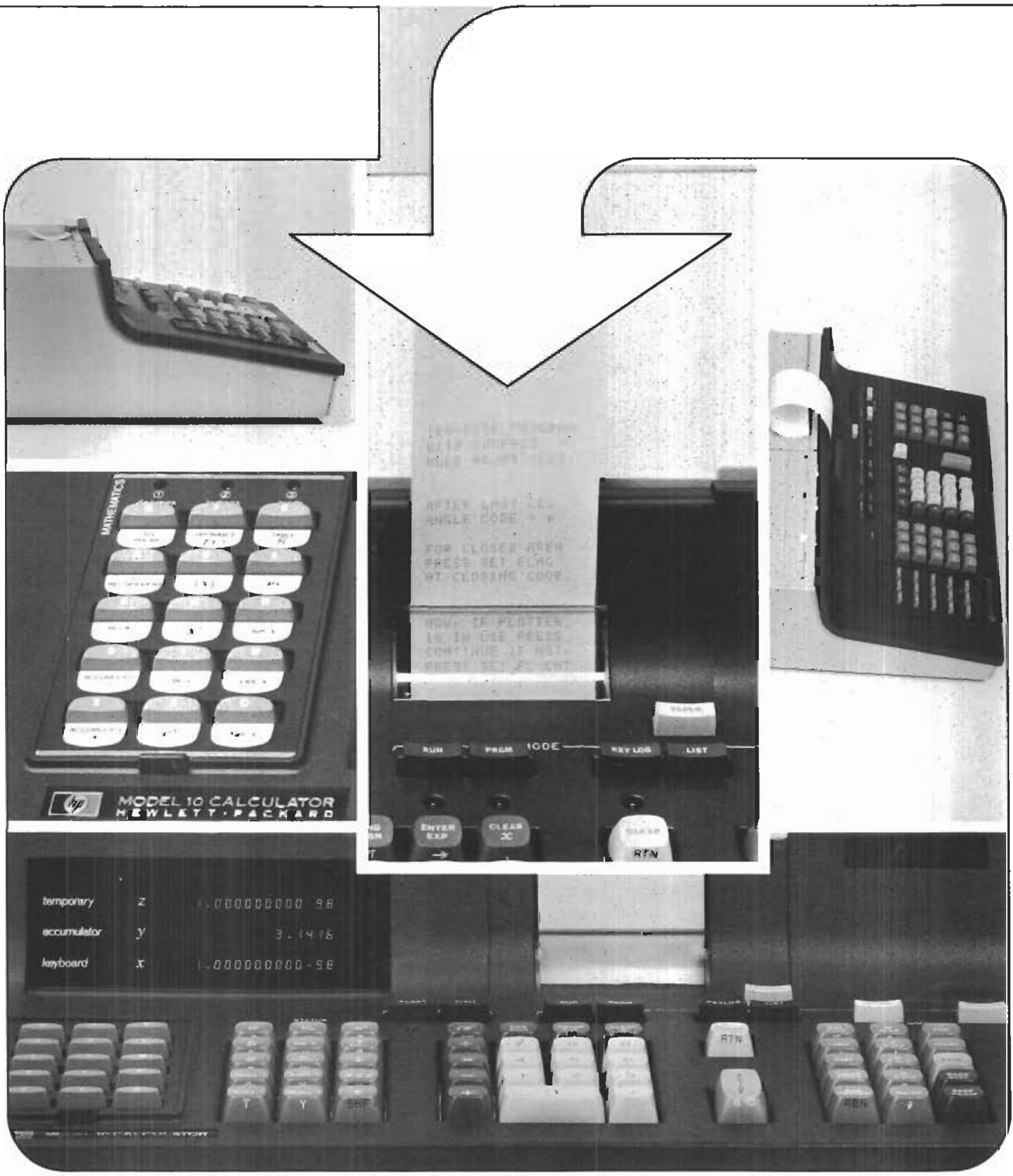
HEWLETT-PACKARD

KEYBOARD

VOL. 3 NO. 3



TO HEWLETT-PACKARD KEYBOARD READERS

Hewlett-Packard is constantly striving to provide its customers with the electronic equipment that best meets their needs without costly excess capability. The Series 9800, Model 10 Calculator announced in July and featured in this issue was designed in response to the expressed needs of many calculator users.

With a choice of memory options, plug-in ROM's and with or without the column printer, marked card reader, and x-y plotter, at least 288 Model 10 system configurations are now possible. The addition of future peripherals will significantly increase the number of possible configurations. A system can be specified for any desired combination of applications.

Support of existing 9100 systems will continue in the form of peripheral equipment, programs, supplies, service, repairs, and information in *KEYBOARD*. You are invited to continue sending in your programming tips, programs, and other interesting information on all HP calculating systems for possible publication. See the announcement in this issue regarding the free Calculator Products Program Catalog, which lists all programs and libraries currently available.

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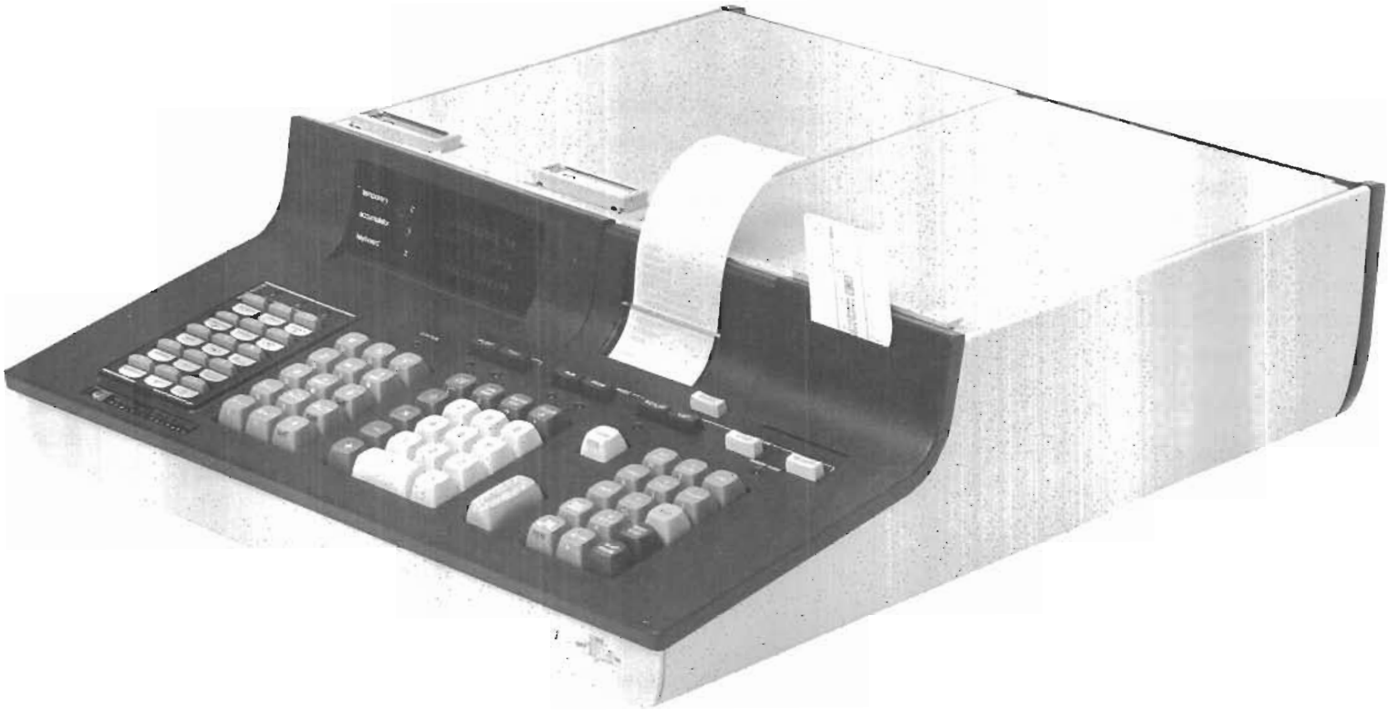
COVER

The cover of this *KEYBOARD* illustrates a few of the many details of the new HP Model 9810A Calculator, including the built-in thermal printer, keyboard, and display. Further information is given in the feature articles on the following pages.

the
NEW HP Series 9800
Model 10



THE NEW HP SERIES 9800/Model 10

Hewlett-Packard's new Series 9800 Model 10 Programmable Calculator has a modular design so that the user can tailor it to his specific problem-solving needs. Plug-ins and other options can expand its memory, customize its keyboard functions, extend its input/output capability, and provide problem solutions in words, numbers, drawings or a combination of all three.

All the basic arithmetic functions such as addition, subtraction, multiplication, division, and square root are performed by the basic Model 10. Only one keystroke is required to square a number or get its reciprocal. Plug-in function blocks allow the user to customize other keys for specific problem-solving needs.

Many problems can be solved with a single keystroke on the keyboard of the Model 10. More complex problems are handled by recording data and program steps on magnetic cards. As an illustration of its increased computational "horsepower", the Model 10 can solve 17 simultaneous equations.

CUSTOM KEYBOARDS

The Model 10 allows the user to select from special keyboard plug-in blocks to personalize problem-solving. This unique HP feature vastly extends computing power, simplifies programming, and reduces computing time.

The function blocks are completely interchangeable and require absolutely no modification to the calculator or any special tools or skills to install. To install the math functions for example, the user merely inserts the math memory block in the left slot at the top of the calculator and places the key identification template over the left-hand block of keys. All math functions are now only a keystroke away.

MATHEMATICS

The mathematics function block allows single-key control of powerful mathematics operations and additional capability for subroutine control and peripheral control. In addition to all the log, trig, and transcendental functions normally found on an engineering slide rule, $\frac{\text{TABLE}}{\text{N}}$ followed by keys 1, 2, 3, . . . 9 or FMT gives the user access to ten more functions.

Functions 1-9 are: SET DEGREES; SET RADIANS; SET GRADS; $\log_{10}x$; 10^x; degrees/minutes/seconds to decimal degrees conversion; decimal degrees to degrees/minutes/seconds conversion; X!; and Round. $\frac{\text{TABLE}}{\text{N}}$, FMT is an automatic scaling control for use with the new Model 62 X-Y Plotter which saves the user from manual data scaling routines.

Another feature of the Model 10's Math Block is the availability of performing a "DO LOOP", found before only on large computers. This allows the user to cycle through a subroutine or function a specified number of times.

A user definable key is also included. It can be programmed to perform any function, or it can define one program which can call other programs.

No programming is required for any of the functions in the Math block (with the exception of $\frac{\text{DEFINABLE}}{\text{f ( )}}$). These functions have a separate (ROM) memory block dedicated to them so that they do not draw upon the main calculator memory.

STATISTICS

The Statistics block offers powerful statistical computations commanded by a single keystroke. Its primary function is to carry out the summations of variables, cross products and squares needed as fundamental quantities in a variety of commonly used statistical analyses. A Variables key defines the number of variables to be treated, from one to five.

A Summation key accumulates the data summations of variables, cross products and squares. The Mean key computes (from the collected summations) the arithmetic mean of up to three variables. Other keys include Variance, Regression (least squares curve fitting), Max/Min to collect the maximum and minimum values of variables, t-paired, chi-squared and log keys, both natural logs and logs to the base 10.

A Random key generates a sequence of psuedo-random numbers. In addition, erroneous data can be removed by the use of the exclusive Correct key. No programming or addressing is required for any of these functions. More statistics functions are included in the Model 10's Stat block than are available in any other presently available programmable calculators, including the specially designated "statistics" calculators.

A separate (ROM) memory block is dedicated to the statistics functions so that they do not draw upon the main calculator programming memory.

USER DEFINABLE

For the ultimate in keyboard personalization, the User Definable function block allows the user to customize each of the nine keys labeled f_1 through f_9 to perform his specific functions at the touch of a single key.

The user may, for example, program a single key to calculate amortization. Or the Bessel function of the number in the X display register could be computed with a single keystroke. Any subroutine or function may be keyed in, then executed.

All functions are fully protected by the Model 10's automatic "bookkeeping" system - until the user wants to change them. Any time a function is getting less use than anticipated and the user would like another in its place, it's a simple matter to delete the old function and add the new one without disturbing any other functions or programs.

EXPANDABLE MEMORIES

A data memory of 51 registers and a program memory of 500 steps, enough to solve 10 simultaneous equations, come with the basic Model 10. Both the data storage memory and the program memory can be expanded.

A Model 10 can thus be configured with 51 or 111 data storage registers and with 500, 1000, or 2000 program steps. Both the read/write (R/W) and read-only memories (ROM) use the newest in MOS/LSI technology which allows this increased capability at a lower cost.

Dividing the memory into separate program and data units has some advantages. The user can now perform more complex problems with larger amounts of data since data and program do not impinge upon each other. Detailed program "bookkeeping" is eliminated and replaced by a more efficient symbolic addressing.

Each data storage register is an "accumulating" register. Mathematical operations can be performed on data directly in the storage registers, without recalling it to a "working" register. Indirect addressing and indirect arithmetic save innumerable programming operations.

ALPHANUMERIC PRINTING

Labeling computer data as it is printed out is an obvious advantage. It is not necessary to interpret code numbers or abbreviated symbols. Medical data, payroll figures, and statistical data of all kinds can be labeled while printed out so that anyone can read the results from the tape with no danger of misinterpretation. The printout may be used directly as a report of results.

User instructions in a program may also be printed out to eliminate the need to refer to instruction manuals.

Generating a message is quite simple. The user plugs in the alpha block in the right-hand slot at the top of the calculator. Each key in the left-hand block has an alpha character. The remaining letters of the alphabet and punctuation symbols are stamped on the front of other keys. For instance, x ← ( ) has a "y" on the front, and "x ⇄ y" a "TAB" on the front. To print the word "average", the user would push FMT, FMT, A, V, E, R, A, G, E, FMT, PRINT.

Front of keys shows alpha mode function.

Alphanumeric characters may be printed directly from the keyboard, or automatically via programmed request. Alpha capability greatly simplifies programming and program editing. A list of keystrokes may be printed as the keys are depressed using the new KEYLOG key. Or a list of program steps may be printed out by pressing the LIST key. With the Alpha block in place, each step is listed by its numeric symbol - - - and by easy mnemonics such as CLR for CLEAR. Errors are thus easy to spot and correct.

