomplished as a genuine movement, rather than by simply setting a new origin. It is possible to continue to translate the origin until it is no longer located on the digitizing surface. When this happens, the coordinates of points on the digitizing surface will have ordinates and/or abscissas whose absolute values are greater than 17 inches (the size of the digitizing surface). By correctly translating the origin, it is possible to effectively locate the origin anywhere on the document, even though the document is larger than the digitizing surface.

HOLD
[H]

Pressing [H] activates the hold feature. It will remain active until either [H] is pressed again, or [O] is pressed. While hold is active you may remove the cursor from the digitizing surface.

> NOTE
>
> If, while hold is in effect, [O] is pressed while the cursor is away from the digitizing surface, the hold feature will be released; the digitizer will then indicate improper cursor motion. See Handling The Cursor on Page 2-3.

While hold is active the digitizer ignores any (improper or otherwise) cursor motion. This allows the operator to translate the origin in any direction.

The digitizer can make single and continuous entries into the calculator while hold is active. However, the coordinates entered will all correspond to the location of the cross hairs at the time when hold was activated. These coordinates will not change until hold is deactivated and the cursor is moved.

TRANSLATING THE ORIGIN WITH HOLD

When hold is activated the cross hairs will be at some definite (but not particular) coordinates. Now the cursor is moved to some new position (perhaps differing in both X and Y values). When the cursor reaches its new position, and hold is deactivated, the coordinates of the new position are the same as they were at the old position. The origin has been moved in X and in Y by an amount exactly equal to the distances in X and Y that the cursor was moved while hold was in effect. Since the origin has been relocated, the coordinates of all the points on the digitizing surface have been changed, and any entries made into the calculator will reflect these changes.

DIGITIZER CONTROL

Consider the example shown in Figure 7. P_1 is the point (8, 7), referenced to the old origin. While the cursor cross hairs are over P_1, hold is activated. Then the cursor is moved to P_2. (Note that the cursor may be removed from the digitizing surface during this movement.) When the cross hairs are over P_2, hold is deactivated. Now P_2 has the same coordinates that P_1 used to have. In this particular example the origin was translated 5 units to the left and 4 units upwards, the same as the resulting difference in cursor position between P_1 and P_2.

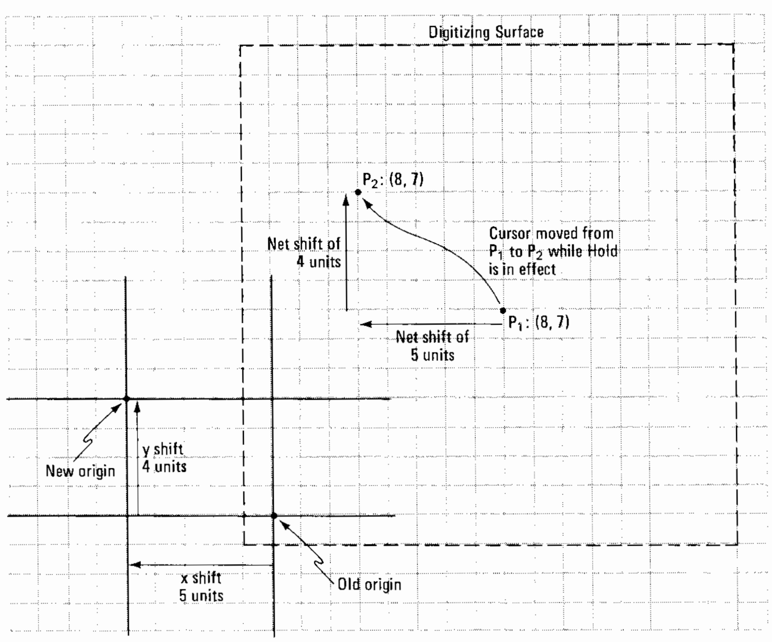


Figure 7. Translation of the Origin using Hold.

Figure 8 contains some points and their new coordinates (with respect to the translated origin). Notice the coordinates of P_4, (19, −1). It has an abscissa of 19, which is a value not obtainable with the original origin. Notice also that P_5 is in the same physical position on the digitizing surface as was P_1 before the origin was translated. The point now has coordinates (13, 3). Observe that the coordinates of P_5 are related to the coordinates of P_1 by the X shift and Y shift induced by the translation.

DIGITIZER CONTROL

TRANSLATING THE ORIGIN WITH HOLD (continued)

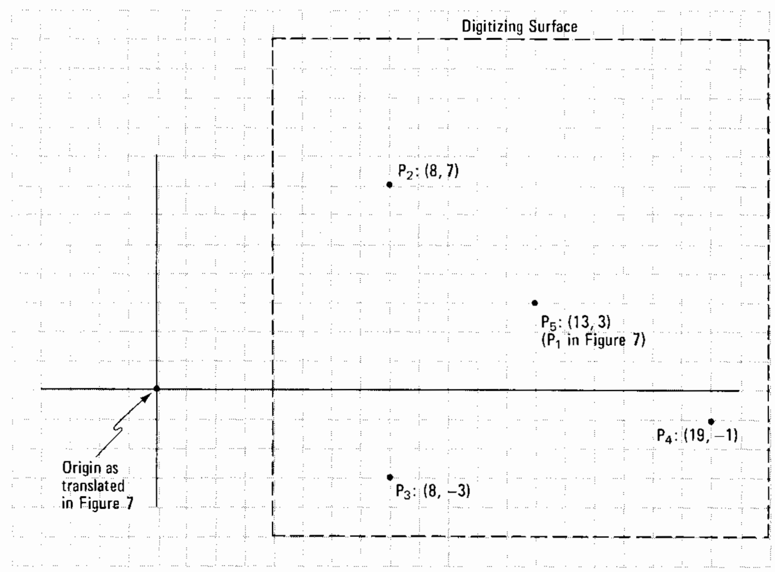


Figure 8. Locations of Points with the Translated Origin of Figure 7.

REPEATED TRANSLATIONS AND MAXIMUM VALUES

The hold feature may be used to translate the origin as many times as desired. In this way the absolute value of either, or both, the abscissa and the ordinate can go as high as 99.99 inches. If a positive value of 99.99 is exceeded by .01 inches, the value will "turn over" to +0.00. Now, for example, if the cursor were moved back toward the origin from say, 1.5 inches (which is really 101.5 inches) for a distance of 2 inches, the resulting value would be –.5 inches, rather than +99.5 inches. The same principle applies to cases where a value of –99.99 is exceeded. In those cases, however, the roles of the signs are reversed.

If the cursor is moved back toward the origin from a "turned over" value of ±0.00, the coordinates may count back from ±100 (go back through ±99.99, etc.) or, they may count back from ±0.00 (go through ±0.01, etc.). Which, depends upon how far the cross hairs penetrated into the hundredth of an inch corresponding to the "turn over" value of ±0.00. If the cross hairs penetrated less than half way, the digitizer will count back from ±100; penetration past half way results in counting back from ±0.00.

DIGITIZER CONTROL

DIGITIZING STRIP CHARTS

The hold feature can be of immense value when digitizing strip charts longer than 17 inches. The method is to digitize the strip chart in sections (probably from left to right), shifting the chart over (to the left) by some amount after completing each section. Each time the chart is shifted over by some amount, use the hold feature to translate the origin by the same amount. This is equivalent to having the origin located over some readily identifiable point, such as the intersection of the data and some graduation printed on the chart. Now activate the hold feature by pressing [H], and then slide the chart over. The chart must be kept parallel to its original position or the forthcoming data will be skewed. However, the chart need not have the same position in the Y direction. (The origin can be translated in Y, just as in X.) Before beginning to digitize the next section, position the cross hairs over exactly the same point on the chart as they were over before hold was activated. Now deactivate hold by pressing [H], again, and continue to digitize across the next section of the chart.

NOTES

SAMPLE DENSITY

Sample density is the number of different coordinates digitized per unit-distance of the cursor movement, and is a function of these things: the sample rate, the rate of cursor movement, the position of the cursor, and the direction of cursor movement.

The effect of the first two factors, sample rate (which is controlled by either the operator or the program), and rate of cursor movement (which is controlled by the operator), is self explanatory. The effect on sample density of the remaining two factors requires explanation.

The maximum sample density varies from a low of approximately 70 points per inch, to a high of approximately 140 points per inch.

Because the resolution of the digitizer is one hundredth of an inch (.01"), the highest sample density possible, which is for a line parallel to either the X axis or the Y axis, is 100 points per inch.

For lines that are not parallel to either axis, the maximum sample density is unpredictable.

Figure 9 shows three .1" line segments. l_1 crosses the X axis at an angle of 45° (it could also cross at 135°). Notice that the placement of l_1 is such that it can be exactly described by the available coordinates of the digitizing surface; the coordinates (to the nearest .01") describing the line actually coincide with the line. As the cursor is moved along the line the X and Y coordinates round to the next values at the same time. Note that the minimum possible distance, between any two adjacent coordinates describing l_1, is the diagonal of a square which is .01" on a side. The length of the diagonal is .014". One inch divided by .014 inches equals 71.4. This implies that the maximum sample density for any line with the properties of l_1 is about 70 points per inch.

