Desktop Data Acquisition

In the scientific laboratory, data acquisition and analysis programs are playing an increasingly important part in the manipulation of experimental data. Similarly, such programs can be used in a variety of industrial applications to control simple processes.

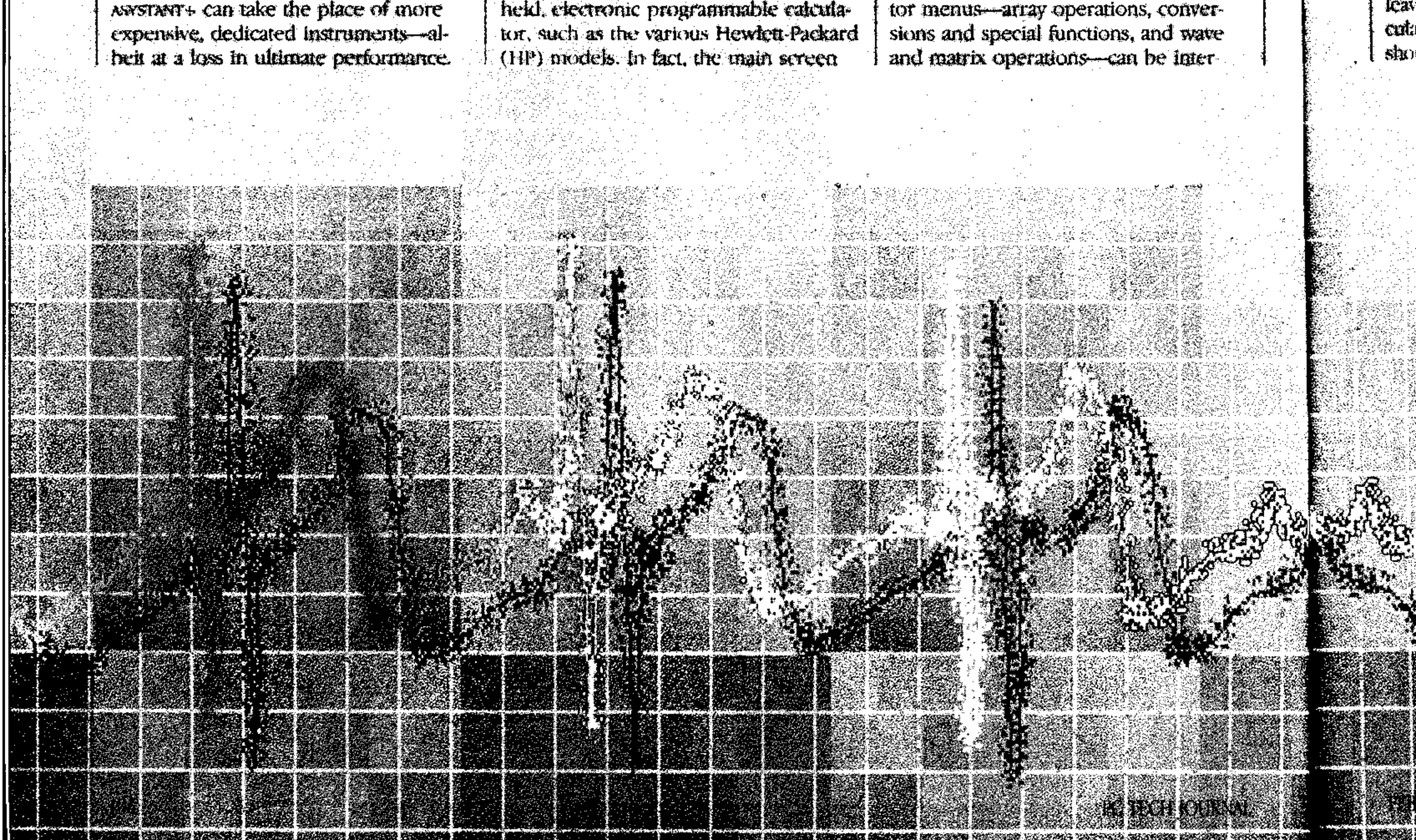
Macmillan Software's ASYSTANT+ converts the IBM PC and compatibles into a desktop data acquisition and analysis system comprising several virtual instruments. For many applications that can tolerate moderate sampling rates, ASYSTANT+ can take the place of more expensive, dedicated instruments—albeit at a loss in ultimate performance.

The basic version of the program, ASYSTANT, converts the PC into a sophisticated calculator. To that basic capability, the more advanced version, ASYSTANT+, adds the ability to control a data acquisition accessory. ASYSTANT+'s capabilities are similar to those of a sister product, ASYST, which provides a FORTH interpreter-like user interface.

A SOPHISTICATED CALCULATOR

ASYSTANT+'s basic user interface is similar to that of a stack-oriented, handheld, electronic programmable calculator, such as the various Hewlett-Packard (HP) models. In fact, the main screen display is referred to as the desktop calculator and resembles a calculator in functionality. It is divided into five windows, four of which correspond to the facilities of an advanced programmable calculator (see photo 1). The fifth window contains the main options that access other parts of the program, such as waveform processing and generating, graphics, and curve fitting.

The calculator windows are stack contents, calculator functions, parameters, and variables. Three other calculator menus—array operations, conversions and special functions, and wave and matrix operations—can be inter-



ASYSTANT+ from Macmillan Software provides sophisticated data acquisition for scientists and engineers from a desktop computer.