PRINTER

Exceptionally quiet, the new Hewlett-Packard designed thermal printer is an option that can be quickly installed. It prints a 16 character line; each of the 16 characters is formed by a 5 by 7 matrix. Inexpensive heat-sensitive paper is used and loading is simple. The roll is simply dropped in; the paper threads itself automatically.

Line spacing is set at six lines per inch vertically, which matches typewriter spacing. The printed out data can thus be taped directly onto a typed report.

LED DISPLAY

For the first time in a large calculator, a solid state (LED) display is used. In the Model 10, segmented characters display the X, Y and Z registers. There is a total of 45 characters.

Advantages of the LED display include their small size, good readability, long life and high reliability. They require only a single 5-volt supply for the entire display. Built into the display circuitry is a fail-safe feature -- should a failure occur in the calculator, the display will turn off to avoid burnout of a single character.

Solutions and intermediate results are displayed in the three registers to ten significant digits, with a two digit exponent. Display can be either fixed or floating point. Should the registers overflow in fixed point, the display automatically switches to floating point. The dynamic range of the Model 10 is 10^{-98} to 10^{98}.

MAGNETIC CARD READER

Programs in the calculator can be recorded on magnetic cards, and likewise entered into the calculator from the cards. A new feed-through card reader accepts magnetic cards to 6 inches long. Cards may be linked automatically for longer programs. A punch-out tab on the leading edge of the magnetic card can be removed to prevent accidental erasure of the recorded program.

POWER SUPPLY

Power supplies within the Model 10 are modular for easy servicing. No adjustments are required. All supplies are crowbar protected against overvoltage.

The Model 10 is designed to conform to IEC (International Electrotechnical Commission) Standards. It has a common line filter to reduce RFI in both directions, one fuse for the entire machine, IEC approved power cord and outlets, and a double pole on-off switch to switch both sides of the line.

Screwdriver-actuated switches on the rear panel are operated to select a variety of line voltages. The Model 10 will operate on 100 volts (Japan), 115 volts, 200 volts (European low voltage) and 230 volts (Europe) and from 48 to 66 Hz. Three convenience outlets (non-switched) are on the back.

PERIPHERALS

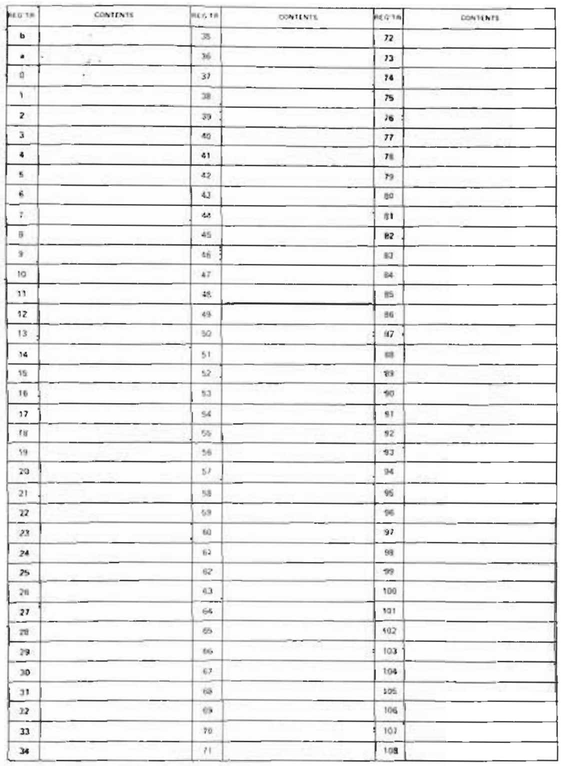
Output peripherals for the Model 10 will include an electric typewriter with formatted output capability and a fast, continuous-line X-Y plotter. A marked card reader that reads cards marked with a soft lead pencil, and paper tape reader capable of reading a variety of ASCII formatted tapes will be introduced later.

Additional information and demonstrations can be obtained by contacting any Hewlett-Packard sales office.

MEMORY MAP PAD FOR MODEL 9810A

Keeping track of data storage in the various registers of the Model 10 is facilitated by the new memory map pad, part number 09810-90018, shown below. One sheet shows the contents of all 111 possible storage registers. This pad is available through your local Hewlett-Packard sales office.

Model 10 Storage Map



REG'TR	CONTENTS	REG'TR	CONTENTS	REG'TR	CONTENTS
b		35		72	
a		36		73	
0		37		74	
1		38		75	
2		39		76	
3		40		77	
4		41		78	
5		42		79	
6		43		80	
7		44		81	
8		45		82	
9		46		83	
10		47		84	
11		48		85	
12		49		86	
13		50		87	
14		51		88	
15		52		89	
16		53		90	
17		54		91	
18		55		92	
19		56		93	
20		57		94	
21		58		95	
22		59		96	
23		60		97	
24		61		98	
25		62		99	
26		63		100	
27		64		101	
28		65		102	
29		66		103	
30		67		104	
31		68		105	
32		69		106	
33		70		107	
34		71		108	

CAN YOU TOP THIS?

Soeren Olsson of the Hewlett-Packard sales office in Stockholm reports a *new* record for the most northern sale of an HP calculator. His customer in Kiruna, Sweden, is the Swedish Department of Roadbuilding. Kiruna is located at 68 degrees north latitude, compared to 67.1 degrees for the previous record reported in *KEYBOARD* Vol. 3 No. 1.

The Model 9100B calculator and 9120A printer will be used in calculations for projecting a road between Kiruna and Narvik, in the Swedish Alps. The unit will be powered by a mobile generator.

Can you top this? Send any information about applications of the HP calculator in unusual locations or conditions to the nearest editor, *HP KEYBOARD*.

TELEPHONE ANSWERING SERVICE

The following short program is for busy calculator owners who may wish they could have a telephone answering service. This program is offered as a vicarious device.

USER INSTRUCTIONS
1. PRESS: x, y, z on 9120A.
2. Set DECIMAL wheel at 5.
3. PRESS: END; enter program.
4. PRESS: END, CONTINUE.
5. Tear off printer tape.
6. Turn tape upside down; read it.

```
STEP  KEY   CODE
 00    .     21
 01    0     00
 02    7     07
 03    7     07
 04    3     03
 05    4     04
 06   UP     27
 07   UP     27
 08   PNT    45
 09   PNT    45
 0a   PNT    45
 0b   PNT    45
 0c   PNT    45
 0d   PNT    45

 10   CLR    20
 11   END    46
```

HISTOGRAM GENERATION WITH PRINTER PLOT

This program generates a 20-cell histogram (frequency distribution) for a set of data values (x_i). In addition, various basic statistics of the set (x_i) are determined; these being:

n = number of observations

$$x = \frac{1}{n} \Sigma x_i$$

$$s_x = \frac{1}{n-1}\sqrt{\Sigma x_i^2 - \frac{(\Sigma x)^2}{n}}$$

$$x_{max}$$

$$x_{min}$$

$$\text{Range} = x_{max} - x_{min}$$

The program permits a constant value x_0 to be removed from the data set such that the 20 histogram cells can be optimally distributed over the data range.

The program outputs:

$$\left.\begin{array}{l}\text{Cell no.}\\ \text{No. of observations in cell}\\ \text{\% relative frequency of cell}\end{array}\right\}\text{ for each cell}$$

The computed histogram can optionally be plotted on the printer. The histogram plot via the printer can be run *only* if the Printer Alpha ROM is available. If more than 15% of the observations occur in a cell, that cell will be filled with 0's (zeros).

Editor's Note:

The Model 10 Math Pac, HP Part Number 09810-70000, contains 25 popular mathematics programs for the new Model 10 Calculator. It is supplied at no charge with the purchase of a Model 9810A.

This library is also available as a separate complete item, although programs from it are not sold individually.

EQUIPMENT NEEDED

☑ PRINTER
☐ 9860A MARKED CARD READER
☐ 9861A TYPEWRITER
☐ 9862A PLOTTER

TOTAL REGISTERS
☑ 51
☐ 111

TOTAL PROGRAM STEPS
☑ 500
☐ 1012
☐ 2036

ROM'S
1 Statistics*
2
3 Printer Alpha

	Press: FMT, GO TO			
	LOAD Program 1	0	0	0
1.	Enter: W (cell width)	W		
	Press: CONTINUE	0	0	0
	Enter: x_0	x_0		
	Press: CONTINUE	0	i	0
2.	Enter: x_i	x_i		
	Press: CONTINUE			
	If all x_i have been entered, go to Step 3; otherwise repeat Step 2.			
3.	Press: SET FLAG			
4.	Press: CONTINUE (Display or Print)	% relat. freq.	No. in Cell	Cell No.
	Repeat Step 4 for all cells			
	Press: CONTINUE (Display or Print)	n	$\bar{x}$	s_x
	Press: CONTINUE (Display or Print)	Range	x_{min}	x_{max}
	Press: CONTINUE (Display or Print)	0	off-scale below	off-scale above
	a. To plot histogram:			
	Press: SET FLAG	1	1	1
	Press: CONTINUE			
	LOAD Program 2			
	b. To run another case: Press: CONTINUE			

*If the Statistics ROM is not available, place CONTINUEs in program steps: 0021, 0022, 0023, 0024, 0099, 0284 through 0319.

EXAMPLE

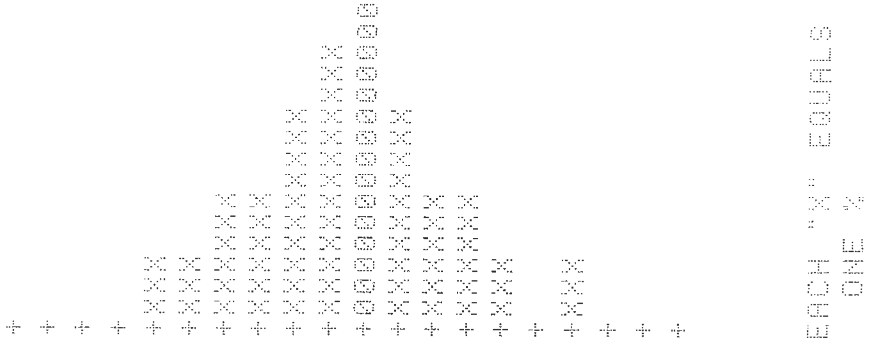
Input Data

```
ENTER
   CELL WIDTH
           1.00*
ENTER "X0"
           5.00*

           9.10
          11.50
          15.60
          15.00
          12.20
          14.10
          15.30
          17.90
          10.50
          26.30
          14.20
          15.60
          16.10
          18.40
          21.60
          11.20
          13.10
          15.10
          14.70
          16.80
          13.60
           3.80
          12.00
          13.00
          19.30
          18.50
          14.20
          16.80
          17.70
           4.50
```

Output of Program 1

```
CELL #
# OBS. IN CELL
% RELATIVE FREQ.
           1.00
           0.00
           0.00

           2.00
           0.00
           0.00

           3.00
           0.00
           0.00

           4.00
           0.00
           0.00

           5.00
           1.00
           3.33

           6.00
           1.00
           3.33

           7.00
           2.00
           6.67

           8.00
           2.00
           6.67

           9.00
           3.00
          10.00

          10.00
           4.00
          13.33

          11.00
           5.00
          16.67

          12.00
           3.00
          10.00

          13.00
           2.00
           6.67

          14.00
           2.00
           6.67

          15.00
           1.00
           3.33

          16.00
           0.00
           0.00

          17.00
           1.00
           3.33

          18.00
           0.00
           0.00

          19.00
           0.00
           0.00

          20.00
           0.00
           0.00
STANDARD DEV.
MEAN
N
           4.47
          14.59
          30.00
XMAX
XMIN
RANGE
          26.30
           3.80
          22.50
NUMBER OFF SCALE
    ABOVE
    BELOW
           1.00
           2.00
SET FLAG TO
PLOT HISTOGRAM
```

Output of Program 2

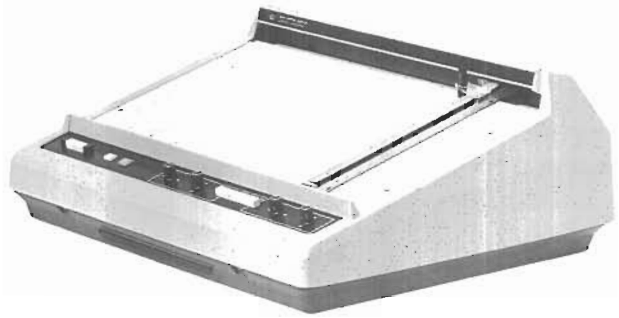


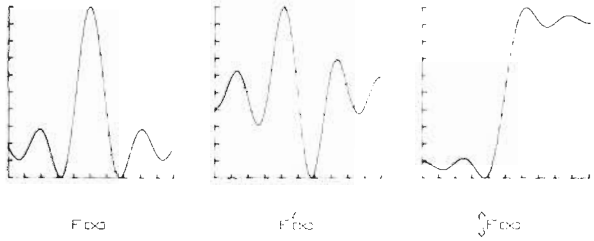
REG'TR	CONTENTS	REG'TR	CONTENTS	REG'
	Working			
	W, Cell width			
	n, number of observations			
	cell 1 accumulation			
	⋮			
10				
11		48		
12		49		
13		50		
14		51		
15		52		
16		53		
17		54		
18		55		
19	⋮	56		93
20	cell 20 accumulation	57		94
21	x_{min}	58		95
22	x_{max}	59		96
23	no. of obs. below x_0	60		
24	no. of obs. above (20W - x_0)	61		98
25	working	62		99
26	x_0	63		100
27	Σ_x	64		101
28	Σ_x^2	65		102
29	working	66		103
30	x	67		104
31	s_x	68		105
32		69		106
33		70		107
34				108

Sample Program
Printout

```
0000--CLR---20
0001--XTO---23
0002--IND---31
0003-- a ---13
0004-- 1 ---01
0005--XTO---23
0006-- + ---33
0007-- a ---13
0008-- a ---13
0009-- UP---27
0010-- 4 ---04
0011-- 0 ---00
0012--X=Y---50
0013-- 0 ---00
0014-- 0 ---00
0015-- 2 ---02
0016-- 1 ---01
0017-- DN---25
0018-- DN---25
0019--GTO---44
0020-- 1 ---01
0021-- K ---55
0022-- 1 ---01
0023-- A ---62
0024-- N ---73
0025--CLR---20
0026--FMT---42
0027--FMT---42
0028-- E ---60
0029-- N ---73
0030--XTO---23
0031-- E ---60
0032-- a ---13
0033--CLR---20
0034--CNT---47
0035--CNT---47
0036--CNT---47
0037-- C ---61
0038-- E ---60
0039-- L ---72
0040-- L ---72
```

Graphic Output for the Model 10





Plot made with Model 10 and Model 62

Output in the form of accurately-scaled graphs and charts has become an essential part of modern calculating systems. This is true today in technical, professional and business areas requiring the higher efficiency, better accuracy, and error-free presentations needed for economic survival.