Now consider l_2; it also crosses the X axis at an angle of 45°. However, l_2 cannot be exactly described by the coordinates available because of its position with respect to those coordinates. Notice that for every one point describing l_1 there are two points describing l_2; as the cursor is moved along l_2, the X and Y coordinates **do not round to the next values at the same time**. If the cursor were moved upwards and to the right along l_2, the X coordinate would round to the next value before the Y coordinate would. Thus the maximum sample density for a line such as l_2 is twice that of l_1, or approximately 140 points per inch.

The conditions surrounding l_3 are similar to those surrounding l_2, Here, the X and Y coordinates do not round to the next value at the same time because the line does not cross the X axis at either 45° or 135°. In a case like this, the maximum sample density is affected by the angle at which the line crosses the X axis, and by its position with respect to the origin.

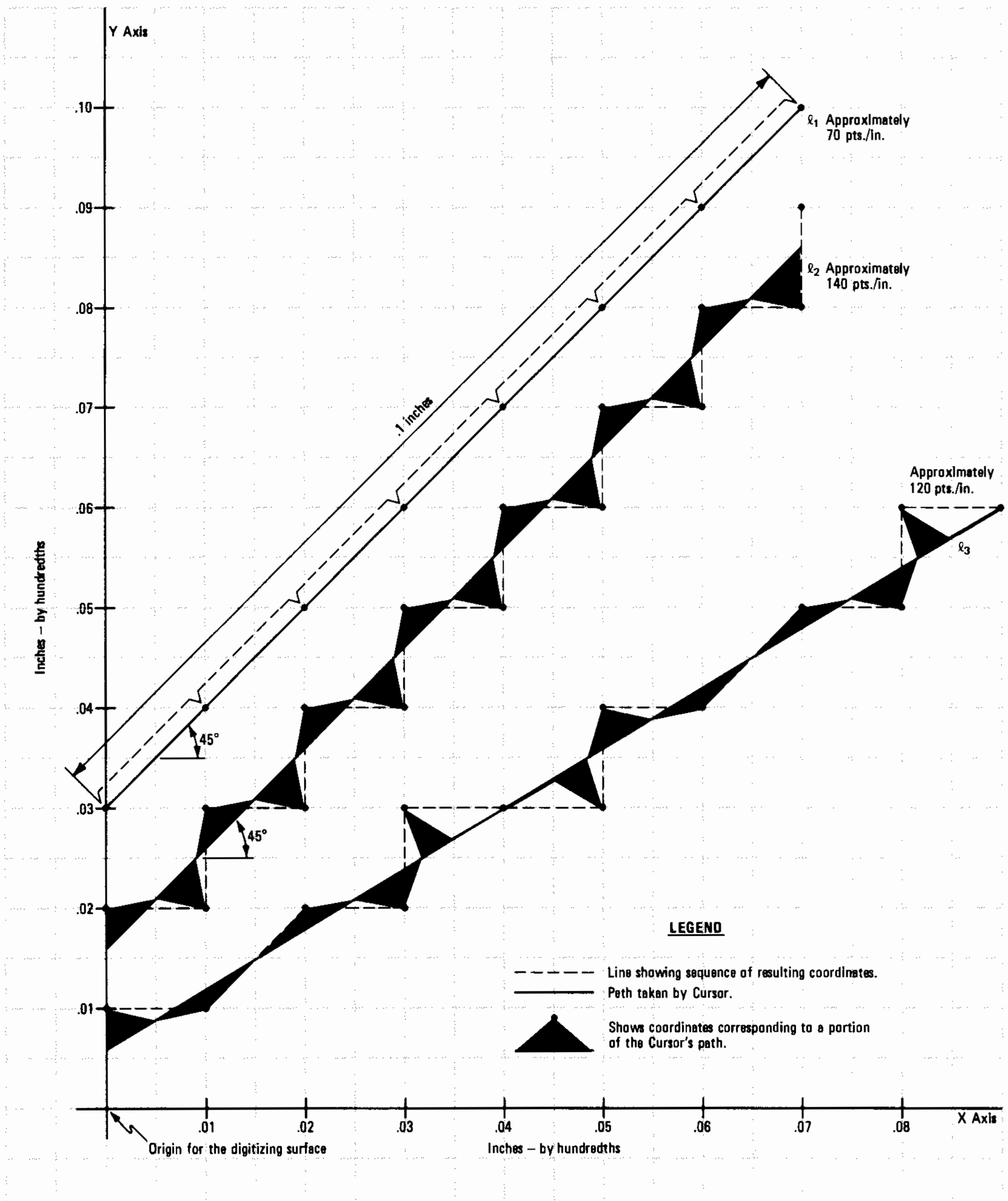


Figure 9. Effects of Cursor Motion and Position on Maximum Sample Density.

In certain applications, when a line such as l_2 or l_3 is digitized, the resulting coordinates must be smoothed before they can be used. See the section titled SMOOTHING for information describing when smoothing is necessary, and how it is accomplished.

SMOOTHING

THE NEED FOR SMOOTHING

Some applications require that the incoming coordinate data from the digitizer be smoothed before it is used in any calculations of a result. This is especially true in curved line length applications where a plotter is used to plot curved data at some size larger than the original source.

Smoothing is needed because of a phenomenon known a "jitter" in the incoming coordinates. Jitter can best be described in terms of (un-smoothed) data taken from a smooth curve. If this data were used to plot the curve several times larger than the original, the plotted curve would not be smooth; it would contain rapid, small scale deviations from an ideal plot.

THE CAUSES OF JITTER

Jitter occurs primarily during continuous sampling, and has two causes; the finite resolution of coordinates by the digitizer, and (to a lesser extent) minor deviations from the intended path of cursor motion.

The digitizer's finite resolution of coordinates to the nearest hundredth of an inch puts a limit on the degree of approximation to which a smooth curve can be described by the digitizer. Thus, some of the points on the actual curve may be as much as a half hundredth inch (.005") away, in either or both axes, from the corresponding points supplied by the digitizer. Furthermore, the direction of these errors can alternate. When the coordinates supplied by the digitizer are connected together in sequence, the result is a "staircase" approximation of the original curve (see Figure 9 on Page 3-2). It is clear that the length of the "staircase" can exceed the actual length of the line. The error in line length induced by this type of jitter is worst when the line is parallel to a line passing through the origin at 45° or 135°, and has a theoretical maximum of about 43%.

Minor deviations from the intended path of cursor motion are caused by the fact that a human is moving the cursor. It is difficult not to make some error while digitizing in the continuous mode. The amount of error is influenced by the intangible factors that are largely beyond the control of the operator; as such, they are difficult to predict, and the amount of error will vary from time to time. Smoothing, however, can significantly reduce the effect of this type of jitter.

SMOOTHING

SMOOTHING TECHNIQUES

There are two types of smoothing that can be used to deal with jitter; discrimination and averaging. Discrimination involves rejection of some coordinates and outright acceptance of the rest. The discrimination is based on the distance between successive incoming points; points that are not sufficiently far enough away from the previously accepted point are rejected. This type of smoothing is called "partial smoothing". Averaging involves using the incoming data as the input values in a formula that produces adjusted values for the coordinates of each point. There is a highly effective combination of discrimination and averaging, called "full smoothing".

EFFECT OF SAMPLE DENSITY ON SMOOTHING

High sample densities produce more accurate results than do low sample densities, because high sample densities greatly enhance the effects of smoothing. This is true despite the fact that high sample densities actually increase jitter.

High sample densities are achieved by slow, deliberate movement of the cursor. Unfortunately, this increases jitter in two ways; by removing the discrimination inherent in low density sampling, and by increasing the difficulty of obtaining smooth motion of the cursor itself.

Although low density sampling acts as a form of discrimination, and thus smoothing, it is an unsure method of smoothing because sample density is a difficult parameter to regulate. It is far better to sample at a high density and let the program do the discrimination. Otherwise, useful data could be lost if the sample density somehow went too low.

EXAMPLES OF SMOOTHING

Figures 10 through 15 illustrate the concepts of smoothing discussed in this section. It is helpful to know how these figures were made.

The original data for the figures were certain sections of the Sample Data Overlay supplied with your digitizer. The unsmoothed data was stored in a bulk data storage device. Curves showing unsmoothed data were made by plotting these stored values with the plotter. Next, the data was read and smoothed (in the appropriate way for each figure) before it was plotted. To allow easy comparison of the results, all plotting was done at ten times the size of the original data. The minor divisions of the grid shown in each figure represent one hundredth of an inch (.01").

Each figure contains a table that summarizes the important particulars for that figure. Any estimates given in these tables were made by assuming that the actual length was closely approximately by the fully smoothed length.

SMOOTHING

Figure 10 through 12 show the effect of partial smoothing. The degree of smoothing is controlled by the value of $\Delta\ell$ min. $\Delta\ell$ min is the distance from the previously accepted point which must be exceeded before a successive point will be accepted and used in the distance calculations. Notice that the most accurate results are achieved in Figure 12, where $\Delta\ell$ min equals .05. Also, the partially smoothed data of Figure 12 is pleasing approximation of the original curve (which was the smaller lobe of A_4 of the Sample Data Overlay).

Figure 11 shows the result of setting $\Delta\ell$ min too large. Notice the strong tendancy of the smoothed data to always lie "inside" the original curve.