VICTOR E. WRIGHT

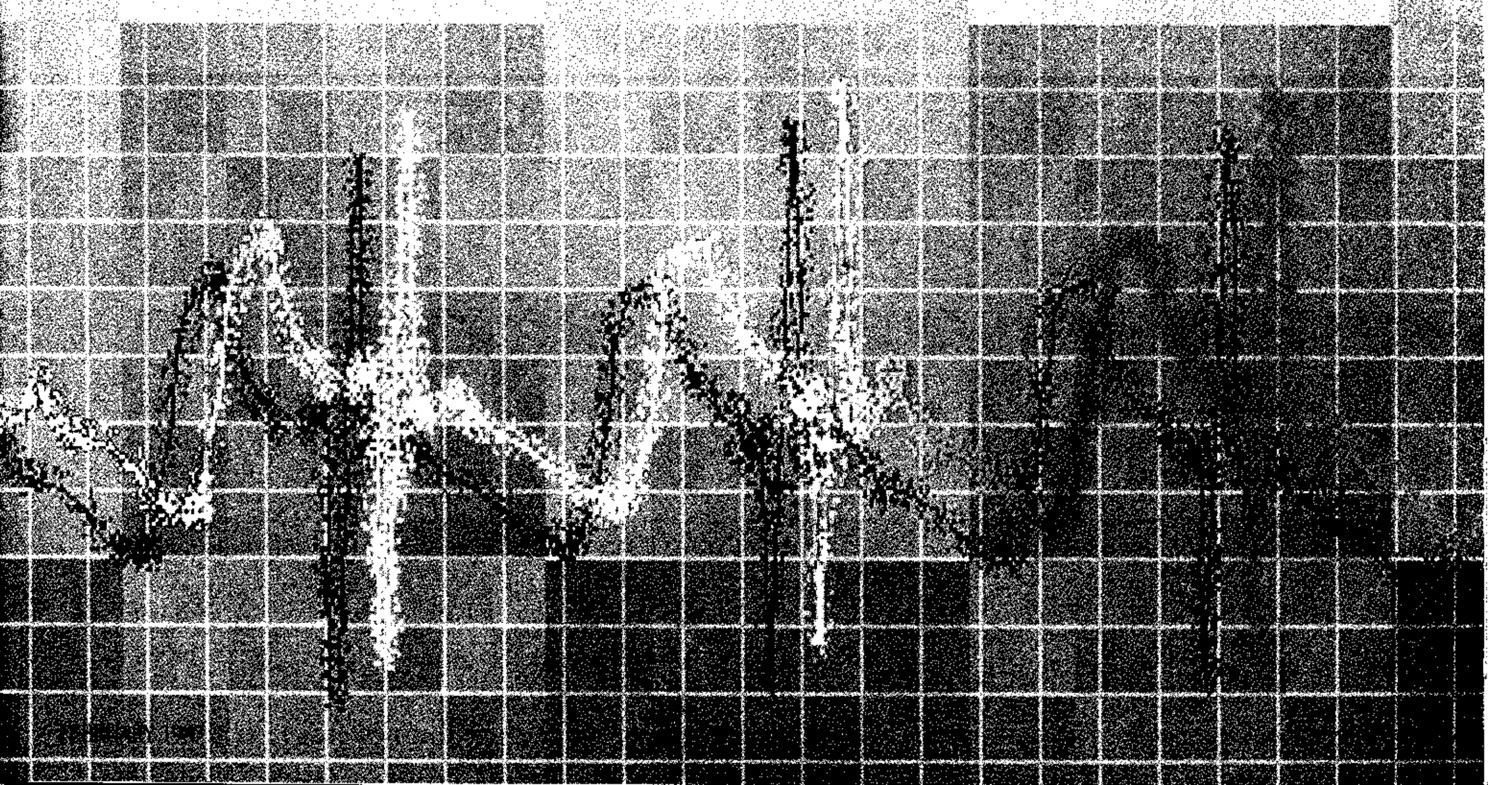
changed with the calculator functions (see figure 1). Each calculator menu includes the selection, next, to display the next calculator menu.

A key concept in learning to use ASYSTANT+ is that of the stack—an area of memory used for temporary data storage. Data can be placed on the stack from the keyboard or from other storage areas, and can be removed from the stack to be placed in other storage areas. Most operations and functions take their arguments from the stack and leave their results on the stack. HP calculator users and FORTH programmers should be comfortable with the system.

The program begins with a cursor positioned on the first selection of the main menu, acquire. Pressing PgUp moves the cursor to the calculator functions menu. This gives the expected assortment of mathematical functions and stack operators—store, stores the entry at the top of the stack in a parameter or variable; dup, duplicates the top entry in the stack; drop, drops the entry at the top of the stack; swap, switches the top two entries on the stack; and roll, places the bottom entry on the stack on the top and pushes the other entries down one. A status selection allows the user to select the format of numeric output: angular units for use with trigonometric functions, and data type—integer, double-precision integer, real, double-precision real, complex, or double-precision complex.

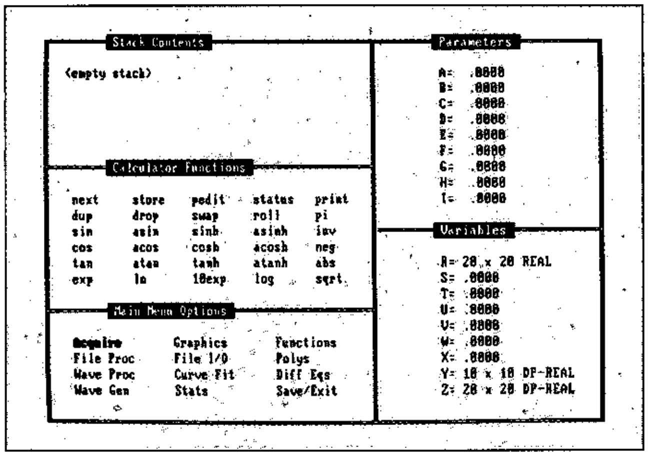
Calculator commands can be entered by moving the cursor to the desired selection with the arrow keys and pressing Enter or by typing them at the keyboard. When a number, letter, or operator is typed, the main menu window clears and a command line area appears in its place, regardless of the location of the cursor.

Commands can be entered in Reverse Polish Notation (RPN) used by HP



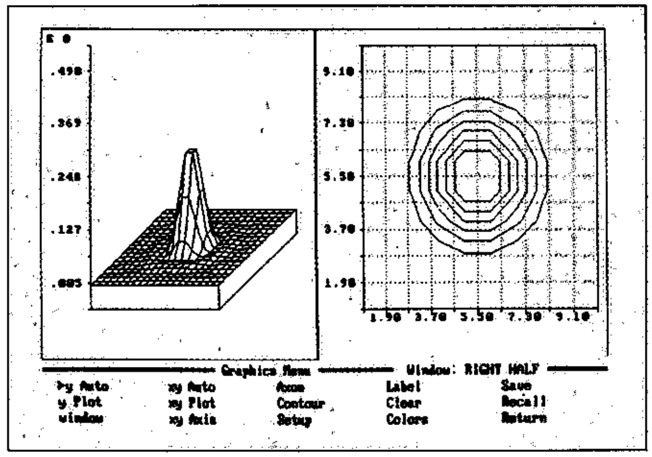
COMPUTER GRAPHIC • NATALE/EAST

PHOTO 1: *Calculator Functions Menu*



The calculator functions menu is replaced with the array menu, the conversion and special functions menu, or the wave and matrix menu by selecting the "next" option.

PHOTO 2: *Window Options*



The screen can be split into a variety of windows by selecting the windows option, and each window can then be used to display data independently.

and FORTH or in algebraic notation. The program expects RPN; an algebraic notation always must be preceded with the \ character. Commands can be entered in strings and then are terminated with the Enter key. Entering a valid number places a result on the stack. ASYSTANT+'s stack is limited to five entries, which are displayed in the stack contents window. Stack entries can be integers, real numbers, complex numbers, or arrays of integers, real numbers, or complex numbers.