Uses of these graphic presentations include, as a few examples:

...A basis for management decisions to buy or sell;
...Determination of economic order quantities;
...Statistical use of trend and other graphs for market analysis;
...Verification of adequate safety factors in structural designs without costly overdesign;
...Fast verification of electronic circuit design compliance and optimization of circuit values;
...Permanent records for the surveyor.

A complete list would include graphic output applications which apply to nearly every field of endeavor in every country. For this reason, an x-y plotter was chosen as one of the first peripheral devices to be made available for use with the Model 9810A Calculator.

The Model 9862A (Model 62) Plotter converts numerical solutions of problems solved by the Model 10 Calculator into permanent graphic records. Plots are made using solid lines connecting points, specified by the calculator as scaled coordinates in the x and y registers, which are sequentially transferred to the x and y control circuits of the plotter. Using increments between points which span not more than five degrees of the arc of a curve results in smooth-appearing curves, each point of which is within closely-specified mechanical tolerances on the resulting graph, as well as within the mathematical accuracy specified by the calculator program.

The Model 9862A eliminates both the drudgery and the frequent human errors encountered in hand-plotting graphs. Not only does the Model 10/Model 62 system reduce the input data and plot graphs in a minimal time; a designer can examine the initial plot, enter new input values, produce a new plot quickly, and immediately see the results of the changes made. Optimum solutions to critical problems can be readily obtained with the Model 9862A's pinpoint resolution.

Additional plotting capability and time savings are available for the Model 62 in the form of two accessory plug-in units for the Model 10 Calculator.

The optional Model 11210A Mathematics ROM (Read-only memory) provides automatic scaling of the user's function for full-surface plots on normal 10 by 15 inch (25 by 38 cm) formats or any smaller size selected by the user.

The optional Model 11215A Plotter ROM adds to the system the capability for complete alphanumeric plotter output, axis generation, automatic function scaling, and point plotting using special symbols. The Plotter ROM thus allows the user to produce plots that are titled, scaled and labeled, ready to photograph or use in a report.

INSTALLATION AND OPERATION

The Model 62 Plotter is easy to install and operate. Only two external connections are required, one for power and the other for signals. Both connections are made to receptacles at the back of the Model 10 Calculator. An electrostatic hold-down device secures the paper firmly to the platen. The user switches the CHART HOLD off when the plot is finished to release the paper.

An exerciser program is supplied with each Model 62 Plotter to confirm that the calculator and plotter are operating properly. This program verifies alignment of the vertical and horizontal plotted lines with the plotter paper grids; that a number of plotted dots are within specified positions; that retraced lines do not open more than a specified amount; and that the servos are matched.

Graph limits are set using the LOWER LEFT and UPPER RIGHT controls. Plot size may be a maximum of 10 inches high by 15 inches wide, or 25 by 38 cm for metric paper, or it may be smaller at the user's discretion.

Redrawing a completely scaled and labeled plot in a different size for inclusion in reports is a frequently recurring problem. This can be easily accomplished with the Model 10, simply by changing the LOWER LEFT and UPPER RIGHT controls to set the new dimensions. No change in the calculator program is necessary.

The Model 10 exhibits excellent plotting speed, with *maximum* plotting time of 90 milliseconds for a half-inch vector. In spite of this speed, there is no limit to the length of a vector that can be drawn. Typically, an 18-inch vector can be drawn from the lower left corner to the upper right corner and retraced without a perceptible opening between the lines.

DEMONSTRATIONS

Demonstrations of the new Model 9862A Plotter may be arranged by contacting any Hewlett-Packard sales office.

9862A SPECIFICATIONS

Plotting Area: 10 inches on the Y axis by 15 inches on the X axis (25 cm by 38 cm on metric paper.)

Graph Limit Controls: The lower left corner of plotting area (origin) may be set anywhere from 0 in. to 5 in. (0 cm to 12,5 cm) on the Y axis, 0 in. to 10 in. (0 cm to 25,4 cm) on the X axis by the lower left graph limit controls. The upper right corner of plotting area (full scale) may be set anywhere on the plotting area after the lower left corner has been set.

Plotter Vector Length: There is no limit to length of vector that the plotter may draw. Maximum corner to corner dimension is 18.03 in. (45,8 cm).

Pen Control: Local control of electric pen lift is by front panel switches. Remote control from calculator is by program commands. Max. operations/sec. = 12. Time required per pen command = 40 cm/sec.

Writing Method: The Model 9862A uses ink supplied by disposable pens.

Plot Accuracy: Better than .3% of full scale at 25°C + .005%/C° worst case.

Numerical Resolution: One part in 10.000

Resetability: .007 in. (.18 mm) maximum

Temperature Range: In the range from 5°C to 45°C, lower left (origin) stability is better than .0025 in./°C (.07 mm/°C). Upper right (full scale) temperature coefficient is better than .016%/°C.

Power: 100V, 115V, 200V, or 230V ± 10% (choice of 4 positions). 40 to 66 Hz, 100 Watts.

Weight: Net 40 lbs. (18,1 Kg); Shipping 52 lbs., (23,6 Kg).

Dimensions: 8 1/2 in. high x 20 in. wide x 19 3/8 in. deep (213 mm x 500 mm x 484 mm).

Plotting Time: The actual plotting time of the 9862A will be determined either by the calculations being performed by the 9810A Calculator or by the plotter itself. The maximum plotting time for a .5 in. vector is 90 msec.

PASSIVE RLC NETWORK ANALYSIS PROGRAM

for the Hewlett-Packard 9100
Programmable Calculator
by C.E. Weller and W.H. Glass

PART NO.
09100–71505

A general network analysis program has been developed for the HP programmable calculator with its extended memory and plotter equipments. Purpose: This program makes it possible to analyze a ladder-like network. In its present form, the performance of a network of up to fifteen (15) series and shunt branches can be calculated. Each branch can contain up to three elements, making a total of forty-five elements. The HP extended memory is large enough to increase this capability in terms of network size, if required for some special reason. As can be seen in the memory map layout, the storage block of registers 165 through 186 could be moved to registers 123 through 144. This would allow for ten (10) additional branches by enlarging the continuous storage space required for element values and circuit types. This would of course require modification of the program instructions which reference these relocated memory registers. Networks with twenty-five branches or seventy-five R, L, C elements could then be analyzed. Figure 1 depicts the general form of the ladder type network.

The elements in each branch may be series, parallel or series-parallel combinations of R, L and C. The acceptable branch element configurations and their associated entry codes are shown in Figure 2. The circuit element values are entered for each branch with an accompanying circuit type number from one through five. The user should utilize the five circuit branch types shown in Figure 2 in such a way that the network to be analyzed will conform to the general network configuration that is shown in Figure 1. If the network to be analyzed does not contain a corresponding Block 1 branch (reference Figure 1) of the general form, the user should simulate Block 1 by entering a Circuit Type 1 with a resistance value of zero. While it is required to make the first branch entry a series branch (Block 1 of general form) the Nth entry may be either a series or a shunt branch. Therefore the total number of branches can be either odd or even. For a network which contains more complex branch configurations, it may be possible to utilize dummy branches to effectively combine adjacent shunt or series branches. Series branches can be eliminated by being entered as short circuits (Circuit type 1 with R equal to zero). Shunt branches entered as circuit type 1 with a very large value of resistance will nearly have the effect of combining two series branches directly. All dummy branch entries must be counted in the total branch count entry. When entering the program data, the element values and source and load resistances are independently specified. The amplitude and phase of the transfer function, reflection coefficient or vswr *vs* frequency can be obtained in plotted form. Amplitude and Phase plots can be made with either a linear or log frequency scale.

For plotting the insertion loss versus frequency (plot type 1 and 3), this program calculates the power delivered to the load referred to the power available from the source.

The insertion loss is calculated by the following equation:

Equation 1:

$$I_L\,(\mathrm{dB}) = 10 \log \frac{\text{Power out}}{\text{Power available}} = 20 \log \frac{e_o}{e_s} + 10 \log \frac{4\,R_s}{R_L}$$

For filter and matching networks etc., the program will plot insertion loss as defined by Equation 1 without the possibility of "apparent power gain" from a passive network.

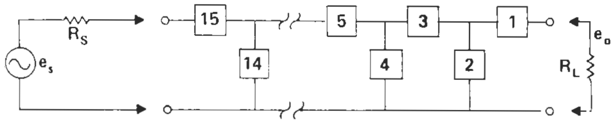


Figure 1
General Form of R L C Network

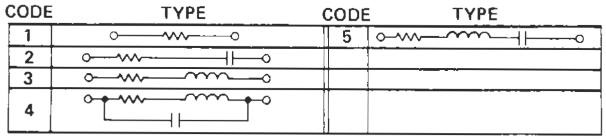


Figure 2
Branch Circuit Types and Their Associated Codes

For a circuit type such as might occur in a servo network analysis application, the second term in the equation could be precalculated with R_s made very small ($R_s > 0$!!) and this result could then be entered as the Y-shift entry in the program.

The program would then plot the voltage transfer function, rather than the power transfer function, as defined by equation (2).

Equation 2:

$$I_L \text{ (dB)} = 20 \log \frac{e_o}{e_s}$$

Another method for obtaining the voltage transfer plot without modifying the plot routine would be to treat the first input, series element of the network (providing it is a resistor) as the generator resistance.

The second term of equation (1) could then be eliminated by precalculating its value and entering this value as the Y-shift parameter.

If this method is inconvenient or causes inaccuracy due to R_L approaching infinity, the second term could be eliminated by re-writing a portion of the plot routine.

The reflection coefficient (Γ) may be plotted on a standard Smith Chart with either an expanded or normal scale. The "plot type" entry code is "5". The chart diameter is entered in units of inches. The program will automatically display "7.18" inches for the chart diameter. At this time the user has the option to accept or change this value. The program will ignore any X-shift, Y-shift, X-scale or Y-scale entry values when a plot type "5" has been chosen. Therefore if this plot type is chosen, the afore mentioned parameters may be entered without regard to their values by simply depressing the CONTINUE key for each of these four entries.

To plot reflection coefficients of small magnitude an expanded plot may be obtained by entering an appropriately scaled value for the Smith Chart diameter.

In all cases, the Smith Chart plots are normalized to the value which has been entered for the generator resistance (R_S).

The diagnostic display codes and their definitions which will be encountered in the event a non-allowable code entry is made are shown in Table 1.

Program Diagnostics			
Diagnostic Message	Display Code		
	x	y	z
Improper Exponent Entry			888
Improper Plot Type Entry	100	100	100
Improper Circuit Type Entry	π 3.14	π 3.14	π 3.14

Table 1

In addition to the present circuit type calculation programs, if desired the user can write his own program to calculate impedance for a circuit type not shown and label it with a number previously used for a circuit type not needed and insert it into memory by referring to the memory map.

The 1st branch is always considered series. If the user's network does not have this configuration this branch can be eliminated by using the circuit type equal to 1 and resistance equal to zero.

This technique can also be used to connect shunt branches directly in parallel.

Also, shunt branches can be eliminated by using circuit type No. 1 and making resistance very large.

WARNING

This program calculates insertion loss as referred to the available power from the source. To obtain accurate results for open circuit type analysis you can use a small R_S (not equal to zero) and a value of R_L large compared to the circuit element values. Y shift can then be used to offset the insertion loss caused by the impedance mismatch.

For Servo Type analysis it might be worthwhile rewriting portions of plot subroutine to calculate:

$$20 \text{ Log of } \frac{e_o}{e_N}$$

Present Equation

$$I_N \text{ Loss} = 20 \text{ Log} \frac{e_o}{e_s} + 10 \text{ Log } 4\left(\frac{R_s}{R_L}\right)$$

EQUIPMENT NEEDED ☑ 9100A ☑ 9100B ☐ 9120 ☑ 9125 ☐ 9160 ✓ ☐ 9104 ☐ 9106

☐ DEGREES ☐ RADIANS ☐ FLOATING ☐ FIXED DECIMAL WHEEL AT 3 PRE ☐ ☐ ON 9120

PROGRAM LOADING

1. File Protect Switch OFF			
2. PRESS: END			
3. PRESS: CLEAR, FMT, SET FLAG	0	0	0
4. ENTER: P_1			
5. PRESS: 1, FMT, FMT	6		
6. ENTER: P_2			
7. PRESS: 2, FMT, FMT	14		
8. ENTER: P_4			
9. PRESS: 4, FMT, FMT	19		
10. ENTER: P_5			
11. PRESS: 5, FMT, FMT	21		
12. ENTER: P_6			
13. PRESS: 6, FMT, FMT	28		
14. ENTER: P_7			
15. PRESS: 7, FMT, FMT	37		
16. ENTER: P_9			
17. PRESS: 9, FMT, FMT	40		
18. ENTER: P_{10}			
19. PRESS: 10 FMT, FMT	44		
20. ENTER: P_{11}			
21. PRESS: 11, FMT, FMT	54		
22. ENTER: P_{12}			
23. PRESS: 12, FMT, FMT	60		
24. ENTER: P_{13}			
25. PRESS: 13, FMT, FMT	66		
26. ENTER: P_{14}			
27. PRESS: 14, FMT, FMT	71		
28. ENTER: P_{15}			
29. PRESS: 15, FMT, FMT	74		
30. ENTER: P_{20}			
31. PRESS: 20, FMT, FMT	84		
32. ENTER: P_{22}			
33. PRESS: 22, FMT, FMT	89		
34. ENTER: P_{23}			

PROGRAM LOADING (CONTINUED)

35. PRESS: 23, FMT, FMT	98
36. ENTER: P_{24}	
37. PRESS: 24, FMT, FMT	106
38. ENTER: P_{25}	
39. PRESS: 25, FMT, FMT	113
40. ENTER: P_{26}	
41. PRESS: 26, FMT, FMT	122
42. File Protect Switch ON	

PROGRAM EXECUTION

	X	Y	Z
1. PRESS: 1, FMT, GO TO	6		
2. PRESS: END, CONTINUE	99	99	99
3. ENTER: Data N = Total Number of Series and Shunt Branches $\leqslant 15$	N	99	99
4. PRESS: CONTINUE	10	0	10
5. ENTER: Exponent Code of R of 1st branch	Exp		

Exponent Code

6 = Mega
3 = Kilo
0 = 10^0 = 1
-3 = Milli
-6 = Micro
-9 = Nano
-12 = Pico

Note: *Only* the exponent codes shown (6, 3, 0, etc.) are allowable; e.g., entry of exponent code 2 will prevent the program from running, and will result in an 888 diagnostic display.