Figure 13 shows the fully smoothed and unsmoothed results obtained from digitizing exactly one eighth of the one inch radius circle on the Sample Data Overlay. (That it was exactly one eighth of the circle was verified by listing the points which were previously stored in a bulk storage device.) Since it is known that exactly one eighth of the circle was digitized, it was possible to measure the accuracy attained with the full smoothing algorithm. That accuracy exceeded 99%.

Figures 14 and 15 compare the effects of sample density on full smoothing. It is clear from these figures that the sample density should be as high as possible.

The algorithm used for full smoothing in these examples involved both discrimination and averaging. Discrimination was accomplished by partial smoothing (taking points which are no less than .02" apart). The partially smoothed data was then averaged by a technique known as "single exponential smoothing".

Partial smoothing first, does a lot to smooth the data. It tends to suppress and space out the peak excursions of the jitter. Partial smoothing before averaging allows the averaging to be less severe, in turn allowing the fully smoothed results to track the original curve with less error when the original curve changes direction rapidly.

Single exponential smoothing retards any tendancy for change in the incoming coordinates, thus smoothing out any small bumps in the smoothed data.

The formula for single exponential smoothing is:

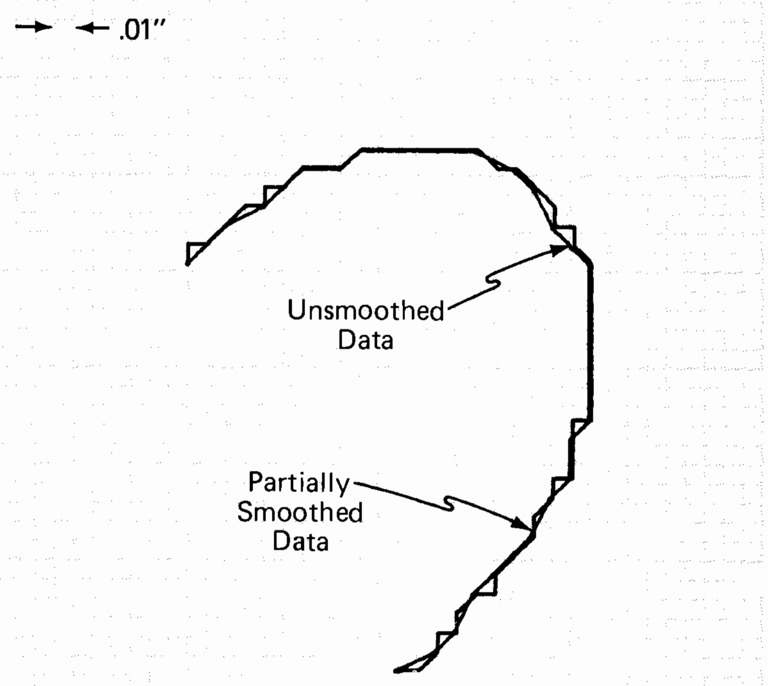
$\tilde{S}_n = \alpha S_n + (1 - \alpha)\tilde{S}_{n-1}$, where

S_n is the n^{th} unsmoothed incoming value

$\tilde{S}_n$ is the smoothed result for the n^{th} incoming value

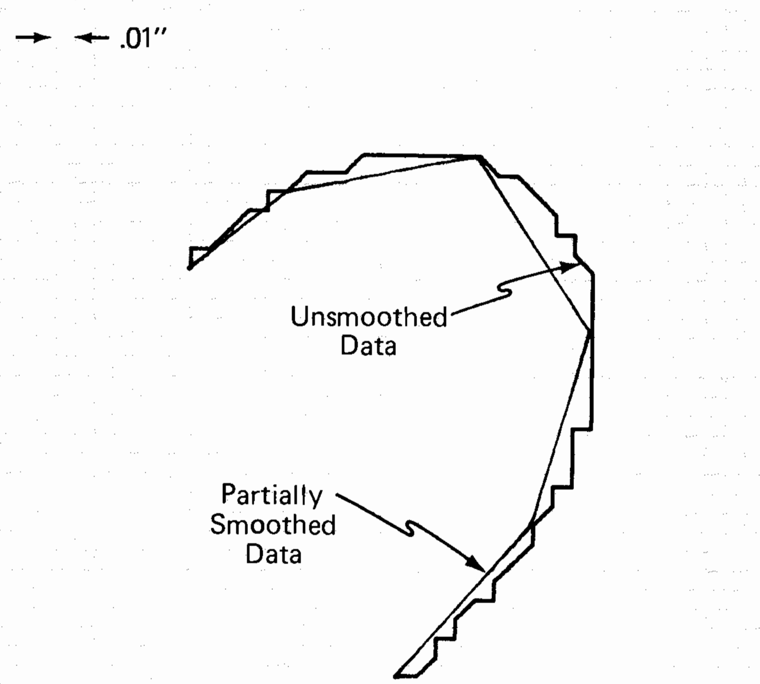
$\tilde{S}_{n-1}$ is the previous smoothed value, (obtained for S_{n-1})

α (alpha) is a positive number between 0 and 1.



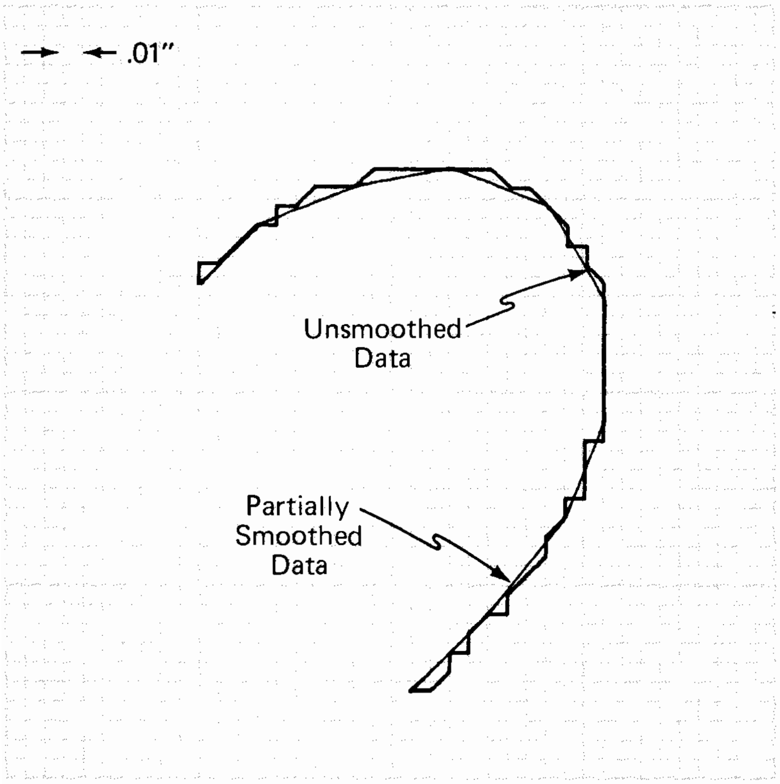
Sample Density . . . 70-140 pts./in.
Estimated Actual Length
(Fully Smoothed Length) . . . .49 in.
Unsmoothed Length . . . . . . .56 in.
Partially Smoothed Length . . .51 in.
Estimated Error of
Unsmoothed Length 14.3%
Estimated Error of
Partially Smoothed Length . . 4.1%

Figure 10. Partial Smoothing With $\Delta \ell$ min = .01.



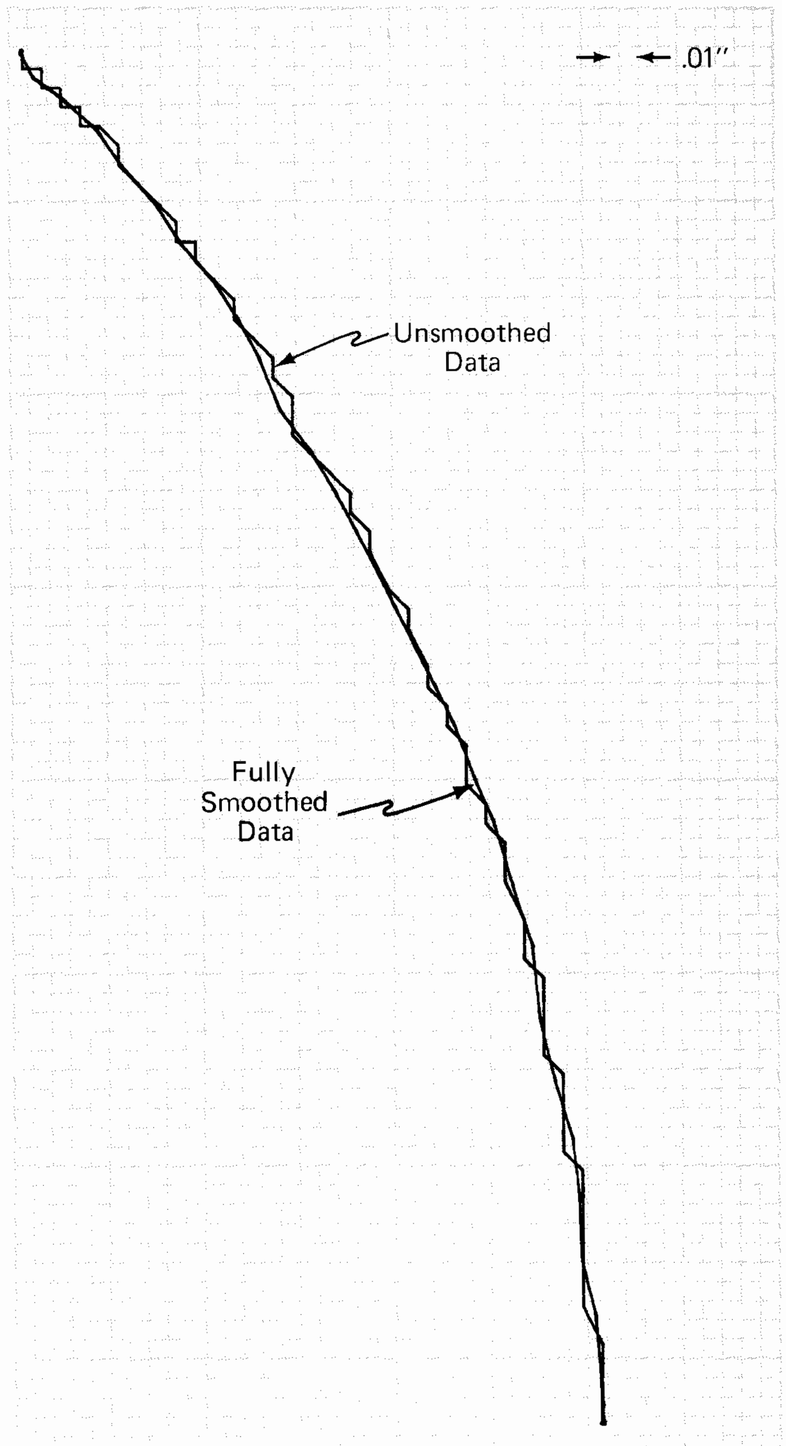
Sample Density . . . 70-140 pts./in.
Estimated Actual Length
(Fully Smoothed Length) . . . .49 in.
Unsmoothed Length . . . . . . .56 in.
Partially Smoothed Length . . .48 in.
Estimated Error of
Unsmoothed Length 14.3%
Estimated Error of
Partially Smoothed Length . . 2.0%