In the calculator menu, macros ("user functions") can be assigned to the ten function keys. Each key can be assigned up to five lines of RPN or algebraic notation. Pressing a function key while in the Calculator executes the macro. The macro assigned to one key can include the name of another key, so that additional functions may be performed by a single macro.

The parameters and variables windows on the main screen display provide two types of storage registers, nine of each. Parameters, *A* through *I*, store numbers; and variables, *R* through *Z*, store either numbers or arrays. Parameter and variable values can be copied to the stack, and stack entries can be copied or moved to the parameter and variable registers. Parameters and variables are available in all parts of the program, and they can be assigned descriptive names.

VECTORS AND MATRICES

The array operations menu is displayed by selecting the **next** option from the calculator functions menu. It offers a set of commands to create and manipulate arrays. ASYSTANT+ provides for two types of arrays; one-dimensional arrays, or vectors, and two-dimensional arrays, or matrices. An array occupies one slot on the stack or one variable. Arrays cannot be stored in parameters.

The program uses two 64KB segments of RAM for storage of arrays. One segment contains the arrays assigned to the variables *R* through *Z*, and the other segment contains any unnamed arrays on the stack. A single array can occupy an entire 64KB segment.

The array operations menu offers selections for the basic vector and matrix operations. Three commands, **n:ramp**, **nm:ramp**, and **aedit**, generate unnamed arrays and place them on the stack. **N:ramp** takes the top entry on the stack as the size of a one-dimensional array (vector) and replaces it with a vector in which the i^{th} element contains the value *i*—the value of each element is equal to the index. **Nm:ramp** takes the top two entries as the number of rows and columns of a two-dimensional array and replaces them with an array in which the ij^{th} element contains the value $(i-1)m+j$—i is the row index and j is the column index.

The commands **xsect**, **sub**, **trans**, **diag**, and **reverse** access certain array elements. **Xsect** takes the top element of the stack and replaces it with an element, **sub** with a subarray, **trans** with the transpose of the array, **diag** with the main diagonal, and **reverse** replaces the top element of the stack with an array with reversed column indices.

Arrays can be reordered with the commands **n:rot**, **reshape**, **sort**, and **lookup**, and they can be indexed with **index** and **n:search**. Two commands combine two arrays to form a third; **cat** stacks the two arrays one over the other, and **lam** places them side by side. Cumulative operations can be performed on the rows of an array to calculate sums and products and find cumulative maxima and minima.

Arrays can be examined in spreadsheet format with the array editor function, **aedit**. Arrays can be created directly with **aedit** or with another command, **n:ramp**, **nm:ramp**, **lam**, or **cat**, for example, and then edited. They also can be built and edited by using other menu options and functions, but using the array editor is the easiest way to make minor changes.

Switching to the third calculator menu, conversions and special functions, provides an assortment of options for converting data from one coordinate system to another, or from one data type to another, as well as special advanced functions. Numbers can be converted from a pair of values on the stack, one real and one imaginary, into a single complex entry on the stack. A single complex entry can then be split into a pair of values.

Data sets representing coordinates can be converted between Cartesian coordinates and polar coordinates or spherical coordinates. Also, complex numbers in the form $x + jy$ can be converted to the polar form. (Note that *PC Tech Journal* is using the electrical engineering notation *j* for the imaginary part of the complex number rather than the mathematical form *i*.)

The more advanced functions include the error function, factorials, the number of combinations of things taken *r* at a time from a set of *n* things, the number of permutations of things taken

r at a time from a set of n things, the Bessel functions, elliptic integrals, the gamma function, and the incomplete beta function.

The wave and matrix menu, the fourth calculator menu, offers several numerical techniques for the analysis of waveforms and matrices. Storing waveforms as arrays allows the use of many operations for the analysis of waveforms or matrices. A series of waveforms can be stored in a two-dimensional array, one waveform per row.

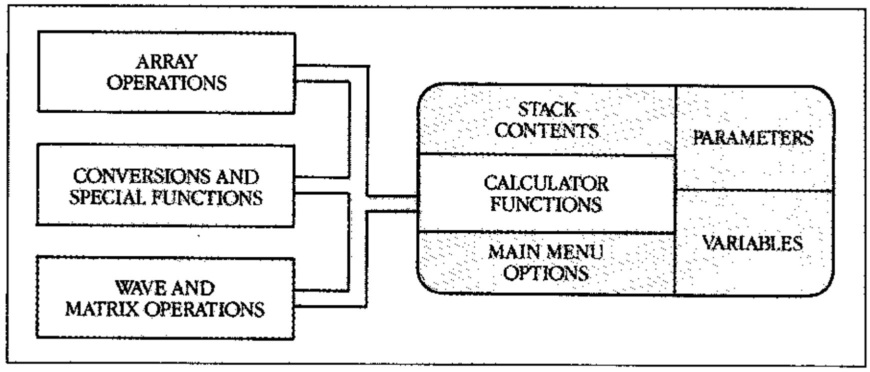
Once the waveforms have been stored, two functions, **smooth** and **window**, are available to filter them. The **smooth** function, a low-pass filter, removes high-frequency components of a waveform in the time domain, to eliminate noise in a signal, for example. The **window** function simulates a Blackman window, filtering out selected high and low frequencies. This function is better suited to waveforms stored in the frequency domain.

A waveform can be integrated by using Simpson's 1/3 rule or differentiated by using interpolating polynomials of a user-specified degree, as many as seven. Four functions are provided for Fourier transformations: fast Fourier transforms and inverse fast Fourier transforms for both one- and two-dimensional arrays. An additional function calculates the power spectrum (the square of the magnitude of the Fourier transform) of an array.

Other matrix operations included in the fourth calculator menu are the autocorrelation function, which is applied to the top entry on the stack; the aperiodic convolution of the top two entries; the application of a Blackman window to a subset of the top entry; the Hilbert transform of the top entry; and the cross correlation of the top two entries. By combining these advanced functions, the user can filter signals with low-pass or band-pass filters to remove noise or isolate signal components, process images, generate spectral analysis displays, generate diffraction patterns, and analyze signals in both the time and frequency domains.

The program performs the basic statistical operations, average, standard deviation, maximum, and minimum. A single operator is provided to solve the matrix equation, $y = Ax$. The operator expects the y vector as the top stack entry, and the A matrix (n by n) as the second entry. It replaces these two entries with the x, or solution, vector. Additional matrix functions are available, they include commands to return the trace of a matrix (the sum of the diagonal elements), the matrix product of two arrays, the Kronecker product of two arrays, the determinant of a matrix, and the inverse of a matrix.

FIGURE 1: *Calculator Menus*



ASYSTANT+'s available calculator menus provide a versatile selection of mathematical functions for manipulating the obtained waveforms and matrices.