PROGRAM EXECUTION (CONTINUED)

6. PRESS: XEY		Exp	
7. ENTER: Resistance value of first branch	R	Exp	
8. PRESS: CONTINUE	11	0	11
9. ENTER Exponent Code of L value of the first branch	Exp		
10. PRESS: XEY		Exp	
11. ENTER: L value of first branch	L	Exp	
12. PRESS: CONTINUE	12	0	12
13. ENTER: Exponent Code of C value of first branch	Exp	0	12
14. PRESS: XEY		Exp	
15. ENTER: C value of first branch	C	Exp	
16. PRESS: CONTINUE	13	0	13
17. ENTER: Circuit type (1-5) of first branch	Cir type	0	13
18. PRESS: CONTINUE	20	0	20

The Branches in the Circuit are called out in Increments of tens

1st Branch	2nd	3rd	. . . 15th
10 R	20	30	150
11 C	21	31	151
12 L	22	32	152
13 Circuit type	23	33	153

After the Last Circuit Type of Last Branch is Entered and the CONTINUE Key has been Pressed

This Display will Appear	1	0	1
19. ENTER: Exponent of R_L value	Exp		
20. PRESS: XEY		Exp	
21. ENTER: Resistor Load value	R_L	Exp	
22. PRESS: CONTINUE	2	0	2
23. ENTER: Exponent of R_s value	Exp		
24. PRESS: XEY		Exp	
25. ENTER: Source Resistance value	R_s	Exp	
26. PRESS: CONTINUE	3	0	3
27. ENTER: Exponent of initial frequency value	Exp		
28. PRESS: XEY		Exp	
29. ENTER: First Frequency value	f_1	Exp	
30. PRESS: CONTINUE	4	0	4

PROGRAM EXECUTION (CONTINUED)

31. ENTER: Exponent of the delta frequency function value			
32. PRESS: XEY	Exp	Exp	
33. For Linear Plot			
ENTER: Δf or Frequency Increment value.	Δf	Exp	
For Log Plot			
ENTER: $(F_n+1)/F_n$ (or the Ratio of Successive Frequencies value)			
34. PRESS: CONTINUE	5	0	5
35. ENTER: The following Number for the Plot Desired	N		
1 = Magnitude *vs* Frequency (Lin)			
2 = Phase *vs* Frequency Linear			
3 = Magnitude *vs* Frequency Log			
4 = Phase *vs* Frequency Log			
5 = Gamma *vs* Frequency Lin (Smith Chart)			
If you select Number "5" ignore the next four entries by pressing CONTINUE at Steps 37, 41, 45 and 49.			
6 = VSWR *vs* Frequency Lin.			
36. PRESS: CONTINUE	6	0	6
37. ENTER: Exponent of X-shift value	Exp		
38. PRESS: XEY		Exp	
39. ENTER: X-Shift value	X_{shift}	Exp	
40. PRESS: CONTINUE	7	0	7
41. ENTER: Exponent of Y-shift value	Exp		
42. PRESS: XEY		Exp	
43. ENTER: Y-Shift value	Y_{shift}	Exp	
44. PRESS: CONTINUE	8	0	8
45. ENTER: Exponent of X-scale value	Exp		
46. PRESS: XEY		Exp	
47. ENTER: X-Scale value	X_{scale}	Exp	
48. PRESS: CONTINUE	9	0	9
49. ENTER: Exponent of Y-scale value	Exp		
50. PRESS: XEY		Exp	
51. ENTER: Y-scale value	Y_{scale}	Exp	

PROGRAM EXECUTION (CONTINUED)

52. PRESS: CONTINUE 7.18 10 10

Enter New Smith Chart Diameter if desired, if not go to Step 53 and 7.18 will automatically be entered for Smith Chart Diameter and used only if Plot Type "5" has been previously requested.

53. PRESS: CONTINUE

Calculation and Plotting now begins

Changes in the "Circuit Problem" may be incorporated in the following manner.

A. Press (1), FMT, GO TO, END, CONTINUE and Re-Enter until Desired Change is made or, (2) Address Change to Extended Memory using FMT, Y Command Set, and Consulting Memory Map for Storage of Particular Constant.

Then Press 10, FMT, GO TO, END, CONTINUE and Calculations and Plot will begin.

B. To Change R_L, R_s F_1 and, or ΔF

Press 6, FMT, GO TO, END, CONTINUE then Repeat Entry

Then Press 10, FMT, GO TO, END, CONTINUE and Calculations will Begin.

C. To Change Plot and Plot Data, Press 7, FMT, GO TO, END, CONTINUE.

Repeat Plot Data Entry.

Then PRESS: CONTINUE, and Calculations begin.

P-1
Entry
of
Circuit
Data

P2
Exponent
Calculation
Subroutine

P4
Circuit Type 4
Calculation

P5
Circuit Type 3

P6
Entry of
R_L, R_s
fo, Δf

P7
Entry of
P_n, X-shift,
Y-shift,
X-scale, Y-scale
Smith Chart
Diameter

P9
Circuit Type 2
Calculations

P10
Initialization
of Variables

P11
Circuit Type
Data Transfer
to Work Area

Routine Caller
for Z
Calculation

P12
Odd-Even
Decision and
Odd Branch
Calculation

P13
Final
Calculations
Exit to
Plot

P14
Even Branch
Calculation

P15
Circuit Type 5
Calculation

P20
Plot Types
1 and 2
Driver

P22
Plot Type
Decision

P23
Plot Type
3 Driver

P24
Plot Type
4 Driver

P25
Plot Type
5 Driver

P26
Plot Type
6 Driver

Spare

Spare
500/Y-scale
500/X-scale
Y-shift
X-shift
Odd-Even Count
Smith Chart Dia.
Spare
Real Z
Imaginary Z
R_L
R_s
Address Pointer
ln e/e mag.
e/e $\measuredangle$
$\Delta\omega$
ω
P_n
Spare
Spare
C_n Value
L_n Value
R_n Value
CT153
C152
L151
R150
CT143
C142
L141
R140
CT133
C132
L131
R130
CT123

C122
L121
R120
CT113
C112
L111
R110
CT103
C102
L101
R100
CT93
C92
L91
R90
CT83
C82
L81
R80
CT73
C72
L71
R70
CT63
C62
L61
R60
CT53
C52
L51
R50
CT43
C42
L41
R40
CT33
C32
L31
R30
CT23
C22
L21
R20
CT13
C12
L11
R10
"END OF DATA"
POINTER

Sample Problem

The circuit for this example is taken from the HP 9100A Library -- No. 09100-71001.

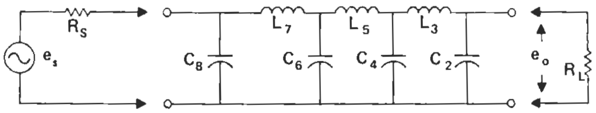


Figure 3. Sample Problem Circuit

Where: $R_S = R_L = 50\Omega$
$C_2 = C_8 = 1175$ pF
$C_4 = C_6 = 2086$ pF
$L_3 = L_7 = 3.538\ \mu$H
$L_5 = 3.913\ \mu$H

Data is entered for eight branches which includes a dummy entry for branch position number 1.

Branch Data Entry Summary Table

Data Entered	Display			
	X	Y	Z	
	99	99	99	before entry
(No. of Branches)	8	99	99	after entry

Branch No.		1	2	3	4	5	6	7	8
	X Displays	10	20	30	40	50	60	70	80
R	Exp Entry	0	0	0	0	0	0	0	0
	Value Entry	0	0	0	0	0	0	0	0
	X Displays	11	21	31	41	51	61	71	81
L	Exp Entry	0	0	-6	0	-6	0	-6	0
	Value	0	0	3.538	0	3.913	0	3.538	0
	X Displays	12	22	32	42	52	62	72	82
C	Exp Entry	0	-12	0	-12	0	-12	0	-12
	Value	0	1175	0	2086	0	2086	0	1175
Circuit	X Displays	13	23	33	43	53	63	73	83
Type	Entry Code	1	2	3	2	3	2	3	2

Each column of data is entered in numerical sequence.
Other data entry is shown below.

Branch Data Entry Summary Table (Cont'd)

Display			Data Entry		Problem Data
X	Y	Z	Value	Exponent Code	
1	0	1	50	0	$R_L = 50\Omega$
2	0	2	50	0	$R_s = 50\Omega$
3	0	3	100	3	fo = 100 kHz
4	0	4	50	3	Δf = 50 kHz
5	0	5	6	0	Plot Type
6	0	6	0	0	X-Shift
7	0	7	0	0	Y-Shift
8	0	8	.5	6	X-Scale = ½ MHz per inch
9	0	9	1	0	Y-Scale = 1:1 per inch
7.18	10	10	None	None	Sm. Chart Dia.

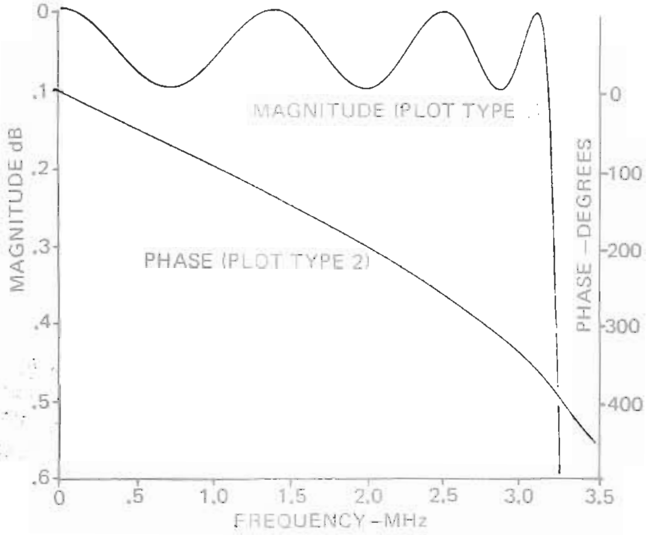


Figure 4. Magnitude and Phase vs Linear Frequency

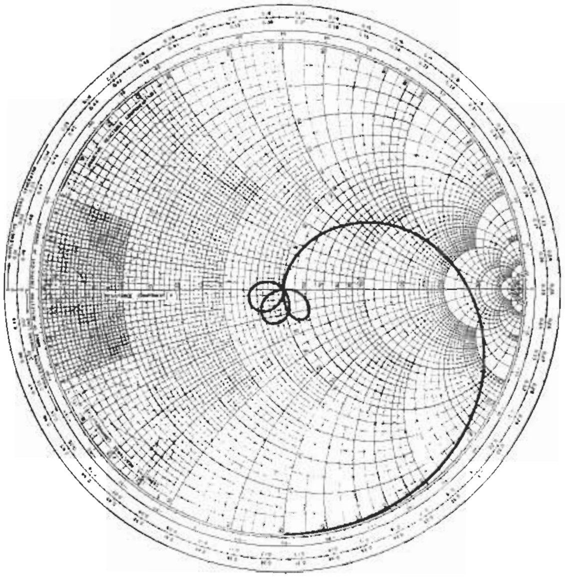


Figure 5. Gamma vs Linear Frequency (Smith Chart)

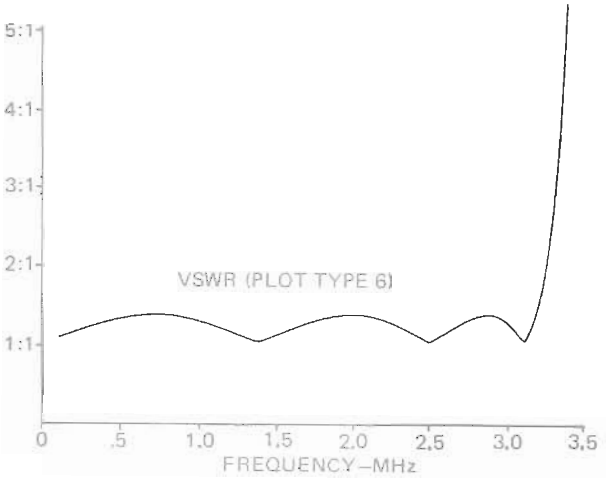


Figure 6. VSWR vs Linear Frequency

C.E. Weller

Mr. Weller is a senior staff engineer at Avco Electronics Division. He is currently engaged in company-sponsored programs involving thin-film work at UHF frequencies. He is a graduate of Michigan State with a B.S. and M.S. in Electrical Engineering. He is a member of IEEE, Eta Kappa Nu and Sigma Pi Sigma.

W.H. Glass

Mr. Glass's experience includes ten years on computer applications in the engineering field. The general areas of applications are real-time systems, automatic test equipment, large systems simulation and specific engineering problem solving. Mr. Glass received a B.S. degree in Physics from Murray State University in 1961 and is presently employed with Avco Electronics Division as a senior engineer.