Figure 11. Partial Smoothing With $\Delta \ell$ min excessively large; $\Delta \ell$ min = .1



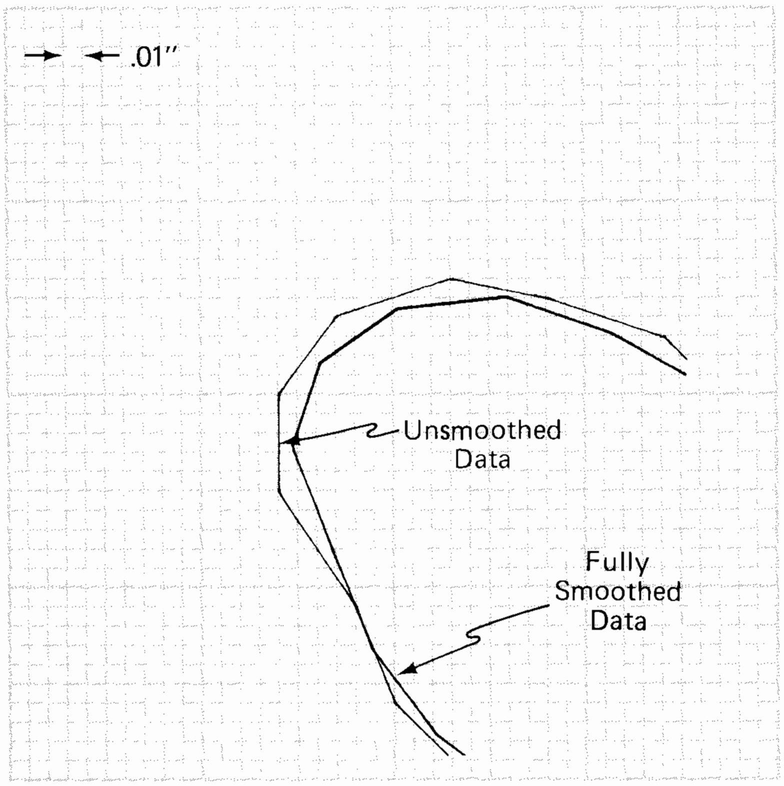
Sample Density . . .	70-140 pts./in.
Estimated Actual Length (Fully Smoothed Length) . . .	.49 in.
Unsmoothed Length	.56 in.
Partially Smoothed Length . .	.49 in.
Estimated Error of Unsmoothed Length	14.3%
Estimated Error of Partially Smoothed Length . .	<.5%

Figure 12. Partial Smoothing With $\Delta \ell$ min = .05



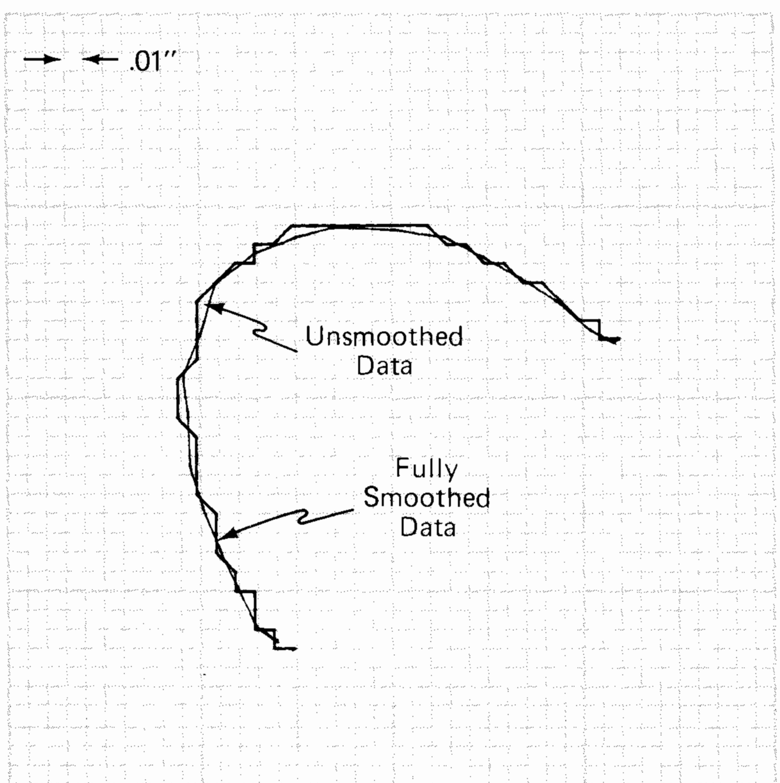
Sample Density . . .	70-140 pts./in.
Actual Length (by Computation)	.785 in.
Unsmoothed Length	.856 in.
Fully Smoothed Length . . .	.781 in.
Absolute Error of Unsmoothed Length	9.0%
Absolute Error of Smoothed Length	.51%

Figure 13. Smoothed Data Describing One-Eighth of a One Inch Circle



Sample Density . . . . 15-20 pts./in.

Figure 14. Effects of Insufficient Sample Density on Fully Smoothed Data.



Sample Density . . . 70-140 pts./in.

Figure 15. Fully Smoothed Data with Adequate Sample Density

MISCELLANEA

DOCUMENT ALIGNMENT

Some digitizer applications require that the document be aligned parallel to the X or Y axis; the simple method represented below will help in the alignment process.

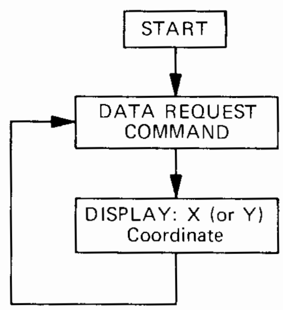


Figure 16. Document Alignment Program Flowchart

After writing a program to implement the preceding flowchart, enter it into the calculator and place the document on the digitizing surface, in approximately the position you desire. Set the origin at one end of a line (on the document) that is to be made parallel to an axis. Start the program from the calculator keyboard, and press [C] on the cursor. Use your thumbnail to keep the end of the line that is over the origin from shifting. Now use the digitizer to find the X or Y coordinate of the other end of the line. The coordinate is continuously displayed by the calculator. Adjust the document until the coordinate indicates that the line is parallel with the appropriate axis. Now remove your thumb from the other end of the line and use that hand to hold the document firmly to the digitizing surface. Recheck each end of the line and make any necessary adjustments in document position, before taping it to the digitizing surface.

ROTATION OF COORDINATES

The need for precise alignment of a document can be eliminated by the use of a program which takes any misalignment into account. The program flowcharted in Figure 18 contains a routine to correct digitized coordinates; the corrected coordinates are then available for data reduction.

The technique is based on the mathematical relationships illustrated by Figure 17. The degree of misalignment (represented by the angle θ) is limited to acute angles, however, the X axis of the document may lie above or below the X axis on the digitizer (θ may be positive or negative).