CHOOSING FROM THE MENU

The main menu of ASYSTANT+ provides 11 options that enhance the versatility of the program. These options include, graphics, a waveform generator and processor, two file operations, users functions, curve fitting, polynomials, statistics, differential equations, and a data acquisition menu.

Graphics. ASYSTANT+'s graphics commands allow data to be displayed on the screen, on a graphics printer, or on a pen plotter. Graphics boards, printers, and plotters are selected from menus at the beginning of the initial session, and the selection can be changed at the beginning of any session thereafter.

Arrays are used to store graphics data. Two types of graphic displays can be generated, Cartesian plots and three-dimensional plots. Cartesian plots include line graphs of a single vector variable or a row of a rectangular array, plotted as a function of the indices; and line graphs of two vector variables or rows of rectangular arrays, with one variable or row taken as the independent variable and the other as the dependent variable.

Three-dimensional representations include axonometric plots and contour plots of two-dimensional arrays (shown in photo 2). An axonometric plot displays a surface representing the values of the plotted array superimposed over a rectangular grid; the height of the surface above the grid is proportional to the value of the array element. A contour plot displays a series of contour lines superimposed over a grid with the contour lines connecting elements of equal magnitude.

The graphics display is available to preview graphics before plotting. The default screen display includes a graphics menu and a graphics window. The graphics window can be split into left and right halves, upper and lower halves, and four quarters.

ASYSTANT+ is able to produce a plot with a minimum of information, by using default values and scaling the axes to display all of the data in a single plot. The **Setup** command gives the user the ability to customize the plot by specifying minimum and maximum values, linear or logarithmic scales, labels, grids, and the location of the origin. Whenever an IBM Enhanced Graphics Adapter (EGA) is used, the axes, labels, background, and plot can be displayed in different colors.

Users also can customize graphics windows with the addition of text labels. Labels can be positioned and aligned as desired. The contents of a graphics window can be saved to disk, and recalled at a later time for display.

A graphics display is generated by selecting the type of plot —**y Auto**, **y Plot**, **xy Auto**, **xy Plot**, **xy Axis**, **Axon**, or **Contour**. The program prompts for the variable to be plotted and then displays a menu that includes the selections **display graph and to plotter**; these selections produce screen displays and plots.

Waveforms. ASYSTANT+ includes both a waveform generator and processor. The generator creates arrays of values that represent a variety of continuous waveforms typically available from analog function generators. These include sine waves, cosine waves, square waves, triangular waves, sawtooth waves, pulses, uniform noise, white noise, and Poisson pulse trains. In addition to selecting the type of waveform, the user can control the gain, bias, and frequency of the waveform. These created arrays can be displayed on the screen, stored on disk, plotted on the pen plotter, and used as the digital input to an digital-to-analog convertor in ASYSTANT+.

The waveform generator produces a single output—one of the waveforms listed above. However, the output can be stored in memory and then pushed onto the stack. Successive output waveforms can be pushed onto the stack, and then the calculator can be used to manipulate or combine them, creating waveforms of arbitrary complexity.

While in the waveform generator, two waveforms are immediately available: the output of the generator and a waveform stored in memory. The output waveform can be added to the memory waveform to create complex waveforms without leaving the generator. Waveforms can be plotted on either the screen or the plotter.

The waveform processor provides a graphic alternative to the calculator for processing one-dimensional arrays (waveforms) or specified rows of two-dimensional arrays. The waveform processor display includes a large window in which a waveform is displayed, a series of small windows that summarize the history of the wave processing session, and a menu of commands.

The commands available in the waveform processor are a subset of those available in the calculator and file processor. However, intermediate results are displayed on the screen interactively, and several graphic aspects of display can be specified by the user.

Waveforms can be processed in segments, allowing uninteresting portions of the waveform to be ignored, or separate segments to be processed in different ways. A current segment can be selected graphically, by positioning two cursors in the main graphic window. Segments of the waveform are stored in several *repositories*—WFM (waveform), ORG (original segment), MEM (memory segment), PRV (previous segment), and SEG (current segment). Images of the repositories are shown at the top of the screen for reference; contents of MEM and SEG can be combined with selections from the waveform processor's memory ops menu.

Processing options include scaling the waveform with a fifth-degree polynomial, clipping SEG to a specified minimum and maximum, computing the derivative of the waveform (to a user-specified order), computing the integral, smoothing the current segment, computing the power spectrum, and finding the envelope of the waveform. An analysis menu provides selections to find the basic statistics, rise time, fall time, area under the curve, and width of a specified peak.

Data file operations. Two submenus from the main menu are devoted to file operations: file I/O, and file processor. File I/O provides the basic facilities for storing and retrieving data associated with variables and for converting data files into files that can be used by other programs. The program supports two external formats: DIF and ASCII.

ASYSTANT+ data files are physically composed of a block of comments followed by a series of data subfiles. Logically, the file can consist of comments and data sets. Both subfiles and data sets contain multiple data points, and both are limited to 64KB, which corresponds to the area in RAM that ASYSTANT+ sets aside for the storage of variables. A data file can contain several blocks that may represent various aspects of a model or experiment.

ASYSTANT+'s file I/O menu allows subfiles and data sets to be selected as rectangular sections of a group of arrays. Even though the data file is actually a linear sequence of values, data can be addressed by row and column number, just as if the data were arranged in two dimensions. Data sets can be selected by specifying values or by scrolling through the file graphically.

The file processor menu integrates calculator functions and disk I/O functions. The processing capabilities of the desktop calculator and the file processor are identical. However, the file processor allows the user to specify the data source, the operations to be performed, and the destination for the results. The actual processing can be allowed to proceed unattended, whereas processing with the desktop calculator usually must be performed step by step.

Curve fitting. The curve fitting of ASYSTANT+ gives an interactive environment for fitting smooth curves through *x-y* data sets. Results are displayed as mathematical values and in graphic form.

The fitted curve can be specified as linear, polynomial, logarithmic, exponential, multilinear, or user-defined. Multilinear fits operate on one rectangular array and one vector, and the remaining fits operate on two vectors. The *goodness of fit* is determined by the least-squares fitting method.

Both the original data and the fitted curve are displayed, superimposed in a graphic window. The residual error curve is plotted in a separate window.

Polynomials. An extensive set of polynomial operations can be performed from the polys menu. Polynomials can be added, subtracted, multiplied, divided, and shifted by a factor. Polynomial coefficients can be edited and copied to a variable. Roots can be extracted and saved in a variable, and polynomials can be integrated and differentiated. Finally, selections are provided to generate Legendre, Laguerre, Tchebyshev, and Hermite polynomials.