P1

Step	Key	Code
00	CLR	20
01	2	02
02	4	04
03	6	06
04	UP	27
05	2	02
06	4	04
07	7	07
08	FMT	42
09	YTO	40
0a	9	11
0b	9	11
0c	UP	27
0d	UP	27
10	STP	41
11	UP	27
12	1	01
13	0	00
14	X	36
15	3	03
16	+	33
17	YTO	40
18	c	16
19	1	01
1a	0	00
1b	XTO	23
1c	d	17
1d	0	00
20	XTO	23
21	e	12
22	d	17
23	UP	27
24	UP	27
25	0	00
26	RUP	22
27	STP	41
28	YTO	40
29	a	13
2a	XTO	23
2b	b	14
2c	2	02
2d	FMT	42
30	GTO	44
31	a	13
32	UP	27
33	2	02
34	4	04
35	7	07
36	FMT	42
37	π	56
38	FMT	42
39	YTO	40
3a	UP	27
3b	1	01
3c	-	34
3d	2	02
40	4	04
41	7	07
42	FMT	42
43	YTO	40
44	e	12
45	UP	27
46	1	01
47	+	33
48	YTO	40
49	e	12
4a	d	17
4b	UP	27
4c	1	01
4d	+	33
50	YTO	40
51	d	17
52	4	04
53	UP	27
54	e	12
55	X<Y	52
56	2	02
57	2	02
58	d	17
59	UP	27
5a	c	16
5b	X<Y	52
5c	6	06
5d	7	07
60	6	06
61	+	33
62	YTO	40
63	d	17
64	GTO	44
65	1	01
66	d	17
67	6	06
68	FMT	42
69	GTO	44
6a	END	46

P2

Step	Key	Code
00	CNT	47
01	b	14
02	UP	27
03	a	13
04	UP	27
05	0	00
06	X=Y	50
07	7	07
08	9	11
09	3	03
0a	X=Y	50
0b	6	06
0c	d	17
0d	6	06
10	X=Y	50
11	6	06
12	3	03
13	3	03
14	CHS	32
15	X=Y	50
16	5	05
17	6	06
18	6	06
19	CHS	32
1a	X=Y	50
1b	4	04
1c	9	11
1d	9	11
20	CHS	32
21	X=Y	50
22	3	03
23	c	16
24	1	01
25	2	02
26	CHS	32
27	X=Y	50
28	3	03
29	0	00
2a	8	10
2b	8	10
2c	8	10
2d	STP	41
30	DN	25
31	1	01
32	EEX	26
33	1	01
34	2	02
35	CHS	32
36	X	36
37	YTO	40
38	a	13
39	GTO	44
3a	7	07
3b	c	16
3c	DN	25
3d	1	01
40	EEX	26
41	9	11
42	CHS	32
43	X	36
44	YTO	40
45	a	13
46	GTO	44
47	7	07
48	c	16
49	DN	25
4a	1	01
4b	EEX	26
4c	6	06
4d	CHS	32
50	X	36
51	YTO	40
52	a	13
53	GTO	44
54	7	07
55	c	16
56	DN	25
57	1	01
58	EEX	26
59	3	03
5a	CHS	32
5b	X	36
5c	YTO	40
5d	a	13
60	GTO	44
61	7	07
62	c	16
63	DN	25
64	1	01
65	EEX	26
66	6	06
67	X	36
68	YTO	40
69	a	13
6a	GTO	44
6b	7	07
6c	c	16
6d	DN	25
70	1	01
71	EEX	26
72	3	03
73	X	36
74	YTO	40
75	a	13
76	GTO	44
77	7	07
78	c	16
79	DN	25
7a	YTO	40
7b	a	13
7c	FMT	42
7d	END	46

P4

Step	Key	Code
00	CLR	20
01	1	01
02	8	10
03	6	06
04	FMT	42
05	π	56
06	UP	27
07	1	01
08	8	10
09	5	05
0a	FMT	42
0b	π	56
0c	YTO	40
0d	a	13
10	XTO	23
11	b	14
12	1	01
13	8	10
14	4	04
15	FMT	42
16	π	56
17	UP	27
18	1	01
19	8	10
1a	0	00
1b	FMT	42
1c	π	56
1d	XTO	23
20	d	17
21	X	36
22	1	01
23	XEY	30
24	DIV	35
25	b	14
26	YTO	40
27	b	14
28	UP	27
29	d	17
2a	X	36
2b	YTO	40
2c	c	16
2d	DN	25
30	X	36
31	RUP	22
32	XEY	30
33	a	13
34	CHS	32
35	X	36
36	RDN	31
37	XEY	30
38	POL	62
39	LN	65
3a	AC+	60
3b	c	16
3c	UP	27
3d	b	14
40	-	34
41	a	13
42	POL	62
43	LN	65
44	AC-	63
45	RCL	61
46	EXP	74
47	RCT	66
48	YTO	40
49	a	13
4a	XTO	23
4b	b	14
4c	FMT	42
4d	END	46

P5

Step	Key	Code
00	CLR	20
01	1	01
02	8	10
03	6	06
04	FMT	42
05	π	56
06	UP	27
07	1	01
08	8	10
09	5	05
0a	FMT	42
0b	π	56
0c	UP	27
0d	1	01
10	8	10
11	0	00
12	FMT	42
13	π	56
14	X	36
15	DN	25
16	XTO	23
17	a	13
18	YTO	40
19	b	14
1a	FMT	42
1b	END	46

P6

Step	Key	Code
00	CLR	20
01	1	01
02	UP	27
03	UP	27
04	0	00
05	XEY	30
06	STP	41
07	YTO	40
08	a	13
09	XTO	23
0a	b	14
0b	2	02
0c	FMT	42
0d	GTO	44
10	a	13
11	UP	27
12	1	01
13	7	07
14	4	04
15	FMT	42
16	YTO	40
17	2	02
18	UP	27
19	0	00
1a	UP	27
1b	2	02
1c	STP	41
1d	XTO	23
20	b	14
21	YTO	40
22	a	13
23	2	02
24	FMT	42
25	GTO	44
26	a	13
27	UP	27
28	1	01
29	7	07
2a	5	05
2b	FMT	42
2c	YTO	40
2d	3	03
30	UP	27
31	0	00
32	UP	27
33	3	03
34	STP	41
35	XTO	23
36	b	14
37	YTO	40
38	a	13
39	2	02
3a	FMT	42
3b	GTO	44
3c	a	13
3d	UP	27
40	2	02
41	X	36
42	π	56
43	X	36
44	1	01
45	8	10
46	0	00
47	FMT	42
48	YTO	40
49	4	04
4a	UP	27
4b	0	00
4c	UP	27
4d	4	04
50	STP	41
51	XTO	23
52	b	14
53	YTO	40
54	a	13
55	2	02
56	FMT	42
57	GTO	44
58	a	13
59	UP	27
5a	2	02
5b	X	36
5c	π	56
5d	X	36
60	1	01
61	7	07
62	9	11
63	FMT	42
64	YTO	40
65	7	07
66	FMT	42
67	GTO	44
68	END	46

P7

Step	Key	Code
00	CLR	20
01	5	05
02	UP	27
03	0	00
04	UP	27
05	5	05
06	STP	41
07	UP	27
08	1	01
09	8	10
0a	1	01
0b	FMT	42
0c	YTO	40
0d	6	06
10	UP	27
11	0	00
12	UP	27
13	6	06
14	STP	41
15	YTO	40
16	a	13
17	XTO	23
18	b	14
19	2	02
1a	FMT	42
1b	GTO	44
1c	a	13
1d	UP	27
20	1	01
21	6	06
22	8	10
23	FMT	42
24	YTO	40
25	7	07
26	UP	27
27	0	00
28	UP	27
29	7	07
2a	STP	41
2b	YTO	40
2c	a	13
2d	XTO	23

Storage

Plus Page

f	
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Minus Page

Step	Key	Code
30	b	14
31	2	02
32	FMT	42
33	GTO	44
34	a	13
35	UP	27
36	1	01
37	6	06
38	7	07
39	FMT	42
3a	YTO	40
3b	8	10
3c	UP	27
3d	0	00
40	UP	27
41	8	10
42	STP	41
43	YTO	40
44	a	13
45	XTO	23
46	b	14
47	2	02
48	FMT	42
49	GTO	44
4a	5	05
4b	0	00
4c	0	00
4d	UP	27
50	a	13
51	DIV	35
52	1	01
53	6	06
54	6	06
55	FMT	42
56	YTO	40
57	9	11
58	UP	27
59	0	00
5a	UP	27
5b	9	11
5c	STP	41
5d	YTO	40
60	a	13
61	XTO	23
62	b	14
63	2	02
64	FMT	42
65	GTO	44
66	5	05
67	0	00
68	0	00
69	UP	27
6a	a	13
6b	DIV	35
6c	1	01
6d	6	06
70	5	05
71	FMT	42
72	YTO	40
73	1	01
74	0	00
75	UP	27
76	UP	27
77	7	07
78	.	21
79	1	01
7a	8	10
7b	STP	41
7c	UP	27
7d	1	01
80	7	07
81	0	00
82	FMT	42
83	YTO	40
84	1	01
85	0	00
86	FMT	42
87	GTO	44
88	END	46

P_9

Step	Key	Code
00	CLR	20
01	1	01
02	8	10
03	6	06
04	FMT	42
05	π	56
06	UP	27
07	1	01
08	8	10
09	4	04
0a	FMT	42
0b	π	56
0c	UP	27
0d	1	01
10	8	10
11	0	00
12	FMT	42
13	π	56
14	X	36
15	1	01
16	CHS	32
17	XEY	30
18	DIV	35
19	DN	25
1a	XTO	23
1b	a	13
1c	YTO	40
1d	b	14
20	FMT	42
21	END	46

P_{10}

Step	Key	Code
00	CLR	20
01	1	01
02	7	07
03	4	04
04	FMT	42
05	π	56
06	UP	27
07	1	01
08	7	07
09	2	02
0a	FMT	42
0b	YTO	40
0c	DN	25
0d	1	01
10	7	07
11	3	03
12	FMT	42
13	YTO	40
14	1	01
15	7	07
16	7	07
17	FMT	42
18	YTO	40
19	1	01
1a	7	07
1b	8	10
1c	FMT	42
1d	YTO	40
20	2	02
21	4	04
22	6	06
23	UP	27
24	1	01
25	7	07
26	6	06
27	FMT	42
28	YTO	40
29	1	01
2a	UP	27
2b	1	01
2c	6	06
2d	9	11
30	FMT	42
31	YTO	40
32	1	01
33	1	01
34	FMT	42
35	GTO	44
36	END	46

P_{11}

Step	Key	Code
00	CLR	20
01	1	01
02	7	07
03	6	06
04	FMT	42
05	π	56
06	XTO	23
07	a	13
08	XTO	23
09	b	14
0a	UP	27
0b	3	03
0c	-	34
0d	YTO	40
10	c	16
11	b	14
12	FMT	42
13	π	56
14	UP	27
15	a	13
16	UP	27
17	b	14
18	-	34
19	1	01
1a	8	10
1b	6	06
1c	XEY	30
1d	-	34
20	DN	25
21	FMT	42
22	YTO	40
23	b	14
24	UP	27
25	1	01
26	-	34
27	YTO	40
28	b	14
29	c	16
2a	X<Y	52
2b	1	01
2c	1	01
2d	XEY	30
30	UP	27
31	1	01
32	-	34
33	1	01
34	7	07
35	6	06
36	FMT	42
37	YTO	40
38	RUP	22
39	FMT	42
3a	π	56
3b	UP	27
3c	1	01
3d	X=Y	50
40	8	10
41	7	07
42	2	02
43	X=Y	50
44	8	10
45	0	00
46	3	03
47	X=Y	50
48	7	07
49	7	07
4a	4	04
4b	X=Y	50
4c	7	07
4d	0	00
50	5	05
51	X=Y	50
52	6	06
53	6	06
54	6	06
55	X=Y	50
56	5	05
57	c	16
58	π	56
59	UP	27
5a	UP	27
5b	STP	41
5c	CNT	47
5d	CNT	47
60	FMT	42
61	GTO	44
62	1	01
63	2	02
64	FMT	42
65	GTO	44
66	1	01
67	5	05
68	FMT	42
69	GTO	44
6a	1	01
6b	2	02
6c	FMT	42
6d	GTO	44
70	4	04
71	FMT	42
72	GTO	44
73	1	01
74	2	02
75	FMT	42
76	GTO	44
77	5	05
78	FMT	42
79	GTO	44
7a	1	01
7b	2	02
7c	FMT	42
7d	GTO	44
80	9	11
81	FMT	42
82	GTO	44
83	1	01
84	2	02
85	FMT	42
86	GTO	44
87	1	01
88	8	10
89	6	06
8a	FMT	42
8b	π	56
8c	XTO	23
8d	b	14
90	0	00
91	XTO	23
92	a	13
93	1	01
94	2	02
95	FMT	42
96	GTO	44
97	END	46

P_{12}

Step	Key	Code
00	CLR	20
01	1	01
02	6	06
03	9	11
04	FMT	42
05	π	56
06	UP	27
07	1	01
08	X=Y	50
09	1	01
0a	1	01
0b	1	01
0c	4	04
0d	FMT	42
10	GTO	44
11	0	00
12	UP	27
13	1	01
14	6	06
15	9	11
16	FMT	42
17	YTO	40
18	1	01
19	7	07
1a	3	03
1b	FMT	42
1c	π	56
1d	UP	27
20	1	01
21	7	07
22	2	02
23	FMT	42
24	π	56
25	AC+	60
26	YTO	40
27	c	16
28	XTO	23
29	d	17
2a	a	13
2b	UP	27
2c	b	14
2d	AC+	60
30	RCL	61
31	UP	27
32	1	01
33	7	07
34	2	02
35	FMT	42
36	YTO	40
37	DN	25
38	1	01
39	7	07
3a	3	03
3b	FMT	42
3c	YTO	40
3d	RCL	61
40	AC-	63
41	POL	62
42	LN	65
43	AC-	63
44	c	16
45	UP	27
46	d	17
47	POL	62
48	LN	65
49	AC+	60
4a	RCL	61
4b	UP	27
4c	1	01
4d	7	07
50	7	07
51	FMT	42
52	+	33
53	DN	25
54	1	01
55	7	07
56	8	10
57	FMT	42
58	+	33
59	1	01
5a	3	03
5b	FMT	42
5c	GTO	44
5d	END	46

P_{13}

Step	Key	Code
00	CLR	20
01	1	01
02	7	07
03	6	06
04	FMT	42
05	π	56
06	UP	27
07	2	02
08	4	04
09	7	07
0a	FMT	42
0b	π	56
0c	X<Y	52
0d	1	01
10	4	04
11	GTO	44
12	1	01
13	8	10
14	1	01
15	1	01
16	FMT	42
17	GTO	44
18	1	01
19	7	07
1a	2	02
1b	FMT	42
1c	π	56
1d	UP	27
20	UP	27
21	1	01
22	7	07
23	5	05
24	FMT	42
25	π	56
26	+	33
27	1	01
28	7	07
29	3	03
2a	FMT	42
2b	π	56
2c	XTO	23
2d	d	17