MISCELLANEA

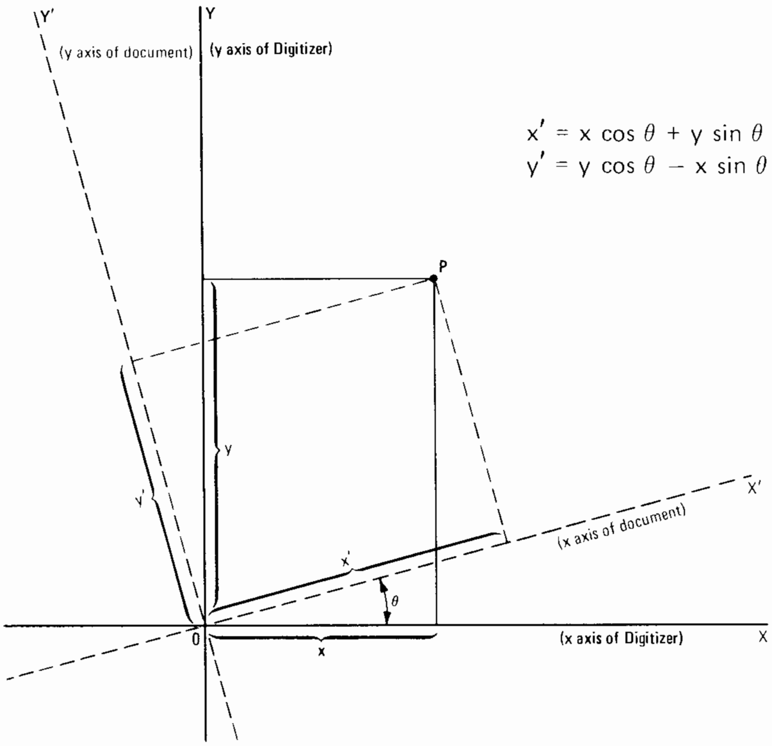


Figure 17. Relationships of Axes Rotation.

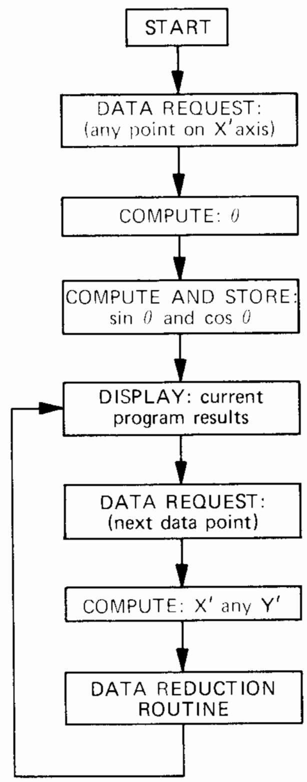


Figure 18. Flowchart of a Digitizer Program with Provision for Rotation of Coordinates

The following should be taken into account when operating a program based on the preceding flowchart:

1. The program assumes that the origin of the axes on the document lies directly over the origin as set by pressing [O]; thus, the origin must be set while the cross-hairs are centered over the origin of the document.

2. The first point digitized must be digitized with [S], and must lie on the extreme right hand portion of the X axis of the document. Digitizing this point allows the program to determine the angle of rotation.

3. Any subsequent digitizing would be done in the normal manner for the type of data reduction being performed.

MISCELLANEA

AUTOMATIC CLOSURE

Many problems require digitizing around a closed figure or curve. In these applications, it is often desirable to construct the program in such a way that it detects the fact that the complete figure has been digitized. Then at that time, the program signals the operator with the audible tone. This type of operation removes the need for the operator to remember where he started to digitize the figure, or to mark the figure with the starting point.

Such a program stores the coordinates of the first point digitized. As each successive point is digitized, a comparison is made to see if the new point lies within a circle (or a square) of some small size, centered around the initial point. If the new point is sufficiently close to the first point (typical closure values range from .02 to .05 inches), a check is made to determine if there were ever **any** points entered that **did not** lie inside the closure range. For if there have not been, the cursor must still be on its way **out** of the closure range. Closure is achieved when the cursor comes back into the closure range, after having been out of it. The program uses a flag to indicate whether or not the closure range has ever been left. After closure has been detected, and the new point has been used for normal data reduction, the very first point entered by the program is recalled from memory and used as the next value in the data reduction process. This actually closes the figure as far as the computations are concerned. At this point the program might branch to a segment that would give the audible tones, and then stop.

Whenever you sample in the continuous mode, around a closed figure, it is good practice to always press [C] when closure occurs. This cancels the continuous mode. There is no way for the program in the calculator to terminate the continuous mode. If you fail to cancel the continuous mode, and wish to use the program again, for the same or a different figure, you may get some erroneous entries.

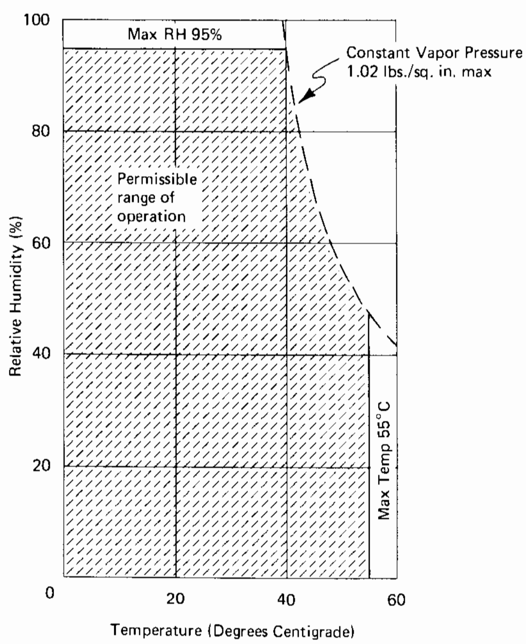
APPLICATIONS OF THE AUDIBLE TONE

There are numerous uses for the programmable audible tone. As previously mentioned, it can be used to indicate closure when digitizing around a closed figure. It can also be used to indicate that the cursor is being moved too quickly to maintain a desired minimum sample density. It can be used to aid the operator in taking samples that are equally spaced in one of the axes. In this application, the tone would be sounded whenever the cursor had been moved through the next interval without the associated point having been entered. The tone would continue to sound until the operator moved the cursor back along its path (actually retracing the route taken along the figure) until the missed point was entered. Also, the tone can be used to indicate that a certain maximum number of samples have been taken.

The calculator command to sound the audible tone is described in the peripheral control block operating manual.

APPENDIX-DIGITIZER SPECIFICATIONS

PARAMETER	SPECIFICATION
Size of digitizing surface:	17 inches by 17 inches, minimum.
Graphic media:	Flat, non-magnetic material less than .025 inches thick may be digitized without loss of accuracy.
Origin selection:	Any point on the digitizing surface may be designated as the origin.
Loss of origin:	The cursor may be lifted .040 inches above the digitizing surface before the origin is lost.
Origin translation:	The origin may be translated in any direction. The amount of shift in each axis during a translation is limited by the size of the digitizing surface. However, the origin can be repeatedly translated, even after it is no longer located on the digitizing surface.
Maximum coordinates:	±99.99 inches for both the abscissa and the ordinate.
Resolution:	To the nearest .01 inches.
Absolute accuracy, relative to a non-translated origin, including any error induced by non-perpendicularity of the axes:	Over the entire digitizing surface, the absolute error of the abscissa and of the ordinate will not exceed ±.015 inches from 15°C to 30°C, nor exceed ±.03 inches from 0°C to 15°C or from 30°C to 50°C.
Useful accuracy, relative to a translated origin:	Depends upon the accuracy with which the document was shifted when the origin was translated.
Maximum rate at which the cursor may be moved:	150 inches per second.
Maximum sample rate:	Approximately 50 per second; varies from program to program due to variations in execution times.
Power requirements:	90 to 126.5V and 180 to 253V; 47 to 66 Hz; 200 voltamps, max.
Altitude range:	During operation: 0 to 15,000 feet. During storage: 0 to 25;000 feet.
Environmental temperature and humidity range:	During operation: see graph. During storage: −40°C to 75°C, provided relative humidity does not exceed 30%.



SALES & SERVICE OFFICES

UNITED STATES

ALABAMA
P.O. Box 4207
2003 Byrd Spring Road S.W.
Huntsville 35802
Tel: (205) 881-4591
TWX: 810-726-2204

ARIZONA
2336 E. Magnolia St.
Phoenix 85034
Tel: (602) 252-5061
TWX: 910-951-1330

5737 East Broadway
Tucson 85716
Tel: (602) 298-2313
TWX: 910-952-1162

CALIFORNIA
1430 East Orangethorpe Ave.
Fullerton 92631
Tel: (714) 870-1000

3939 Lankershim Boulevard
North Hollywood 91604
Tel: (213) 877-1282
TWX: 910-499-2170

1101 Embarcadero Road
Palo Alto 94303
Tel: (415) 327-6500
TWX: 910-373-1280

2220 Watt Ave.
Sacramento 95825
Tel: (916) 482-1463
TWX: 910-367-2092

9606 Aero Drive
San Diego 92123
Tel: (714) 279-3200
TWX: 910-335-2000

COLORADO
7965 East Prentice
Englewood 80110
Tel: (303) 771-3455
TWX: 910-935-0705

CONNECTICUT
508 Tolland Street
East Hartford 06108
Tel: (203) 289-9394
TWX: 710-425-3416

111 East Avenue
Norwalk 06851
Tel: (203) 853-1251
TWX: 710-468-3750

FLORIDA
P.O. Box 24210
2806 W. Oakland Park Blvd.
Ft. Lauderdale 33307
Tel: (305) 731-2020
TWX: 510-955-4099