ASYSTANT+ can handle 10 polynomials. Each polynomial can contain real or complex coefficients and can be up to the ninth degree. A polynomial is first defined, and then it can be applied to the top stack entry.

Statistics. The stats selection of the main menu presents a submenu of statistical operations and messages. An edit function is available to allow the user to create or edit a data table without leaving the menu. The stats editor is identical to the array editor that is provided in the desk calculator.

The basic stats option computes and displays the basic statistics for a variable or subset of a variable. The statistics displayed include the maximum value, the minimum value, the sum of the values, the mean, the median, the variance, the standard deviation, skewness, kurtosis, the sum of the squares, and the root mean square. These values are displayed in a window on the screen and can be sent to the printer. Other basic statistical functions such as sorting, percentile calculations, and hypothesis testing also can be performed from the menu. The hypothesis tests that are provided include the Kolmogorov-Smirnov normality test, the 1 sample *t* test, the 2 sample *t* test, the 1 sample chi-square test, the 2 sample F test, the Wilcoxon signed-rank test, and the Mann-Whitney rank-sum test.

Histograms can be generated and plotted. The user specifies the number of breakpoints between "bins". The program sets up the specified number of bins, equally spaced between the minimum and maximum data values. Once generated, the histogram can be plotted, saved to a disk file, or left in the calculator variables.

A menu selection is available to generate commonly used frequency distributions. These include both percentages and percentiles of the normal distribution, the chi-squared distribution, the student *t* distribution, and the $F(n,m)$ distribution.

Two advanced analysis techniques are provided by ASYSTANT+. Stepwise regression is included with three variations of the analysis of variance (ANOVA) technique, one-way, two-way, and table. The ANOVA techniques indicate which of several independent variables are most significant in explaining the variations in the dependent variable. ASYSTANT+ displays the results of ANOVA in a table listing the sum of the squares, the degrees of freedom, the mean sum of the squares, the F-value, and the significance level of the F-value for each component and the residuals.

The regression option allows the construction of a model representing a dependent variable as a linear function of several independent variables. A vector holds the dependent variable, and an array holds the independent variables. The technique is interactive. Terms can be entered into and removed from the model with a few keystrokes; this allows several combinations of terms to be examined easily.

Differential equations. ASYSTANT+ provides a numerical method for solving first-order differential equations, ranging from a single equation to a system of five equations, using the fourth order Runge-Kutta method. Up to six variables are used, the *X* variable for the independent variable, and *Y*, *Z*, *U*, *V*, and *W* for dependent variables.

The model to be examined is specified by entering the system of differential equations, the initial conditions, and extrapolation parameters, consisting of step size used to generate the solution curves and the final *X*-value. Solution curves are stored in variables that can be displayed on the screen under the graphics menu, saved to disk, or sent directly to the plotter.

Notepad. ASYSTANT+ includes a simple screen editor, the notepad, which is available from both text and graphics screens by pressing Ctrl-N. The manual cautions that the notepad is not intended to take the place of a word processor; however, the editor is equal to the task of taking notes during experiments and creating simple reports.

The notepad is limited to straight ASCII text files with no control characters (such as the ones inserted by most word processors), 16KB total file size, and 80-character lines. Arrow keys and function keys are implemented, to provide cursor movement by character, word, line, word, and file. A limited set of block operations is available, as well as search and replace capability.

Text can be inserted into the current notepad file when the editor itself is inactive. ASYSTANT+ stores the current file name, and a cursor location. The calculator functions menu includes a print command that sends the top stack entry to the screen, printer, or current notepad disk file. Disk file output can be inserted at the current cursor location or appended to the end of the file. Charts and tables can be constructed in the stack with the various matrix operators and functions, edited with the **aedit** command, and then inserted into the notepad file.

Mini-calculator. A streamlined version of the desk calculator, the mini-calculator, is available from both text and graphics displays when any of the main menu options is active. Only the command line can be used for input; menu input is not available, and those commands that are only available as menu selections cannot be called from the mini-calculator. The display consists of the stack and a command line.

DOS commands and help. A menu of basic DOS operations can be invoked by pressing Ctrl-D. Menu selections can delete, copy, and rename files, display directories, and return to ASYSTANT+. An on-line help facility can be invoked by pressing the ? key. It is context sensitive and organized to follow the structure of the manual. The help display can be paged by pressing the Space Bar, or navigated with the function keys.

ACQUIRING THE DATA

In addition to the basic ASYSTANT facilities, ASYSTANT+ includes the software necessary to control data acquisition hardware, The host computer, under the control of ASYSTANT+, becomes the control panel and graphic display for several such devices. In each case, the computer display resembles a traditional analog instrument.

Data acquisition functions are available from the data acquisition menu, which is displayed when the **acquire** option is selected from the main menu. This menu includes selections for the various instruments ASYSTANT+ can emulate and a selection for configuring the software to match the data acquisition board or external chassis.

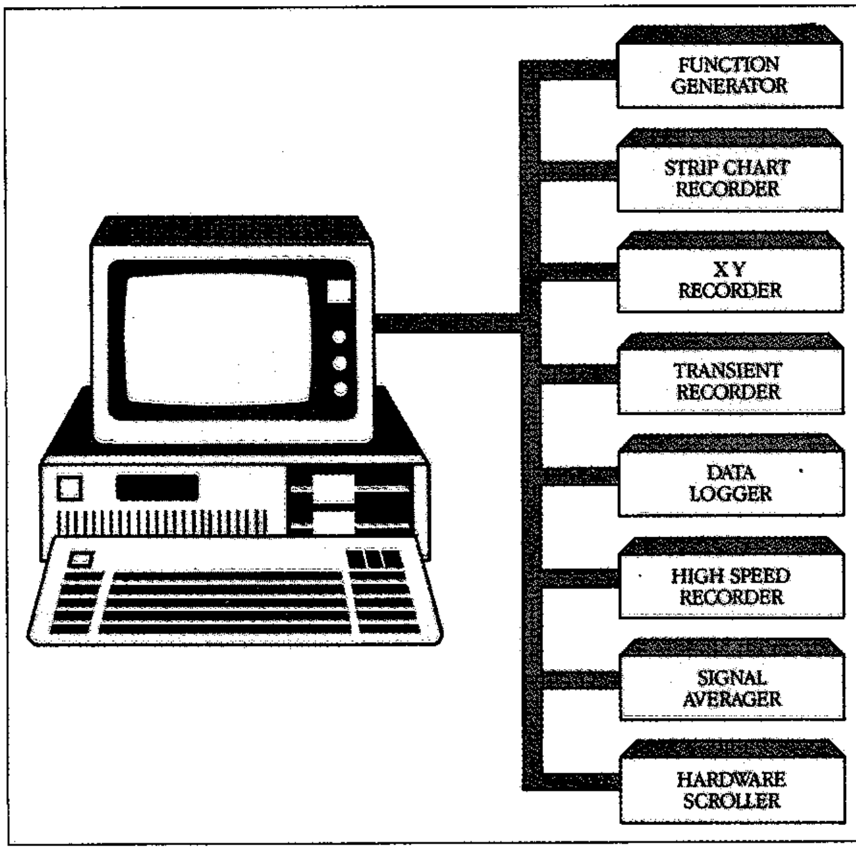
Configuration of the system is menu-driven. It consists of selecting the host computer and the data acquisition board from lists of supported devices and then setting various parameters to match the physical configuration of the data acquisition board. The manual astutely warns the user that determining the physical configuration of the hardware may not be a trivial matter. A detailed appendix provides information about the configuration of supported boards; it is presented clearly and concisely enough to replace most data acquisition board manuals for standard applications.