Storage

Plus Page

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Minus Page

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HEWLETT-PACKARD

Step	Key	Code
30	XEY	30
31	POL	62
32	LN	65
33	AC-	63
34	d	17
35	RUP	22
36	POL	62
37	LN	65
38	AC+	60
39	1	01
3a	7	07
3b	8	10
3c	FMT	42
3d	π	56
40	UP	27
41	1	01
42	7	07
43	7	07
44	FMT	42
45	π	56
46	AC+	60
47	RCL	61
48	EXP	74
49	UP	27
4a	1	01
4b	7	07
4c	7	07
4d	FMT	42
50	YTO	40
51	DN	25
52	1	01
53	7	07
54	8	10
55	FMT	42
56	YTO	40
57	2	02
58	2	02
59	FMT	42
5a	GTO	44
5b	END	46

P14

00	CLR	20
01	1	01
02	UP	27
03	1	01
04	6	06
05	9	11
06	FMT	42
07	YTO	40
08	a	13
09	UP	27
0a	b	14
0b	POL	62
0c	LN	65
0d	AC-	63
10	RCL	61
11	AC-	63
12	YTO	40
13	c	16
14	XTO	23
15	d	17
16	1	01
17	7	07
18	3	03
19	FMT	42
1a	π	56
1b	UP	27
1c	1	01
1d	7	07

Step	Key	Code
20	2	02
21	FMT	42
22	π	56
23	POL	62
24	LN	65
25	AC-	63
26	RCL	61
27	AC-	63
28	EXP	74
29	RCT	66
2a	AC+	60
2b	c	16
2c	UP	27
2d	d	17
30	EXP	74
31	RCT	66
32	AC+	60
33	RCL	61
34	AC-	63
35	POL	62
36	LN	65
37	AC-	63
38	RCL	61
39	EXP	74
3a	RCT	66
3b	UP	27
3c	1	01
3d	7	07
40	2	02
41	FMT	42
42	YTO	40
43	DN	25
44	1	01
45	7	07
46	3	03
47	FMT	42
48	YTO	40
49	1	01
4a	3	03
4b	FMT	42
4c	GTO	44
4d	END	46

P15

00	CLR	20
01	1	01
02	8	10
03	5	05
04	FMT	42
05	π	56
06	UP	27
07	1	01
08	8	10
09	0	00
0a	FMT	42
0b	π	56
0c	X	36
0d	UP	27
10	1	01
11	8	10
12	4	04
13	FMT	42
14	π	56
15	X	36
16	1	01
17	XEY	30
18	DIV	35
19	DN	25
1a	-	34
1b	1	01
1c	8	10
1d	6	06

Step	Key	Code
20	FMT	42
21	π	56
22	YTO	40
23	a	13
24	XTO	23
25	b	14
26	FMT	42
27	END	46

P20

00	CLR	20
01	1	01
02	6	06
03	5	05
04	FMT	42
05	π	56
06	XTO	23
07	a	13
08	1	01
09	6	06
0a	7	07
0b	FMT	42
0c	π	56
0d	XTO	23
10	b	14
11	1	01
12	8	10
13	0	00
14	FMT	42
15	π	56
16	UP	27
17	2	02
18	DIV	35
19	π	56
1a	DIV	35
1b	1	01
1c	6	06
1d	8	10
20	FMT	42
21	π	56
22	-	34
23	1	01
24	6	06
25	6	06
26	FMT	42
27	π	56
28	X	36
29	YTO	40
2a	c	16
2b	1	01
2c	8	10
2d	1	01
30	FMT	42
31	π	56
32	UP	27
33	3	03
34	X=Y	50
35	4	04
36	1	01
37	1	01
38	X=Y	50
39	5	05
3a	6	06
3b	2	02
3c	X=Y	50
3d	4	04

Step	Key	Code
40	7	07
41	1	01
42	0	00
43	0	00
44	UP	27
45	UP	27
46	STP	41
47	1	01
48	7	07
49	8	10
4a	FMT	42
4b	π	56
4c	UP	27
4d	b	14
50	-	34
51	a	13
52	X	36
53	GTO	44
54	8	10
55	0	00
56	1	01
57	7	07
58	7	07
59	FMT	42
5a	π	56
5b	LOG	75
5c	UP	27
5d	2	02
60	0	00
61	X	36
62	1	01
63	7	07
64	5	05
65	FMT	42
66	π	56
67	UP	27
68	4	04
69	X	36
6a	1	01
6b	7	07
6c	4	04
6d	FMT	42
70	π	56
71	DIV	35
72	XEY	30
73	LOG	75
74	XEY	30
75	1	01
76	0	00
77	X	36
78	DN	25
79	+	33
7a	b	14
7b	-	34
7c	a	13
7d	X	36
80	c	16
81	FMT	42
82	DN	25
83	1	01
84	8	10
85	0	00
86	FMT	42
87	π	56
88	UP	27
89	1	01
8a	7	07
8b	9	11
8c	FMT	42
8d	π	56

Step	Key	Code
90	+	33
91	1	01
92	8	10
93	0	00
94	FMT	42
95	YTO	40
96	1	01
97	0	00
98	FMT	42
99	GTO	44
9a	END	46

P22

00	CLR	20
01	1	01
02	8	10
03	1	01
04	FMT	42
05	π	56
06	UP	27
07	1	01
08	X=Y	50
09	2	02
0a	9	11
0b	2	02
0c	X=Y	50
0d	2	02
10	9	11
11	3	03
12	X=Y	50
13	3	03
14	b	14
15	4	04
16	X=Y	50
17	2	02
18	d	17
19	5	05
1a	X=Y	50
1b	3	03
1c	3	03
1d	6	06
20	X=Y	50
21	3	03
22	7	07
23	1	01
24	0	00
25	0	00
26	UP	27
27	UP	27
28	STP	41
29	2	02
2a	0	00
2b	FMT	42
2c	GTO	44
2d	2	02
30	4	04
31	FMT	42
32	GTO	44
33	2	02
34	5	05
35	FMT	42
36	GTO	44
37	2	02
38	6	06
39	FMT	42
3a	GTO	44
3b	2	02
3c	3	03
3d	FMT	42

Step	Key	Code
40	GTO	44
41	END	46

P23

00	CLR	20
01	1	01
02	6	06
03	5	05
04	FMT	42
05	π	56
06	XTO	23
07	a	13
08	1	01
09	6	06
0a	7	07
0b	FMT	42
0c	π	56
0d	XTO	23
10	b	14
11	1	01
12	8	10
13	0	00
14	FMT	42
15	π	56
16	UP	27
17	2	02
18	DIV	35
19	π	56
1a	DIV	35
1b	DN	25
1c	LOG	75
1d	UP	27
20	1	01
21	6	06
22	8	10
23	FMT	42
24	π	56
25	LOG	75
26	-	34
27	1	01
28	6	06
29	6	06
2a	FMT	42
2b	π	56
2c	UP	27
2d	5	05
30	0	00
31	0	00
32	DIV	35
33	1	01
34	XEY	30
35	DIV	35
36	XEY	30
37	LOG	75
38	XEY	30
39	DN	25
3a	DIV	35
3b	5	05
3c	0	00
3d	0	00

Step	Key	Code
40	X	36
41	1	01
42	7	07
43	7	07
44	FMT	42
45	π	56
46	LOG	75
47	YTO	40
48	c	16
49	UP	27
4a	2	02
4b	0	00
4c	X	36
4d	1	01
50	7	07
51	5	05
52	FMT	42
53	π	56
54	UP	27
55	1	01
56	7	07
57	4	04
58	FMT	42
59	π	56
5a	DIV	35
5b	4	04
5c	X	36
5d	XEY	30

Storage

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HEWLETT-PACKARD

Step	Key	Code
60	LOG	75
61	XEY	30
62	1	01
63	0	00
64	X	36
65	DN	25
66	+	33
67	b	14
68	-	34
69	a	13
6a	X	36
6b	c	16
6c	FMT	42
6d	DN	25
70	1	01
71	8	10
72	0	00
73	FMT	42
74	π	56
75	UP	27
76	1	01
77	7	07
78	9	11
79	FMT	42
7a	π	56
7b	UP	27
7c	2	02
7d	DIV	35
80	π	56
81	DIV	35
82	DN	25
83	X	36
84	1	01
85	8	10
86	0	00
87	FMT	42
88	YTO	40
89	1	01
8a	0	00
8b	FMT	42
8c	GTO	44
8d	END	46

P24

00	CLR	20
01	1	01
02	6	06
03	5	05
04	FMT	42
05	π	56
06	XTO	23
07	a	13
08	1	01
09	6	06
0a	7	07
0b	FMT	42
0c	π	56
0d	XTO	23
10	b	14
11	1	01
12	8	10
13	0	00
14	FMT	42
15	π	56
16	UP	27
17	2	02
18	DIV	35
19	π	56
1a	DIV	35
1b	DN	25
1c	LOG	75
1d	UP	27

Step	Key	Code
20	1	01
21	6	06
22	8	10
23	FMT	42
24	π	56
25	LOG	75
26	-	34
27	1	01
28	6	06
29	6	06
2a	FMT	42
2b	π	56
2c	UP	27
2d	5	05
30	0	00
31	0	00
32	DIV	35
33	1	01
34	XEY	30
35	DIV	35
36	XEY	30
37	LOG	75
38	XEY	30
39	DN	25
3a	DIV	35
3b	5	05
3c	0	00
3d	0	00
40	X	36
41	1	01
42	7	07
43	8	10
44	FMT	42
45	π	56
46	UP	27
47	b	14
48	-	34
49	a	13
4a	X	36
4b	DN	25
4c	XEY	30
4d	FMT	42
50	DN	25
51	1	01
52	8	10
53	0	00
54	FMT	42
55	π	56
56	UP	27
57	1	01
58	7	07
59	9	11
5a	FMT	42
5b	π	56
5c	UP	27
5d	2	02
60	DIV	35
61	π	56
62	DIV	35
63	DN	25
64	X	36
65	1	01
66	8	10
67	0	00
68	FMT	42
69	YTO	40
6a	1	01
6b	0	00
6c	FMT	42
6d	GTO	44

Step	Key	Code
70	END	46

P25

00	CLR	20
01	1	01
02	7	07
03	3	03
04	FMT	42
05	π	56
06	UP	27
07	1	01
08	7	07
09	2	02
0a	FMT	42
0b	π	56
0c	YTO	40
0d	a	13
10	XTO	23
11	b	14
12	AC+	60
13	1	01
14	7	07
15	5	05
16	FMT	42
17	π	56
18	RDN	31
19	DN	25
1a	0	00
1b	XEY	30
1c	AC-	63
1d	RCL	61
20	AC-	63
21	POL	62
22	YTO	40
23	c	16
24	XTO	23
25	d	17
26	0	00
27	RUP	22
28	AC+	60
29	a	13
2a	UP	27
2b	b	14
2c	AC+	60
2d	RCL	61
30	AC-	63
31	POL	62
32	LN	65
33	AC-	63
34	c	16
35	UP	27
36	d	17
37	LN	65
38	AC+	60
39	RCL	61
3a	EXP	74
3b	RCT	66
3c	UP	27
3d	1	01

Step	Key	Code
40	7	07
41	0	00
42	FMT	42
43	π	56
44	X	36
45	RUP	22
46	X	36
47	2	02
48	5	05
49	0	00
4a	X	36
4b	RUP	22
4c	X	36
4d	DN	25
50	FMT	42
51	DN	25
52	1	01
53	8	10
54	0	00
55	FMT	42
56	π	56
57	UP	27
58	1	01
59	7	07
5a	9	11
5b	FMT	42
5c	π	56
5d	+	33
60	1	01
61	8	10
62	0	00
63	FMT	42
64	YTO	40
65	1	01
66	0	00
67	FMT	42
68	GTO	44
69	END	46

P26

00	CLR	20
01	1	01
02	7	07
03	3	03
04	FMT	42
05	π	56
06	UP	27
07	1	01
08	7	07
09	2	02
0a	FMT	42
0b	π	56
0c	YTO	40
0d	a	13
10	XTO	23
11	b	14
12	AC+	60
13	1	01
14	7	07
15	5	05
16	FMT	42
17	π	56
18	RDN	31
19	DN	25
1a	0	00
1b	XEY	30
1c	AC-	63
1d	RCL	61

Step	Key	Code
20	AC-	63
21	POL	62
22	YTO	40
23	c	16
24	XTO	23
25	d	17
26	0	00
27	RUP	22
28	AC+	60
29	a	13
2a	UP	27
2b	b	14
2c	AC+	60
2d	RCL	61
30	AC-	63
31	POL	62
32	LN	65
33	AC-	63
34	c	16
35	UP	27
36	d	17
37	LN	65
38	AC+	60
39	RCL	61
3a	EXP	74
3b	UP	27
3c	UP	27
3d	1	01
40	+	33
41	RUP	22
42	-	34
43	DN	25
44	DIV	35
45	1	01
46	6	06
47	7	07
48	FMT	42
49	π	56
4a	-	34
4b	1	01
4c	6	06
4d	5	05
50	FMT	42
51	π	56
52	X	36
53	1	01
54	8	10
55	0	00
56	FMT	42
57	π	56
58	UP	27
59	2	02
5a	DIV	35
5b	π	56
5c	DIV	35
5d	1	01
60	6	06
61	8	10
62	FMT	42
63	π	56
64	-	34
65	1	01
66	6	06
67	6	06
68	FMT	42
69	π	56
6a	X	36
6b	DN	25
6c	FMT	42
6d	DN	25

Step	Key	Code
70	1	01
71	8	10
72	0	00
73	FMT	42
74	π	56
75	UP	27
76	1	01
77	7	07
78	9	11
79	FMT	42
7a	π	56
7b	+	33
7c	1	01
7d	8	10
80	0	00
81	FMT	42
82	YTO	40
83	1	01
84	0	00
85	FMT	42
86	GTO	44
87	END	46

Step	Key	Code

HEWLETT-PACKARD

Storage

Plus Page

f	
e	
d	
c	
b	
a	
9	
8	
7	
6	
5	
4	
3	
2	
1	
0	

Minus Page

f	
e	
d	
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b	
a	
9	
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5	
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2	
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PROGRAM CATALOG AVAILABLE

A new Calculator Products Program Catalog will be off the press soon in a limited quantity. Any *KEYBOARD* reader wanting a copy should fill out and mail the postpaid reply card in this issue.

The catalog lists all HP calculator programs and program pacs for the Model 9100A/B and Model 10 which are now available. Packets and libraries are supplied as complete printed books. Individual programs which are not included in packets or libraries are available for purchase with complete documentation, test examples, and prerecorded magnetic cards.