P.O. Box 20007
Herndon Station 32814
621 Commonwealth Avenue
Orlando
Tel: (305) 841-3970
TWX: 810-850-0113

GEORGIA
P.O. Box 28234
450 Interstate North
Atlanta 30328
Tel: (404) 436-6181
TWX: 810-766-4890

ILLINOIS
5500 Howard Street
Skokie 60076
Tel: (312) 677-0400
TWX: 910-223-3613

INDIANA
3839 Meadows Drive
Indianapolis 46205
Tel: (317) 546-4891
TWX: 810-341-3263

LOUISIANA
P.O. Box 856
1942 Williams Boulevard
Kenner 70062
Tel: (504) 721-6201
TWX: 810-955-5524

MARYLAND
6707 Whitestone Road
Baltimore 21207
Tel: (301) 944-5400
TWX: 710-862-9157

P.O. Box 1648
2 Choke Cherry Road
Rockville 20850
Tel: (301) 948-6370
TWX: 710-828-9684

MASSACHUSETTS
32 Hartwell Ave.
Lexington 02173
Tel: (617) 861-8960
TWX: 710-326-6904

MICHIGAN
21840 West Nine Mile Road
Southfield 48075
Tel: (313) 353-9100
TWX: 810-224-4882

MINNESOTA
2459 University Avenue
St. Paul 55114
Tel: (612) 645-9461
TWX: 910-563-3734

MISSOURI
11131 Colorado Ave.
Kansas City 64137
Tel: (816) 763-8000
TWX: 910-771-2087

2812 South Brentwood Blvd.
St. Louis 63144
Tel: (314) 962-5000
TWX: 910-760-1670

NEW JERSEY
W. 120 Century Road
Paramus 07652
Tel: (201) 265-5000
TWX: 710-990-4951

1060 N. Kings Highway
Cherry Hill 08034
Tel: (609) 667-4000
TWX: 710-892-4945

NEW MEXICO
P.O. Box 8366
Station C
6501 Lomas Boulevard N.E.
Albuquerque 87108
Tel: (505) 265-3713
TWX: 910-989-1665

156 Wyatt Drive
Las Cruces 88001
Tel: (505) 526-2485
TWX: 910-983-0550

NEW YORK
1702 Central Avenue
Albany 12205
Tel: (518) 869-8462
TWX: 710-441-8270

1219 Campville Road
Endicott 13760
Tel: (607) 754-0050
TWX: 510-252-0890

82 Washington Street
Poughkeepsie 12601
Tel: (914) 454-7330
TWX: 510-248-0012

39 Saginaw Drive
Rochester 14623
Tel: (716) 473-9500
TWX: 510-253-5981

5858 East Molloy Road
Syracuse 13211
Tel: (315) 454-2486
TWX: 710-541-0482

1 Crossways Park West
Woodbury 11797
Tel: (516) 921-0300
TWX: 510-223-0811

NORTH CAROLINA
P.O. Box 5188
1923 North Main Street
High Point 27262
Tel: (919) 885-8101
TWX: 510-926-1516

OHIO
25575 Center Ridge Road
Cleveland 44145
Tel: (216) 835-0300
TWX: 810-427-9129

3460 South Dixie Drive
Dayton 45439
Tel: (513) 298-0351
TWX: 810-459-1925

1120 Morse Road
Columbus 43229
Tel: (614) 846-1300

OKLAHOMA
2919 United Founders Boulevard
Oklahoma City 73112
Tel: (405) 848-2801
TWX: 910-830-6862

OREGON
Westhills Mall, Suite 158
4475 S.W. Scholls Ferry Road
Portland 97225
Tel: (503) 292-9171
TWX: 910-464-6103

PENNSYLVANIA
2500 Moss Side Boulevard
Monroeville 15146
Tel: (412) 271-0724
TWX: 710-797-3650

1021 8th Avenue
King of Prussia Industrial Park
King of Prussia 19406
Tel: (215) 265-7000
TWX: 510-660-2670

RHODE ISLAND
873 Waterman Ave.
East Providence 02914
Tel: (401) 434-5535
TWX: 710-381-7573

TEXAS
P.O. Box 1270
201 E. Arapaho Rd.
Richardson 75080
Tel: (214) 231-6101
TWX: 910-867-4723

P.O. Box 22813
6300 Westpark Drive
Suite 100
Houston 77027
Tel: (713) 781-6000
TWX: 910-881-2645

231 Billy Mitchell Road
San Antonio 78226
Tel: (512) 434-4171
TWX: 910-871-1170

UTAH
2890 South Main Street
Salt Lake City 84115
Tel: (801) 487-0715
TWX: 910-925-5681

VERMONT
P.O. Box 2287
Kennedy Drive
South Burlington 05401
Tel: (802) 658-4455
TWX: 510-299-0025

VIRGINIA
P.O. Box 6514
2111 Spencer Road
Richmond 23230
Tel: (703) 285-3431
TWX: 710-956-0157

WASHINGTON
433-108th N.E.
Bellevue 98004
Tel: (206) 454-3971
TWX: 910-443-2303

***WEST VIRGINIA**
Charleston
Tel: (304) 768-1232

FOR U.S. AREAS NOT LISTED:
Contact the regional office nearest you: Atlanta, Georgia . . . North Hollywood, California . . . Paramus, New Jersey . . . Skokie, Illinois. Their complete addresses are listed above.

*Service Only

CANADA

ALBERTA
Hewlett-Packard (Canada) Ltd.
11745 Jasper Ave.
Edmonton
Tel: (403) 482-5561
TWX: 610-831-2431

BRITISH COLUMBIA
Hewlett-Packard (Canada) Ltd.
4519 Canada Way
North Burnaby 2
Tel: (604) 433-8213
TWX: 610-922-5059

MANITOBA
Hewlett-Packard (Canada) Ltd.
511 Bradford Ct.
Winnipeg
Tel: (204) 786-7581
TWX: 610-671-3531

NOVA SCOTIA
Hewlett-Packard (Canada) Ltd.
2745 Dutch Village Rd.
Suite 206
Halifax
Tel: (902) 455-0511
TWX: 610-271-4482

ONTARIO
Hewlett-Packard (Canada) Ltd.
880 Lady Ellen Place
Ottawa 3
Tel: (613) 722-4223
TWX: 610-562-1952

Hewlett-Packard (Canada) Ltd.
50 Galaxy Blvd.
Rexdale
Tel: (416) 677-9611
TWX: 610-492-4246

QUEBEC
Hewlett-Packard (Canada) Ltd.
275 Hymus Boulevard
Pointe Claire
Tel: (514) 697-4232
TWX: 610-422-3022
Telex: 01-20607

FOR CANADIAN AREAS NOT LISTED:
Contact Hewlett-Packard (Canada) Ltd. in Pointe Claire, at the complete address listed above.

CENTRAL AND SOUTH AMERICA

ARGENTINA
Hewlett-Packard Argentina S.A.C.e.I
Lavalle 1171 - 3°
Buenos Aires
Tel: 35-0436, 35-0627, 35-0431
Telex: 012-1009
Cable: HEWPACKARG

BRAZIL
Hewlett-Packard Do Brasil
I.e.C Ltda.
Rua Frei Caneca 1119
Sao Paulo - 3, SP
Tel: 288-7111, 287-5858
Cable: HEWPACK Sao Paulo

Hewlett-Packard Do Brasil
Praca Dom Feliciano 78
Salas 806/808
Porto Alegre
Rio Grande do Sul (RS)-Brasil
Tel: 25-8470
Cable: HEWPACK Porto Alegre

Hewlett-Packard Do Brasil
I.e.C. Ltda.
Rua da Matriz 29
Botafogo ZC-02
Rio de Janeiro, GB
Tel: 246-4417
Cable: HEWPACK Rio de Janeiro

Hewlett-Packard Do Brasil
Indústria e Comercia Ltda.
Praca Dom Feliciano 78
Salas 806-8
Porto Alegre RGS

CHILE
Héctor Calcagni y Cia, Ltda.
Bustos, 1932-3er Piso
Casilla 13942
Santiago
Tel: 423 96
Cable: CALCAGNI Santiago

COLOMBIA
Instrumentacion
Henrik A. Langebaek & Kier Ltda.
Carrera 7 No. 48-59
Apartado Aereo 6287
Bogota, 1 O.E.
Tel: 45-78-06, 45-55-46
Cable: AARIS Bogota
Telex: 44400 INSTCO

COSTA RICA
Lic. Alfredo Gallegos Gurdián
Apartado 10159
San José
Tel: 21-86-13
Cable: GALGUR San José

ECUADOR
Laboratorios de Radio-Ingenieria
Calle Guayaquil 1246
Post Office Box 3199
Quito
Tel: 212-496; 219-185
Cable: HORVATH Quito

EL SALVADOR
Electrónica
Apartado Postal 1589
Blvd. Venezuela 1231
San Salvador
Tel: 217527; 214895
Cable: ELECTRONICA San Salvador

MEXICO
Hewlett-Packard Mexicana, S.A. de C.V.
622 Adolfo Prieto
Col. del Valle
Mexico 12, D.F.
Tel: 543-4232; 523-1874
Telex: 0017-74507

NICARAGUA
Roberto Terán G.
Apartado Postal 689
Edificio Terán
Managua
Tel: 3451, 3452
Cable: ROTERAN Managua