It should be noted that configuration involves specifying the host computer as well as the data acquisition board, even though the program is in use on the host computer. The program must know the clock speed of the host computer to perform timing tasks.

Data acquisition board parameters that are specified during the configuration process include the board's I/O address, the number of A/D channels, the A/D channel voltage range, the hardware gain, the number of D/A channels, and the D/A voltage range. ASYSTANT+ does not necessarily support all of the features and configurations of supported boards, but the manual documents the ones that are.

Additional configuration parameters, selected from the acquisition configuration menu include confirmation that a hardware scroller board (a high-speed, strip-chart recorder) is installed, the specification of engineering units to be used in file conversion, color assignments for A/D channels when an EGA board is installed, the assignment of names to channels, and a bit pattern to

FIGURE 2: *Data Acquisition Menu*



Although the accuracy that can be obtained from a PC-based data acquisition system does not match that of individual laboratory instruments, ASYSTANT+ does manage to provide an economical solution for moderate sampling rates.

be set on the digital output port at the beginning of a data acquisition session. A final option is the selection of an unprotected mode. ASYSTANT+ normally operates in a protected mode, in which it prevents acquisition of data at sampling rates above that known to be reliable (the Nyquist rate). The unprotected mode allows the user to specify higher sampling rates at the risk of hanging the system, requiring a reboot.

With the data acquisition board installed and configured, ASYSTANT+ provides the user with the ability to select the preferred interface, or *metaphor*, from the data acquisition menu. Each selection performs the same basic task, that of controlling the data acquisition board, but it resembles a different laboratory instrument (see figure 2).

ASYSTANT+ can simulate a strip-chart recorder, a hardware scroller (if one is installed), an XY recorder, a transient recorder, a data logger, a high-speed recorder, a signal generator, and a function generator. When an instrument is selected, the program displays a submenu including options to set or modify instrument parameters, to begin acquiring data, and to return to the data acquisition menu. Set-up parameters can be saved to disk and recalled.

In general, acquisition parameters are common to all of the instruments; although some of them require the specification of additional parameters. ASYSTANT+ displays the current parameters on a configuration screen, along with appropriate limitations, and prompts the user for new values. The parameters required to set up a general-purpose instrument for a session are trigger type, internal or external clock, number of analog input channels, the first channel in a scan cycle, value for the software gain, the acquisition rate, the number of data points per channel, the number of scans to perform in the session, and the file to be used for data storage (file storage is optional).

Because data acquisition boards typically multiplex several analog input channels through a single analog to digital converter and have limits on the speed at which they can operate, these parameters are interrelated. For example, in the high-speed recorder mode, the maximum acquisition rate is inversely proportional to the number of channels selected.

ASYSTANT+ extends the operation of its waveform generator to the control of the data acquisition hardware, allowing the system to operate as a function generator. The digital values determined by the function generator are used to produce analog signals with the data acquisition board's digital-to-analog converter. The function generator provides two output channels, taking arrays stored in variables *R* and *S* as the input waveforms. The function generator can create standard waveforms, experimental waveforms acquired from earlier sessions, and waveforms that have been processed by any ASYSTANT+ function. ASYSTANT+'s function generator is capable of providing signals that are not available from conventional analog function generators. It is limited in speed and resolution to a throughput of 300 to 400 points per second.

The function generator can be used as a stand-alone device or in conjunction with other ASYSTANT+ instruments. In either mode, the generator's output can be controlled interactively. As a stand-alone device, it can replace a conventional generator and drive a plotter or real-strip chart recorder to produce a hard copy of a waveform. When used in conjunction with the other instruments, the generator can provide a known stimulus or control signal to the experiment. Using the generator with other ASYSTANT+ devices can affect the operation of the generator or the other device, reducing the throughput of the acquisition instrument. The program, however, does allow the operator to set the priorities of concurrent tasks.

ASYSTANT+'s strip-chart recorder is a digital replacement for an eight channel strip-chart recorder. The screen display resembles an analog strip-chart recorder with data points that appear at the right edge of the display and move across the screen as if on moving paper. The screen displays only the active channels, providing greater resolution as the number of channels is reduced from the maximum of eight.

The strip-chart recorder is limited to a maximum throughput of 40 to 70 Hz (points per second in this context), the exact maximum rate depends upon the hardware configuration. If the maximum number of channels is selected, and data are output to disk concurrently, the throughput is reduced. Thus, the recorder is suited only to slowly varying signals. If data file output is not selected, the data are lost once they scroll off the screen.

While it is operating, the strip-chart recorder can be controlled. The data acquisition rate and gain can be altered; data file output can be suspended and resumed; and the display resolution can be modified by skipping data points. If the function generator is active, it may also be adjusted.

The XY recorder acquires data from a maximum of two channels and displays the data on an *xy* plot—one channel's input corresponding to the *x* axis and the other corresponding to the *y* axis. It is possible to display vertical and horizontal grids either individually or together.

The XY recorder has a higher throughput, ranging from 340 to 670 Hz, than does the strip-chart recorder. The difference in speed is due to the limit of two channels, and to a lack of concurrent data file output that is available only between scan cycles. The user can select a single scan mode in which the recorder pauses to allow data file output or a continuous scan in which data file output is not an option.

The XY recorder can be interactively controlled. While the recorder is acquiring and plotting data, the user can set the acquisition rate and programmable gain, adjust the function generator (if it is enabled), change the display increment and halt the scan. Between scans, data can be saved to disk if data file output was selected; then the next scan can be initiated, and the current scan can be displayed versus time, superimposed on the *xy* plot.

To acquire data before and after an event in an experiment, the transient recorder captures and plots analog data in two stages, based on two triggers. It can acquire data on as many as eight channels with a maximum throughput of 340 to 800 Hz. The user must specify two triggers to begin acquisition of data for each stage. The recorder acquires and then plots the data. As with the XY recorder, data can be output to a disk file only between scans. A continuous mode and active control during operation are available.