Complete sets of prerecorded magnetic cards are listed for many of the program pacs and libraries. Delivery of all items listed in the catalog is subject to sufficient demand.

PROGRAM SHARING PLAN

The program sharing plan was announced in *KEYBOARD* Vol. 3, No. 1. This plan makes available, on a user-to-user trading basis, individual programs which for competitive or other reasons the author does not wish to have widely distributed by including them in *KEYBOARD* or in a published program library, but which the program author is willing to share with other calculator users in related fields.

These programs are kept by the person offering them in return for copies of a like number of programs from another program-sharing user. If you have programs you would like to trade with other calculator owners on a one-for-one basis, send the *KEYBOARD* editor the title of your program, the equipment it requires, and a short summary of the problem and equations it solves. Do not send the program itself. You will be contacted directly by other individuals who wish to exchange a copy of their unpublished programs in return for yours. You may withdraw a program at any time by notifying the *KEYBOARD* editor, P.O. Box 301, Loveland, Colorado 80537, or in Europe, Herrenberger Strasse 110, 703 Boblingen, West Germany.

Listings of shared programs are being mailed to members of the program sharing plan as they are received. Among the titles of programs included in this plan to date are:

British Income Tax Calculation
Crystal to Diffractometer Orientation Matrix
Linear Interpolation Subroutine for 9101A
The Freely Falling Body Experiment with Plot and Least Squares Fit to a Parabola
Parabolic Antenna Parameter Calculation.

MORE PROGRAM LIBRARIES AVAILABLE

Many of our readers gave a vote of appreciation for the list of program libraries in the last *KEYBOARD* issue. Here is an updated list including new pacs for the 9100A/B as well as those for the new Model 9810A. The new ones are asterisked.

Part Number	Description
09100-70800	Stat-Pac Vol. I
09100-70900	Analysis of Variance Pac
09100-70950	Quality Assurance Pac
09100-71200	Microwave Circuit Design Pac
09100-71374	Electric Utilities Pac
09100-74100	Surveying Pac Vol. I
09100-74175	Surveying Pac for 9100A and 9120A*
09100-74200	Structures Pac
09100-75100	Hydraulic Engineering Pac*
09100-75203	Animal Ecology Pac
09100-75300	Cardiology Pac
09100-75350	Clinical Pathology Pac
09100-75450	General Biology Programs*
09100-75598	Chemical Process Pac Vol. 1
09100-75599	Chemical Process Pac Vol. 2
09100-76999	Plotter Program Packet
09100-77000	Bautechnische 1 (German Structures 1)
09100-77017	Bautechnische 2 (German Structures 2)*
09100-77100	Calcoli Di Strutture Civili (Italian Structures)
09100-77200	Genie Civil (French Structures)*
09100-78000	Vermessung I (German Surveying)
09100-78100	Stadsmätning (Swedish Surveying)
09100-78200	British Surveying I
09100-78400	Italian Surveying
09100-79400	Shipbuilding Programmes I*
09100-79500	British Gear Design
09107-90022	9107A Digitizer Program Library*
09107-90031	9107A Digitizer Sample Program Packet*
09810-70000	Model 10 Math Pac*
09810-70800	Model 10 Stat-Pac*

LIBRARIES FOR THE MODEL 10

The Mathematics and Statistics program libraries are the first packets available for the new Model 9810A Calculator. The Math Pac is supplied at no charge with the purchase of a Model 10, and the Stat Pac is furnished with the purchase of a Model 11214A Statistics Plug-in Function Block. Copies of either library can be purchased separately. Here are listings of the programs.

MODEL 10 MATH PAC PROGRAM LISTING
PART NO.
09810-70000

Section I --- GENERAL FUNCTION ANALYSIS

1. Root-Finder
2. Maximum and Minimum of Z = Z(X,Y)
3. Fourier Series

Section II --- NUMERICAL INTEGRATION

1. Numerical Integration Using Simpson's One Third Rule
2. Differential Equations (Runge-Kutta - Gill Method)

Section III --- POLYNOMIALS

1. Polynomial Evaluation ($N \leqslant 10$)
2. Polynomial Coefficients from Roots
3. Roots of Polynomial (Order $n \leqslant 8$)
4. Roots of Polynomial (Order $n \leqslant 20$)
5. Quadratic Equation
6. Synthetic Division of Nth Order Polynomial ($N \leqslant 10$)
7. Interpolation (Equi-Spaced Data)
8. Interpolation (Unequi-Spaced Data)

Section IV --- MATRICES AND SYSTEMS OF SIMULTANEOUS EQUATIONS

1. Solution of N Simultaneous Equations in N Unknowns ($N \leqslant 10$)
2. Solution of N Simultaneous Equations in N Unknowns ($N \leqslant 17$)
3. Matrix Inversion for the Solution of Simultaneous Linear Equations, $N \leqslant 6$ (Gauss-Jordan Elimination)
4. Matrix Inversion for the Solution of Simultaneous Linear Equations, $N \leqslant 9$ (Gauss-Jordan Elimination)

5. Gauss-Jordan Elimination for the Solution of Simultaneous Equations, $N \leqslant 6$
6. Gauss-Jordan Elimination for the Solution of Simultaneous Equations, $N \leqslant 9$
7. Matrix Arithmetic Program
8. Characteristic Equation Solution Matrix (n x n) $n \leqslant 6$
9. Characteristic Equation Solution Matrix (n x n) $n \leqslant 9$

Section V --- STATISTICS

1. Statistics for Single Variable Analysis
2. Linear Regression with ANOVA
3. Histogram Generation (with Printer Plot)

MODEL 10 STAT PAC
PROGRAM LISTING

PART NO.
09810-70800

Section I --- GENERAL STATISTICS

1. Mean, Standard Deviation, Standard Error
2. Mean, Standard Deviation, and Standard Error for Grouped Data
3. Mean, Standard Deviation, Skewness and Kurtosis for Grouped and Ungrouped Data
4. Permutations
5. Combinations
6. Arithmetic, Geometric, Harmonic Means
7. Covariance and Coefficient of Correlation
8. Histogram Generation (with Printer Plot)
9. Uniform Random Number Generation
10. Normal Random Number Generation
11. One-Way Analysis of Variance (Balanced or Unbalanced Design)

Section II --- DISTRIBUTION FUNCTIONS

1. Normal Probability Integral
2. χ^2 - Chi Squared Distribution
3. Binomial Distribution
4. Poisson Distribution

Section III --- CURVE FITTING

1. Two-Variable Linear Regression
   $y = a_0 + a_1 x$
2. Two-Variable Parabolic Regression
   $y = a_0 + a_1 x + a_2 x^2$
3. Two-Variable Cubic Regression
   $y = a_0 + a_1 x + a_2 x^2 + a_3 x^3$
4. Two-Variable Quartic Regression
   $y = a_0 + a_1 x + a_2 x^2 + a_3 x^3 + a_4 x^4$
5. Least Squares Fit - Exponential Curve
   $y = ae^{bx}$
6. Least Squares Fit - Power Curve
   $y = ax^b$

Section IV --- MULTIPLE LINEAR REGRESSION

1. Multiple Linear Regression (3-Variable)
   $y = a_0 + a_1 x_1 + a_2 x_2$
2. Multiple Linear Regression (4-Variable)
   $y = a_0 + a_1 x_1 + a_2 x_2 + a_3 x_3$
3. Multiple Linear Regression (5-Variable)
   $y = a_0 + a_1 x_1 + a_2 x_2 + a_3 x_3 + a_4 x_4$

Section V --- TEST STATISTICS

1. Bartlett's Test for Homogeneity of Variance
2. Outlier Determination
3. Spearman's Rank Correlation Coefficient
4. Intraclass Correlation
5. Paired Observation Test
6. t Statistic for Means of Two Samples
7. χ^2 - Chi Squared Evaluation (Expected Values Equal)
8. χ^2 - Chi Squared Evaluation (Expected Values Unequal)
9. χ^2 - (2 x K) Contingency Table

PROGRAMMING TIPS

RECIPROCAL OF n

According to Brian D. Redmile of Salisbury, Rhodesia, the shortest way to calculate the reciprocal of a number in the x register, and without disturbing the contents of the y or z registers, is the sequence: LN, CHG SIGN, e^x. This works with the 9100A/B.

BLANK REGISTER IDENTIFICATION

Our thanks go to Mr. Redmile also for this tip for the 9100A/B. To create a distinctive display when a blank register is recalled the first time through a program, one or more alphameric characters can be displayed at the left of the screen. For example, if the program at some point recalls the d register, followed by a PAUSE or STOP, or you will be stepping through the program and want to recognize when this first happens, you can preprogram the d register as follows:

d0	yto	or 10th displayed alphameric
1	yto	or 9th displayed alphameric
2	yto	or 8th displayed alphameric
3	yto	or 7th displayed alphameric
4	yto	or 6th displayed alphameric
5	yto	or 5th displayed alphameric
6	yto	or 4th displayed alphameric
7	yto	or 3rd displayed alphameric
8	yto	or 2nd displayed alphameric
9	a	1st displayed alphameric
a	yto	
b	$\lvert y \rvert$	or yto*
c	yto	
d	yto	

*If $\lvert y \rvert$ is used, the display is in the floating-point position, i.e., starting at the left-hand edge of the screen, even though the switch is set at FIXED POINT. If yto is used, the display is in the "fixed-point" position.

ON-LINE PROGRAM BRANCH CONTROL

The following program sequence for the 9100A/B was designed by Eugene W. Urban of NASA's Marshall Space Flight Center, Alabama. It provides the operator with keyboard branching control of a running program. It can be used with any program *not* involving the use of trigonometric functions and, with the obvious restrictions discussed below, in certain programs involving trig functions. Branching is controlled with the DEGREES-RADIANS switch on the keyboard. Since cos (π rad) = -1 and cos (π deg) = 0.998, a test for the sign of the cosine of π provides the control. Either X<Y or X>Y can be used.

Possible uses of this routine include raising or lowering the plotter pen over a certain region of a graph (or providing a dashed curve), selecting a different variable increment during certain portions of a calculation, selecting different variables for printing, branching to a final calculation sequence when an initial calculation has proceeded far enough, etc. It is also possible to use this branch control at more than one location in a lengthy program provided the loops containing the branch points do not overlap.

```
STEP  KEY   CODE

 00    .
 01    .
 02    .
 03    π     56
 04   COS    73
 05   UP     27
 06   CLX    37
 07   X<Y    52
 08    .          }   This branch if DEGREES
 09    .          }
 0a    .          }   This branch if RADIANS
 0b    .          }
 0c    .
 0d    .

 10    .
 11    .
 12   GTO    44
 13    0     00   }   Loop back, for example.
 14    1     01   }
```

The test will work with some programs containing trigonometric functions provided that the functional arguments are selected to correspond to the switch setting. For example, if the program following a branch has trig functions with arguments in radians, an X>Y test would be used in the example shown to provide proper radian computation. If the portion of a program preceeding the branch has trig functions and the switch is set for proper computation, switch reversal to cause branching will lead to incorrect results during the last pass through the loop. This might be avoided by including two or more PAUSE's just before the branch test to provide switch throwing time.

FOUR STEP–SAVING TECHNIQUES

These four step-savers were submitted by Mr. Claude Cardot of Marcoussis, France. These apply to both the 9100A/B and the Model 10 with the Math ROM.

1. Starting with a number x in the x register, y in the y register, and k in the z register, it is desired to multiply

PROGRAMMING TIPS CONTINUED ON PAGE 32

STUDENT RECORDS PROGRAM

by K. R. Lindfors

PART NO.
09100-75904
9100B ONLY

Teachers of large numbers of students must face the problem of the determination of final grades at the end of each semester or term. This often involves calculating the semester average for each student as well as the class average. The following program for the 9100B Calculator with 9160A Marked Card Reader and 9120A Printer eases this task. To format the grade card of each student, access to a standard card punch is necessary.

The normal procedure for entering data from marked cards is to enter just one value per card. This is too awkward and inconvenient for the present application. It is possible with a proper program to read several values from a single card. For example, up to 9 two-digit grades could be entered from a single properly formatted card. The following program reads from each card:

a) A three-digit class number - This is checked to make sure the card is from the right class.
b) A three-digit student number - This is printed out to identify the grades with a particular student.
c) Four two-digit grades
d) A three-digit grade

There is room for another three-digit grade on the card, but it was not needed. These grades are printed, added together, divided by an appropriate number to calculate the student average which is printed out, and stored so that a class average can be calculated.

The key to entering several data values from a single card is timing. The 9100B must be ready to accept input information faster than it can be read from a card and then wait until the card is out of the reader before doing manipulations. This procedure has been used successfully with several programs. If the timing is proper, it works reliably and rapidly. If not, the results are unpredictable and the program in memory may even be altered by the incoming data.

The cards are formatted by entering CONTINUE (No. 47) after each grade. This is easily done using the automatic duplication feature of a standard card punch. A master is prepared by manually multiple punching in the appropriate columns. The punch is then programmed for automatic duplication and copies of the first are made at a rate of about one every five seconds. (NOTE: If the punch has the printing feature, this *must* be turned off.) Thus, a half hour of punch time will produce three hundred or more cards.

These cards are passed out to the students who enter their names, section numbers, etc., in the appropriate blanks. We chose to punch in the class number. Student numbers were entered on each card by pencil as were test scores as they were determined. Thus, the card deck serves as a "grade book." At the end of the semester, the cards are run through the 9100B and the student averages determined. The 9120A printer tape was proof-read against the main grade book and letter grades determined. Errors were avoided and grades determined much more rapidly than by hand as was done in the past.

EQUIPMENT NEEDED ☐ 9100A ☑ 9100B ☑ 9120 ☐ 9125 ☑ 9160 ☐ 9101 ☐ 9104 ☐ 9106

☐ DEGREES ☐ RADIANS ☐ FLOATING ☐ FIXED DECIMAL WHEEL AT 2 PRESS ☑ ☐ ☐ ON 9120

1. PRESS: END
2. Enter Program
3. Store class number in register a.
4. Store divisor in register b. 1 0 0
5. PRESS: CONTINUE
6. Enter class cards. N Class No. Class No.
7. After last class card PRESS: SET FLAG, CONTINUE. DEV, AVE and NT are printed out. 1 0 0
8. To process another class, PRESS: END and return to Step 3.