PANAMA
Electrónico Balboa, S.A.
P.O. Box 4929
Ave. Manuel Espinosa No. 13-50
Bldg. Alina
Panama City
Tel: 230833
Telex: 3481003, Curundu, Canal Zone
Cable: ELECTRON Panama City

PERU
Compañia Electro Medica S.A.
Ave. Enrique Canaual 312
San Isidro
Casilla 1030
Lima
Tel: 22-3900
Cable: ELMED Lima

PUERTO RICO
San Juan Electronics, Inc.
P.O. Box 5167
Ponce de Leon 154
Pda. 3-PTA de Tierra
San Juan 00906
Tel: (809) 725-3342, 722-3342
Cable: SATRONICS San Juan
Telex: SATRON 3450 332

SURINAME
Surtel-Radio Holland N.V.
P.O. Box 155
Paramaribo
Tel: 72118
Cable: Treurniet Paramaribo

URUGUAY
Pablo Ferrando S.A.
Comercial e Industrial
Avenida Italia 2877
Casilla de Correo 370
Montevideo
Tel: 40-3102
Cable: RADIUM Montevideo

VENEZUELA
Hewlett-Packard De Venezuela C.A.
Apartado 50933
Caracas
Tel: 71.88.05, 71.88.69, 71.99.30
Cable: HEWPACK Caracas
Telex: 39521146

FOR AREAS NOT LISTED, CONTACT:
Hewlett-Packard INTERCONTINENTAL
3200 Hillview Ave.
Palo Alto, California 94304
Tel: (415) 493-1501
TWX: 910-373-1267
Cable: HEWPACK Palo Alto
Telex: 034-8461

EUROPE

AUSTRIA
Unilabor GmbH
Wissenschaftliche Instrumente
Rummelhardtgasse 6
P.O. Box 33
A-1095 **Vienna**
Tel: (222) 42 61 81, 43 13 94
Cable: LABORINSTRUMENT Vienna
Telex: 75 762

BELGIUM
Hewlett-Packard S.A. Benelux
348 Boulevard du Souverain
B-1160 **Brussels**
Tel: (02) 722240
Cable: PALOBEN Brussels
Telex: 23 494

DENMARK
Hewlett-Packard A/S
Datavej 38
DK-3460 **Birkerod**
Tel: (01) 81 66 40
Cable: HEWPACK AS
Telex: 66 40

Hewlett-Packard A/S
Torvet 9
DK-8600 **Silkeborg**
Tel: (06)-82-71-66

FINLAND
Hewlett-Packard Oy
Bulevardi 26
P.O. Box 12185
Helsinki 12
Tel: 13-730
Cable: HEWPACKOY-Helsinki
Telex: 12-1563

FRANCE
Hewlett-Packard France
Quartier de Courtaboeuf
Boite Postale No. 6
F-91 Orsay
Tel: 1-920 88 01
Cable: HEWPACK Orsay
Telex: 60048

Hewlett-Packard France
4 Quai des Etroits
F-69 **Lyon** 5ème
Tel: 78-42 63 45
Cable: HEWPACK Lyon
Telex: 31617

Hewlett-Packard France
29 rue de la Gara
F-31 **Blagnac**
Tel: (61) 85 82 29
Telex: 51957

GERMANY
Hewlett-Packard Vertriebs-GmbH
Berliner Strasse 117
Postfach 560/40
D6 Nieder-Eschbach/Ffm 56
Tel: (0611) 50 10 64
Cable: HEWPACKSA Frankfurt
Telex: 41 32 49 FRA

Hewlett-Packard Vertriebs-GmbH
Wilmersdorfer Strasse 113/114
D-1000 **Berlin W.** 12
Tel: (0311) 3137046
Telex: 18 34 05

Hewlett-Packard Vertriebs-GmbH
Herrenbergerstrasse 110
D7030 **Böblingen**, Württemberg
Tel: (07031) 66 72 86
Cable: HEPAG Böblingen
Telex: 72 65 739

Hewlett-Packard Vertriebs-GmbH
Vogelsanger Weg 38
D4 **Düsseldorf**
Tel: (0211 63 80 31/35
Telex: 85/86 533

Hewlett-Packard Vertriebs-GmbH
Wendenstr. 23
D2 **Hamburg** 1
Tel: (0411) 24 05 51/52
Cable: HEWPACKSA Hamburg
Telex: 21 53 32

Hewlett-Packard Vertriebs-GmbH
Reginfriedstrasse 13
D8 **München** 9
Tel: (0811) 69 59 71/75
Cable: HEWPACKSA München
Telex: 52 49 85

GREECE
Kostas Karayannis
18, Ermou Street
Athens 126
Tel: 230301,3,5
Cable: RAKAR Athens
Telex: 21 59 62 RKAR GR

IRELAND
Hewlett-Packard Ltd.
224 Bath Road
Slough, SLI 4 DS, Bucks
Tel: Slough 753-33341
Cable: HEWPIE Slough
Telex: 84413

ITALY
Hewlett-Packard Italiana S.p.A.
Via Amerigo Vespucci 2
1-20124 **Milan**
Tel: (2) 6251 (10 lines)
Cable: HEWPACKIT Milan
Telex: 32046

Hewlett-Packard Italiana S.p.A.
Palazzo Italia
Piazza Marconi 25
1-00144 **Rome - Eur**
Tel: 6-591 2544
Cable: HEWPACKIT Rome
Telex: 61514

NETHERLANDS
Hewlett-Packard Benelux, N.V.
Weerdestein 117
P.O. Box 7825
Amsterdam, Z 11
Tel: 020-42 77 77
Cable: PALOBEN Amsterdam
Telex: 13 216

NORWAY
Hewlett-Packard Norge A/S
Box 149
Nesveien 13
N-1344 **Haslum**
Tel: (02)-53 83 60
Cable: HEWPACK Oslo
Telex: 16621

PORTUGAL
Telectra
Empresa Tecnica de Equipamentos
Electricos, S.a.r.l.
Rua Rodrigo da Fonseca 103
P.O. Box 2531
Lisbon 1
Tel: 68 60 72
Cable: TELECTRA Lisbon
Telex: 1598

SPAIN
Ataio Ingenieros SA
Enrique Larreta 12
Madrid, 16
Tel: 215 35 43
Cable: TELEATAIO Madrid
Telex: 27249E

Ataio Ingenieros SA
Ganduxer 76
Barcelona 6
Tel: 211-44-66
Cable: TELEATAIO Barcelona

SWEDEN
Hewlett-Packard Sverige AB
Enighetsvägen 1-3
Fack
S-161 20 **Bromma** 20
Tel: (08) 98 12 50
Cable: MEASUREMENTS Stockholm
Telex: 10721

Hewlett-Packard Sverige AB
Hagakersgatan 9C
S-431 41 **Mölndal**
Tel: 031 - 27 68 00
Telex: 21 312 hpmlndl

SWITZERLAND
Hewlett Packard Schweiz AG
Zurcherstrasse 20
CH-8952 **Schlieren** Zurich
Tel: (051) 98 18 21/24
Cable: HPAG CH
Telex: 53933

Hewlett Packard Schweiz A.C.
Rue du Bois-du-Lan 7
1217 **Meyrin** 2 **Geneva**
Tel: (022) 41 54 00
Cable: HEWPACKSA Geneva
Telex: 27333 HPSA CH

TURKEY
Telekom Engineering Bureau
P.O. Box 376
Karakoy
Istanbul
Tel: 49 40 40
Cable: TELEMATION Istanbul

UNITED KINGDOM
Hewlett-Packard Ltd.
224 Bath Road
Slough, SLI 4 DS, Bucks
Tel: Slough (0753) 33341
Cable: HEWPIE Slough
Telex: 84413

Hewlett-Packard Ltd.
The Graftons
Stamford New Road
Altrincham, Cheshire
Tel: 061 928-8626
Telex: 668068

YUGOSLAVIA
Belram S.A.
83 avenue des Mimosas
Brussels 1150, Belgium
Tel: 34 33 32, 34 26 19
Cable: BELRAMEL Brussels
Telex: 21790

SOCIALIST COUNTRIES PLEASE CONTACT:
Hewlett-Packard Ges.m.b.H
Innstrasse 23/2
Postfach
A1204 **Vienna**, Austria
Tel: (222) 3366 06/09
Cable: HEWPACK Vienna
Telex: 75923

ALL OTHER EUROPEAN COUNTRIES CONTACT:
Hewlett-Packard S.A.
Rue du Bois-du-Lan 7
1217 Meyrin 2 **Geneva**
Switzerland
Tel: (022) 41 54 00
Cable: HEWPACKSA Geneva
Telex: 2.24.86

AFRICA, ASIA, AUSTRALIA

ANGOLA
Telectra Empresa Técnia de Equipamentos Eléctricos SAR
Rua de Barbosa Rodrigues 42-1°
Box 6487
Luanda
Cable: TELECTRA Luanda

AUSTRALIA
Hewlett-Packard Australia Pty. Ltd.
22-26 Weir Street
Glen Iris, 3146
Victoria
Tel: 20.1371 (6 lines)
Cable: HEWPARD Melbourne
Telex: 31024

Hewlett-Packard Australia Pty. Ltd.
61 Alexander Street
Crows Nest 2065
New South Wales
Tel: 43.7866
Cable: HEWPARD Sydney
Telex: 21561