The data logger is a low-speed device that provides for analog data input from up to four channels and the control of eight digital lines. Its throughput is limited to 1 Hz. However, concurrent data file output, realtime conversion of voltage to engineering units, and simultaneous hard-copy output are available. Data are displayed in text form on the screen in realtime.

Setting the acquisition parameters for the data logger requires three screens instead of the usual one for se-

AN ELECTRONIC DETECTIVE

In a practical application, ASYSTANT+ can be used as a sophisticated detective in an industrial plant. As an example, a plant engineer installs a tachometer on a component of a production line, and it produces a clean, square wave. However, when the tachometer is connected to the control panel several hundred yards away, the control panel display is greatly altered and meaningless. The plant engineer connects a microcomputer with a data acquisition board and ASYSTANT+ installed, and finds a signal like the one shown in figure 1, instead of the square wave.

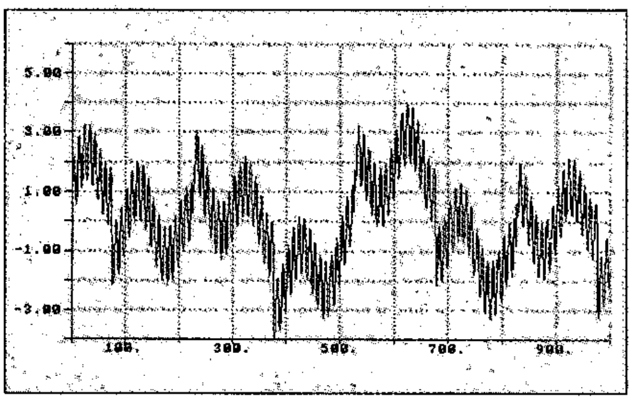
The plant engineer then takes the ASYSTANT+ equipped microcomputer to the tachometer and measures the signal directly. As expected, its output is normal, the square wave shown in figure 2. Evidently, the signal is being degraded between the tachometer and the control panel. Because the line from the tachometer to the control room is routed through the plant, past various machines and switchgear, the plant engineer is not surprised. The problem is to identify the offending signals and their sources.

With the noisy signal at the control panel and the square wave sampled at the tachometer stored in ASYSTANT+ variables, the engineer is ready to begin analyzing the signal. After verifying that the square wave and the noisy signal samples represent the same time interval and the same number of data points, the engineer subtracts the square wave from the composite signal. Subtracting the two arrays stored in the variables from each other and storing the result in another variable leaves just the noise that is picked up in the system. The resulting waveform, plotted in figure 3, is still made up of several components.

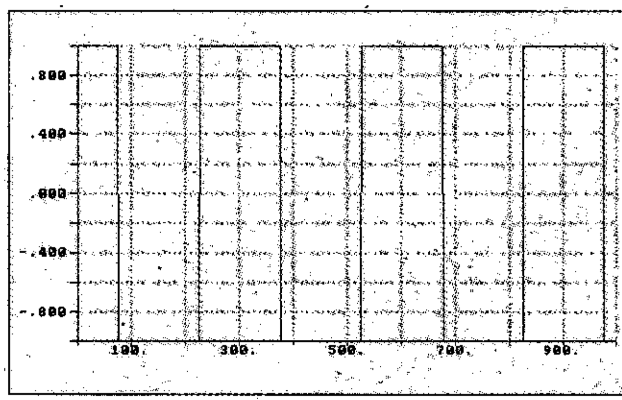
On a logical hunch, the plant engineer tries subtracting a 60 Hz sine wave, to remove any "power hum". After a few attempts with the waveform processor to get the correct amplitude, the waveform of figure 4 results.

At this point, two components are clearly discernible, a high frequency sine wave riding on a lower frequency sine wave. The frequency of each waveform is easily determined, at least in this simplified example. With the frequencies of these components known, the engineer can set about locating their sources. For a more complicated situation, other methods such as plotting the power spectrum can be used.

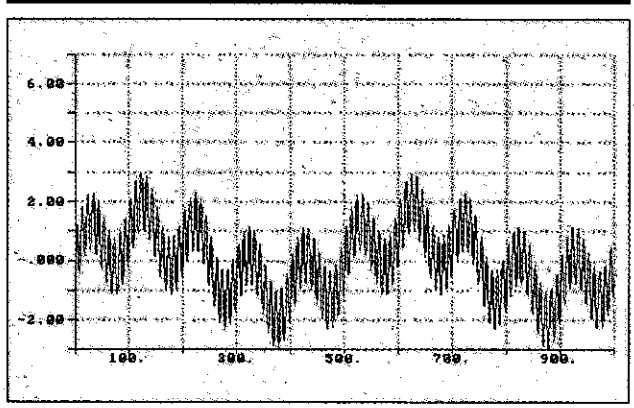
—*Victor E. Wright*



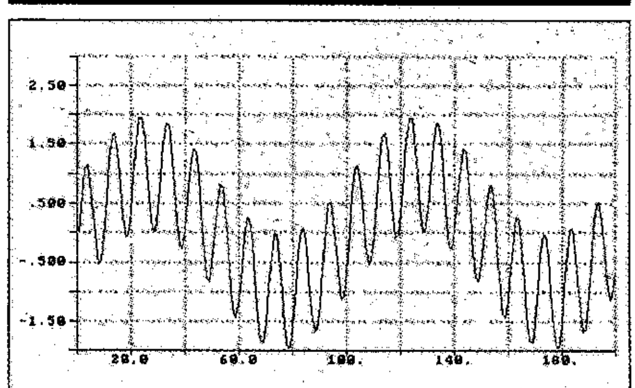
The waveform at the control panel has a large amount of noise superimposed on the square wave.



The waveform that is produced at the tachometer end of the signal lines is in the form of a clean square wave.



Subtracting the square wave from the waveform in figure 1 shows the noise that has been inducted in the cables.



After the removal of the power hum, the remnant noise can be seen to be two waveforms, as shown in this example.

lecting and configuring the analog input channels. Screens are provided to define from one to four stages and up to six alarm triggers. The stages allow the acquisition rate and control logic to be varied during the course of an experiment. The alarm triggers control the display of messages and output of user-defined bit patterns on the digital lines according to analog input levels or digital input bit patterns.

The ability to place bit patterns on the digital port allows the data logger to be used as a controller. It can monitor and display up to four process variables measured with analog sensors, and it can monitor the states of as many as eight digital, two-position, devices. Based on these conditions, the data logger can provide an eight-bit digital output, which can be used to control eight digital devices or, if suitably converted, an analog device. It cannot directly control a proportional control device.