N = number of next class card to be read

NT = total number of cards

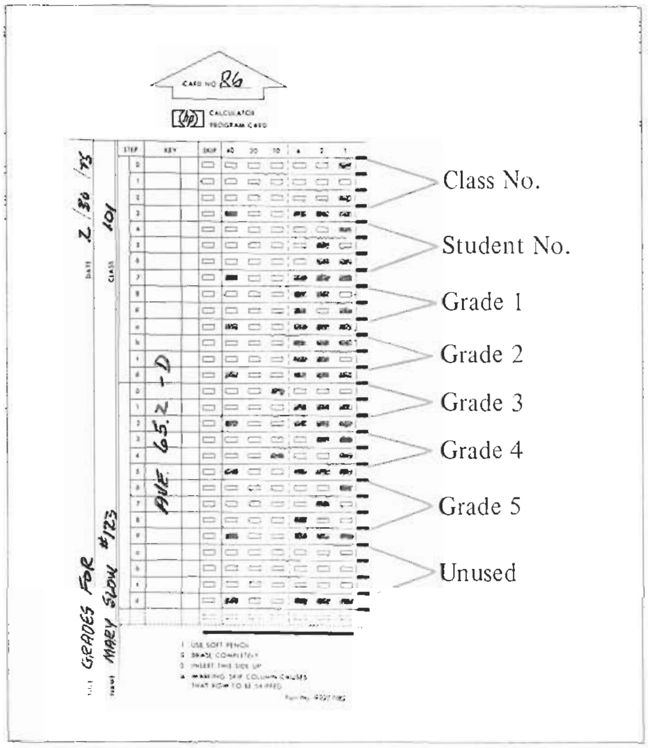
AVE = class average

DEV = standard deviation

Step	Key	Code	Step	Key	Code	Step	Key	Code	Step	Key	Code	Step	Key	Code	Step	Key	Code	Step	Key	Code
00	CLR	20	20	STP	41	40	PNT	45	60	X	36	80	-	34						
01	1	01	21	XTO	23	41	+	33	61	AC+	60	81	d	17						
02	XTO	23	22	-	34	42	XFR	67	62	d	17	82	UP	27						
03	d	17	23	6	06	43	-	34	63	XEY	30	83	1	01						
04	STP	41	24	STP	41	44	4	04	64	1	01	84	-	34						
05	IFG	43	25	XTO	23	45	PNT	45	65	+	33	85	f	15						
06	6	06	26	-	34	46	+	33	66	YTO	40	86	RDN	31						
07	c	16	27	7	07	47	XFR	67	67	d	17	87	DIV	35						
08	CNT	47	28	STP	41	48	-	34	68	DN	25	88	d	17						
09	XTO	23	29	PSE	57	49	5	05	69	GTO	44	89	RDN	31						
0a	-	34	2a	XFR	67	4a	PNT	45	6a	0	00	8a	√	76						
0b	1	01	2b	-	34	4b	+	33	6b	4	04	8b	XEY	30						
0c	STP	41	2c	1	01	4c	XFR	67	6c	d	17	8c	RDN	31						
0d	XTO	23	2d	UP	27	4d	-	34	6d	UP	27	8d	PNT	45						
10	-	34	30	a	13	50	6	06	70	1	01	90	RUP	22						
11	2	02	31	X=Y	50	51	PNT	45	71	-	34	91	PNT	45						
12	STP	41	32	3	03	52	+	33	72	YTO	40	92	RUP	22						
13	XTO	23	33	5	05	53	XFR	67	73	d	17	93	PNT	45						
14	-	34	34	STP	41	54	-	34	74	UP	27	94	PNT	45						
15	3	03	35	XFR	67	55	7	07	75	RCL	61	95	PNT	45						
16	STP	41	36	-	34	56	PNT	45	76	RUP	22	96	PNT	45						
17	XTO	23	37	2	02	57	+	33	77	DIV	35	97	PNT	45						
18	-	34	38	PNT	45	58	b	14	78	YTO	40	98	PNT	45						
19	4	04	39	CLX	37	59	DIV	35	79	f	15	99	GTO	44						
1a	STP	41	3a	UP	27	5a	DN	25	7a	X	36	9a	0	00						
1b	XTO	23	3b	XFR	67	5b	UP	27	7b	f	15	9b	0	00						
1c	-	34	3c	-	34	5c	PNT	45	7c	X	36	9c	END	46						
1d	5	05	3d	3	03	5d	PNT	45	7d	DN	25									

HEWLETT-PACKARD

SAMPLE CLASS CARD



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```
 231.          STUDENT NUMBER
  87.
  76.
  92.          GRADES
  88.
 174.
  86.17        AVERAGE

 243.
  72.
  58.
  80.
  73.
 167.
  76.67

 215.
  62.
  57.
  68.
  43.
 137.
  61.17

 302.
  88.
  74.
  93.
  74.
 168.
  82.83

   7.
  63.
  71.
  82.
  77.
 160.
  75.50

 123.
  65.
  76.
  87.
  39.
 124.
  65.17        STANDARD DEVIATION

   9.76        CLASS AVERAGE
  74.58        
   6.          NUMBER OF STUDENTS
```

SAMPLE PRINT OUT

a = 101
b = 6

600 points possible

the contents of both x and y by k and save k. A normal sequence takes seven steps. This sequence saves two steps:

STEP	KEY	CODE	DISPLAY		
			x	y	z
00	STP	41	x	y	k
01	POL	62			
02	RUP	22			
03	X	36			
04	RDN	31			
05	RCT	66	kx	ky	k

If k is not already in z, it can be entered in any way after step 02.

2. If k has a value of -1 and it is desired to multiply as above, a 3-step sequence: TO POLAR, CHG SIGN, TO RECT will do the operation. The initial sign of either x or y can be either plus or minus.

3. In electronic and acoustic problems it is often necessary to transform a given quantity in decibels (dB) into the corresponding power level, based on 0 dB = 1. A minimal sequence to transform a number of dB in y into the corresponding power level in x is:

STEP	KEY	CODE	DISPLAY		
			x	y	z
00	1	01		dB	
01	0	00	10		
02	DIV	35			
03	LN	65			
04	X	36			
05	DN	25			
06	EXP	74	W		

If the dB level is *below* reference, insert CHG SIGN after step 05.

4. A dB level in y can similarly be transformed into the corresponding voltage or current level in x, since E = $10^{dB/20}$. The trick in this and the above sequence is to use the number 10 for two purposes with one entry.

STEP	KEY	CODE	DISPLAY		
			x	y	z
00	2	02		dB	
01	DIV	35			
02	1	01			
03	0	00			
04	DIV	35			
05	LN	65			
06	X	36			
07	DN	25			
08	EXP	74	E		

FOUR SUBROUTINES IN ONE SUBPROGRAM

This program tip for the 9100A/B and 9101A Extended Memory was devised by W.J. Butterworth of the Admiralty, Underwater Weapons Establishment, Portland, Dorset, U.K. It enables up to four subroutines to be entered in one subprogram, thus reducing the number of magnetic cards required.

In the main program, before inserting the subprogram address in the x register, 1, 2, or 3 is entered in the y register. The fourth subroutine can be addressed by a SET FLAG instruction in the main program.

The beginning of the subprogram should contain the following instructions:

STEP	KEY	CODE	
00	IFG	43	
01	.		Branch to subroutine 4
02	.		
03	2	02	
04	X<Y	52	
05	.		Branch to subroutine 3
06	.		
07	X=Y	50	
08	.		Branch to subroutine 2
09	.		

Step 0a holds the first instruction in subroutine 1 and each of the first three subroutines is ended with GTO, followed by the address of FMT END in the 4th subroutine.

Each subroutine will usually start with a DOWN instruction to get the information back into the y register ready for use. If only two subroutines are to be stored, the SET FLAG instruction is preferred as it is only one instruction in the main program and causes less manoeuvring in the subprogram.

INDIRECT ADDRESSING FOR THE 9100/9101A

The following programming technique was submitted by Robert K.W. McCoy, Jr., Western Electric Company, Winston-Salem, North Carolina.

The HP 9100 Calculator, when used with the HP 9101A Extended Memory, provides a good system of indirect arithmetic but no way to change an address (indirect addressing). The following example is one method the writer found to achieve indirect addressing while writing a larger piece of software.

This procedure assumes the a, b, c, d, e, f registers are not available. If one of these is available, it should be used in place of an extended memory register for the address counter because of less programming space. In addition, this example is designed to work on both the 9100A and 9100B Calculators, so no minus registers were used.

Given: A table of constants or data in the extended memory in registers 100 through 107 is assumed. This table may be of any length the analyst chooses.

Problem: Increment the table pointer (address) and utilize it in the x register to recall the contents using a minimum of programming space.

Solution: Assign another register as a counter, and initialize it to the address of the first piece of data in the table, in this case, 100. The following is a series of program steps to recall the contents of the table and increment the counter. As an aid to understanding these steps, (110) indicates the contents of register 110, and ((110)) indicates the contents of the contents of register 110.

STEP	KEY	CODE	X Register
00	1	01	
01	1	01	
02	0	00	
03	FMT	42	
04	π	56	(110)
05	FMT	42	
06	π	56	((110))
07	UP	27	
08	1	01	
09	UP	27	
0a	1	01	
0b	1	01	
0c	0	00	
0d	FMT	42	
10	+	33	(Increment counter by 1)

Example:

TABLE

Register	Contents
100	123456.
101	543216.
102	246813.
103	292016.
104	585440.
105	130570.
110	Initialized to 100. This number (110) points to the first address or register of the table. It is then incremented to point to each successive address.

The first time through would produce the following results.

(11C) = 100
((110)) = (100) = 123456

Second time:

(110) = 101
((110)) = (101) = 543216

Last time:

(110) = 105
((110)) = (105) = 130570

The above procedure has proved to be effective in accomplishing indirect addressing with the HP 9100 Programmable Calculator and the HP 9101A Extended Memory. With this added flexibility, the user's range of possible programming options is widened for more complex tasks with increased efficiency.

MODEL 10 PRINTER-ALPHA TEST

The Model 9810A Calculator may be purchased with the column printer with or without the Model 11211A Printer Alpha ROM which gives alpha printing capability. The ROM can be purchased separately and plugged in later. Programs can be written which include alpha statements but which are capable of operating either with or without this ROM. This requires a test for the presence of the ROM. The following program sequence will always operate correctly.

	With Alpha			Without Alpha		
	x	y	z	x	y	z
0001--CLR	0	0	0	0	0	0
0002-- 1	1	0	0	1	0	0
0003--FMT	1	0	0	1	0	0
0004--FMT	1	0	0	1	0	0
0005--CLR	1	0	0	0	0	0
0006--FMT	1	0	0	0	0	0
0007--X=Y	1	0	0	0	0	0
0008--GTO						
0009-- 0	Any Address					
0010-- 2						
0011-- 6						
0012						

If the Alpha ROM is in the system, the equality test at step 0007 is not met, so the program skips the next four instructions and continues. Without the Alpha ROM, the test is met and the program branches to the designated address.

Note that the GTO statement *must* follow the X=Y statement in this case only; in the general case branching is automatic, as it is in the 9100A/B. Also note that in the Model 10, the branching address normally takes four steps, and a not-met condition causes the next four steps to be skipped.

From the above point, the program usually follows one of three routes.

1. If there are no other alpha sequences in the program might continue as follows:

```
0012--CLR
0013--FMT
0014--FMT
0015-- E
0016-- N
0017-- T
0018-- E
0019-- R
0020--CNT
```

```
0021-- D
0022-- A
0023-- T
0024-- A
0025--FMT
0026--STP
0027--PNT
0028--PNT
0029--XTO
0030-- 5
0031-- .
0032-- .
0033-- .
```

PROGRAMMING TIPS (CONTINUED)

2. If additional alpha sequences are used in the program, further branching can be directed by activating SET FLAG at the end of each alpha section except the final one. For example:

```
0012--CLR  0092--IFG  0120--LBL
0013--FMT  0093--GTO  0121-- A
0014--FMT  0094--S/R  0122--FMT
0015-- E   0095--LBL  0123--FMT
0016-- N   0096-- A   0124-- O
0017-- T   0097--XFR  0125-- U
0018-- E   0098-- 5   0126-- T
0019-- R   0099--PNT  0127-- P
0020--CNT  0100--PNT  0128-- U
0021-- P           .  0129-- T
0022-- T           .  0130--CNT
0023-- S           .  0131-- P
0024--FMT             0132-- T
0025--SFL             0133-- S
0026--STP             0134--FMT
0027--PNT             0135--SFL
0028--PNT             0136--S/R
        .                     .
        .                     .
        .                     .
        .             0250--END
```

3. If additional alpha sequences are used in the program but the SET FLAG is not available, the 1 or 0 left in the x register at step 0005 above can be stored, then recalled for a test prior to each subsequent alpha sequence. For example:

```
0012--XTO          .
0013-- 0           .
0014--CLR          .
0015--FMT  0026--STP
0016--FMT  0027--PNT
0017-- D   0028--PNT
0018-- A   0029--XTO
0019-- T   0030-- 6
0020-- A           .
0021--FMT          .
        .          .
```

```
0056--XFR  0075--GTO
0057-- 0   0076-- 1
0058-- UP  0077-- 0
0059--CLX  0078-- 6
0060--X<Y  0079--FMT
0061-- 0   0080--FMT
0062-- 0   0081-- D
0063-- 7   0082-- A
0064-- 8   0083-- T
0065--STP  0084-- A
0066--PNT  0085--FMT
0067--XTO          .
0068-- 7           .
        .          .
        .  0106--END
```

NEW HP *KEYBOARD* FIELD EDITORS

HP *KEYBOARD* is proud to announce the addition of two field editors to its staff, as shown in the box below. In Europe, Dr. Eberhard Beck of HP GmbH in Böblingen, Germany will act as field editor. In the western U.S.A., Robert C. Reade of HP's North Hollywood office has agreed to be the field editor.

We are happy to welcome Eberhard and Bob aboard. They will be working with HP calculator users and salesmen to gather publishable applications stories, programs, program tips and other information of general interest for *KEYBOARD.*

If you live in Europe or the western U.S.A., and have questions about submitting information to *KEYBOARD*, or if you have programs you would like to have published, you may elect to contact Eberhard Beck or Bob Reade, respectively. This may save you time in getting your *KEYBOARD* manuscript finalized, or minimize the chance of submitting a program already received by another writer. We will, of course, continue to welcome direct mailings to *KEYBOARD* at Loveland.

A. B. Sperry, Editor

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