Hewlett-Packard Australia Pty. Ltd.
97 Churchill Road
Prospect 5082
South Australia
Tel: 65.2366
Cable: HEWPARD Adelaide

Hewlett Packard Australia Pty. Ltd.
2nd Floor, Suite 13
Casablanca Buildings
196 Adelaide Terrace
Perth, W.A. 6000
Tel: 21-3330
Cable: HEWPARD Perth

Hewlett-Packard Australia Pty. Ltd.
10 Woolley Street
P.O. Box 191
Dickson A.C.T. 2602
Tel: 49-8194
Cable: HEWPARD Canberra ACT

Hewlett-Packard Australia Pty. Ltd.
75 Simpsons Road
Bardon
Queensland, 4068
Tel: 36-5411

CEYLON
United Electricals Ltd.
P.O. Box 681
Yahala Building
Staples Street
Colombo 2
Tel: 5496
Cable: HOTPOINT Colombo

CYPRUS
Kypronics
19 Gregorios & Xenopoulos Road
P.O. Box 1152
Nicosia
Tel: 6282-75628
Cable: HE-I-NAMI

ETHIOPIA
African Salespower & Agency Private Ltd., Co.
P. O. Box 718
58/59 Cunningham St.
Addis Ababa
Tel: 12285
Cable: ASACO Addisababa

HONG KONG
Schmidt & Co. (Hong Kong) Ltd.
P.O. Box 297
1511, Prince's Building 15th Floor
10, Chater Road
Hong Kong
Tel: 240168, 232735
Cable: SCHMIDTCO Hong Kong

INDIA
Blue Star Ltd.
Kasturi Buildings
Jamshedji Tata Rd.
Bombay 20BR, India
Tel: 29 50 21
Telex: 2156
Cable: BLUEFROST

Blue Star Ltd.
Band Box House
Prabhadevi
Bombay 25DD, India
Tel: 45 73 01
Telex: 2156
Cable: BLUESTAR

Blue Star Ltd.
14/40 Civil Lines
Kanpur, India
Tel: 6 88 82
Cable: BLUESTAR

Blue Star, Ltd.
7 Hare Street
P.O. Box 506
Calcutta 1, India
Tel: 23-0131
Telex: 655
Cable: BLUESTAR

Blue Star Ltd.
Blue Star House,
34 Ring Road
Lajpat Nagar
New Delhi 24, India
Tel: 62 32 76
Telex: 463
Cable: BLUESTAR

Blue Star Ltd.
17-C Ulsoor Road
Bangalore-8

Blue Star, Ltd.
96 Park Lane
Secunderabad 3, India
Tel: 7 63 91
Cable: BLUEFROST

Blue Star, Ltd.
23/24 Second Line Beach
Madras 1, India
Tel: 2 39 55
Telex: 379
Cable: BLUESTAR

Blue Star, Ltd.
1B Kaiser Bungalow
Dindli Road
Jamshedpur, India
Tel: 38 04
Cable: BLUESTAR

INDONESIA
Bah Bolon Trading Coy. N.V.
Djalah Merdeka 29
Bandung
Tel: 4915; 51560
Cable: ILMU
Telex: 08-809

IRAN
Telecom, Ltd.
P. O. Box 1812
240 Kh. Saba Shomali
Teheran
Tel: 43850, 48111
Cable: BASCOM Teheran

ISRAEL
Electronics & Engineering Div. of Motorola Israel Ltd.
17 Aminadav Street
Tel-Aviv
Tel: 36941 (3 lines)
Cable: BASTEL Tel-Aviv
Telex: Bastel Tv 033-569

JAPAN
Yokogawa-Hewlett-Packard Ltd.
Ohashi Building
1-59-1 Yoyogi
Shibuya-ku, **Tokyo**
Tel: 03-370-2281/7
Telex: 232-2024YHP
Cable: YHPMARKET TOK 23-724

Yokogawa-Hewlett-Packard Ltd.
Nisei Ibaragi Bldg.
2-2-8 Kasuga
Ibaragi-Shi
Osaka
Tel: (0726) 23-1641
Telex: 385-5332 YHPOSAKA

Yokogawa-Hewlett-Packard Ltd.
Ito Building
No. 59, Kotori-cho
Nakamura-ku, Nagoya City
Tel: (052) 551-0215

Yokogawa-Hewlett-Packard Ltd.
Nitto Bldg.
2300 Shinohara-cho,
Koheku-ku
Yokohama 222
Tel: (405) 432-1504/5

KENYA
Kenya Kinetics
P.O. Box 18311
Nairobi, Kenya
Tel: 57726
Cable: PROTON

KOREA
American Trading Co., Korea, Ltd.
Seoul P.O. Box 1103
7th & 8th floors, DaeKyung Bldg.
107 Sejong Ro
Chongro-Ku, Seoul
Tel: 75-5841 (4 lines)
Cable: AMTRACO Seoul

LEBANON
Constantin E. Macridis
Clemenceau Street
P.O. Box 7213
Beirut
Tel: 220846
Cable: ELECTRONUCLEAR Beirut

MALAYSIA
MECOMB Malaysia Ltd.
2 Lorong 13/6A
Section 13
Petaling Jaya, **Selangor**
Cable: MECOMB Kuala Lumpur

MOZAMBIQUE
A. N. Goncalves, LDA.
4.1 Apt. 14 Av. D. Luis
P.O. Box 107
Lourenco Marques
Cable: NEGON

NEW ZEALAND
Hewlett-Packard (N.Z.) Ltd.
94-96 Dixson St.
P.O. Box 9443
Wellington, N.Z.
Tel: 56-559
Cable: HEWPACK Wellington

Hewlett Packard (N.Z.) Ltd.
Box 51092
Pukuranga
Tel: 573-733
Cable: HEWPACK, Auckland

PAKISTAN (EAST)
Mushko & Company, Ltd.
1, Jinnah Avenue
Dacca 2
Tel: 280058
Cable: NEWDEAL Dacca

PAKISTAN (WEST)
Mushko & Company, Ltd.
Oosman Chambers
Abdullah Haroon Road
Karachi 3
Tel: 511027, 512927
Cable: COOPERATOR Karachi

PHILIPPINES
Electromex Inc.
Makati Commercial Center
2129 Pasong Tamo
Makati, Rizal D 708
P.O. Box 1028
Manila
Tel: 89-85-01; 88-91-71
Cable: ELEMEX Manila

SINGAPORE
Mechanical and Combustion Engineering Company Ltd.
9, Jalan Kilang
Red Hill Industrial Estate
Singapore, 3
Tel: 642361-3; 632611
Cable: MECOMB Singapore

Hewlett-Packard Far East Area Office
P.O. Box 87
Alexandra Post Office
Singapore 3
Tel: 633022
Cable: HEWPACK SINGAPORE

SOUTH AFRICA
Hewlett Packard South Africa (Pty.), Ltd.
P.O. Box 31716
Braamfontein Transvaal
Milnerton
30 De Beer Street
Johannesburg
Tel: 725-2080, 725-2030
Telex: 0226 JH
Cable: HEWPACK Johannesburg

Hewlett Packard South Africa (Pty.), Ltd.
Breecastle House
Bree Street
Cape Town
Tel: 3-6019, 3-6545
Cable: HEWPACK Cape Town
Telex: 5-0006

Hewlett Packard South Africa (Pty.), Ltd.
30B Glenwood Centre
Corner Hunt & Moore Roads
P.O. Box 99
Overport, Natal
Tel: 347536

TAIWAN
Hewlett Packard Taiwan
39 Chung Shiao West Road
Sec. 1
Overseas Insurance Corp. Bldg. 7th Floor
Taipei
Tel: 579-605, 579-610, 579-613
Telex: TP824 HEWPACK
Cable: HEWPACK Taipei

THAILAND
The International Engineering Co., Ltd.
P. O. Box 39
614 Sukhumvit Road
Bangkok
Tel: 910722 (7 lines)
Cable: GYSOM
TLX INTENCO BK-226 Bangkok

UGANDA
Uganda Tele-Electric Co., Ltd.
P.O. Box 4449
Kampala
Tel: 57279
Cable: COMCO Kampala

VIETNAM
Peninsular Trading Inc.
P.O. Box H-3
216 Hien-Vuong
Saigon
Tel: 20805, 93398
Cable: PENTRA, SAIGON 242

ZAMBIA
R. J. Tilbury (Zambia) Ltd.
P.O. Box 2792
Lusaka
Zambia, Central Africa
Tel: 73793
Cable: ARJAYTEE, Lusaka

MEDITERRANEAN AND MIDDLE EAST COUNTRIES NOT SHOWN PLEASE CONTACT:
Hewlett-Packard Correspondence Office
Piazza Marconi 25
I-00144 Rome-Eur, Italy
Tel: (6) 59 40 29
Cable: HEWPACKIT Rome
Telex: 61514

OTHER AREAS NOT LISTED, CONTACT:
Hewlett-Packard INTERCONTINENTAL
3200 Hillview Ave.
Palo Alto, California 94304
Tel: (415) 326-7000 (Feb. 71 493-1501)
TWX: 910-373-1267
Cable: HEWPACK Palo Alto
Telex: 034-8461

PART NO. 09864-90000
MICROFICHE NO. 09864-99000

PRINTED IN U.S.A.
FEBRUARY 1972