The high-speed recorder provides the highest sampling rate of the ASYSTANT+ instruments, matched only by the signal averager. Depending upon the data acquisition hardware, the sampling rate may exceed 30 KHz. The sampling rate that is realized is affected by the number of channels specified, as well as by the add-on hardware limitations.

This high-speed recorder performs its tasks sequentially, first acquiring the data, then plotting them on the screen, and finally recording them to disk. Users can disable the screen display to reduce the time between scans. Active control is provided, allowing the data plot to be examined in detail between each of the scans.

The signal averager is similar to the high-speed recorder, offering the same sampling rate and number of channels and storing a cumulative average of multiple scans. It allows data file output only at the end of a session, at which point it stores the current cumlative average. The display is similar to that of the high-speed recorder, however, it shows the current scan and the cumulative average scan superimposed for each channel.

HARDWARE CONSIDERATIONS

ASYSTANT+ runs on the IBM PC family of computers, as well as on compatibles. The full 640KB of RAM supported by PC-DOS must be installed, along with an 8087 or 80287 math coprocessor, two diskette drives or one diskette and one hard-disk drive, and a supported graphics board. Supported graphics boards include the IBM Color Graphics Adapter (CGA), the IBM EGA, the Hercules Graphics Card, the AT&T High-Resolution card, and the HP Vectra Multimode adapter.

The program performs the basic ASYSTANT tasks without installing additional hardware. However, if data acquisition is to be performed, ASYSTANT+ does require that a data acquisition board or external data acquisition chassis be used. Supported data acquisition hardware includes the Cyborg Issac 91-I, the Dataq WFS-200PC Waveform Scroller, Data Translation's DT2800 series, IBM's Data Acquisition and Control Adapter, the Keithley Series 500 system, Metrabyte's DASH-16 board, and Tecmar's Lab Master and Lab Tender boards. (See "Digitizing Analog Data," Eric M. Miller, May 1986, p. 52 for reviews of some of these products.)

ASYSTANT+ is a demanding program. In addition to installing 640KB of RAM, the user must ensure that the maximum amount of RAM is available. TSR (terminate and stay resident) programs and device drivers must be kept to a minimum; the safest course is to use only the standard DOS configuration.

For this article, ASYSTANT+ was tested on a Heathkit H-241 AT-compatible computer, with 640KB of RAM, 2,176KB of extended memory, an 80287 numeric coprocessor, a Concept Technologies ConceptBoard graphics adapter, and a Data Translation DT2801A data acquisition board.

Although ASYSTANT+ can operate on a dual-diskette system, a hard disk should be considered a practical requirement. Macmillan furnishes ASYSTANT+ on six diskettes—running the program from diskette drives requires frequent swapping of diskettes and severely limits file storage.

Program configuration is an option when the program is first loaded. The program displays a sign-on message and then a menu with options to recall functions, parameters, and variables from a disk file, to perform hardware configuration, and to begin using the program. The second selection, **Setup**, displays a configure menu, with options for selecting the display, plotter, and printer, and for disk assignments for the system overlay, data, and help files. The initial installation of the program consists of copying the files from the distribution disks. Configuration is accomplished at the beginning of the initial session and can be repeated at the beginning of any subsequent session.

ASYSTANT+ uses a straightforward method of configuring and controlling a data acquisition board. However, installation of a data acquisition board in a typical microcomputer system may require the reconfiguration of other boards, the use of a nonstandard configuration of the data acquisition board, or the removal of other boards. Most data acquisition boards are designed and factory-configured to operate in a standard microcomputer system, and ASYSTANT+ assumes the use of a factory-configured board. Microcomputers that have multiple video boards, high-resolution graphics boards, nonstandard mass storage device controllers, mice scanners, and other accessories may be difficult to configure.

The program allows the specification of the I/O address of the data acquisition board, and most data acquisition boards can be jumpered to one of several addresses. Selecting an unused I/O address in a complex system may not be trivial, but it can be accomplished with some research.

To provide high-performance hardware, many data acquisition board companies incorporate circuitry to use the computer's DMA channels, as do the manufacturers of hard-disk controllers, tape backup systems, optical scanners, network interface boards, and other high-performance accessories. The standard PC has four DMA channels, two of which are free for accessories; the XT has only one free channel to support all of the accessories that require DMA services. ASYSTANT+ does not use DMA, but some acquisition boards must be configured to use DMA. The user must pay attention to this issue.

Some data acquisition boards implement a memory mapped addressing scheme rather than an I/O addressing scheme, using the memory above the base 640KB of user RAM. These boards, designed when it appeared that there were "holes" in the PC's memory map, may conflict with the EGA and other video boards or with other accessories that use normally vacant segments of the memory map.

RATING THE PERFORMANCE

As a calculator, ASYSTANT+ is a high-performance program. Most computational tasks, including matrix operations, are performed almost instantaneously. A few of the advanced operations are slower, but still reasonably fast, requiring a few seconds at most.

As a data acquisition system, ASYSTANT+ realizes the potential of the microcomputer. Critical elements of the program are written in assembly language to attain the highest possible speed of operation. However, a microcomputer is limited by its design as a general purpose computing machine. Overall system throughput is limited by the speed of the data acquisition board, the clock speed of the computer, and the speed with which data can be written to disk. ASYSTANT+ achieves its ultimate performance, which is essentially the performance limit of the data acquisition accessory, by dedicating the host computer to controlling the accessory and transferring the acquired data to RAM. Graphic displays and disk I/O are performed between acquisition tasks.

ASYSTANT+, a data acquisition board, and a microcomputer will not replace a battery of high-performance, dedicated laboratory instruments. Dedicated instruments are able to offer higher sampling rates, sometimes by factors of hundreds or thousands, than does an ASYSTANT+ data acquisition system. Furthermore, they provide higher accuracy and resolution. As an example, an HP 3852S Data Acquisition and Control System, suitably configured, can acquire 100,000 readings per second and store up to the order of 64,000 readings locally. High-performance digital storage oscilloscopes and waveform analyzers can acquire data at sampling rates of tens of millions of samples per second. Nevertheless, the ASYSTANT+ based system is a sound solution to the data acquisition problem. An example of ASYSTANT+'s uses is given in the accompanying sidebar.

It should be noted that the basic acquisition and analyzing of data is provided by the data acquisition hardware and not the program. The ambitious experimenter/programmer may be able to do quite well without ASYSTANT+, by writing custom software to control the hardware. But the average experimenter, who must concentrate on the task at hand, will find that ASYSTANT+ makes configuring a comprehensive system a relatively straightforward procedure. Writing custom software to match ASYSTANT+'s analysis and presentation capabilities could not be done within a reasonable timeframe.

THE SOFTWARE PACKAGE

ASYSTANT+ comes with seven diskettes. The program is copy protected; a key diskette must be inserted in a diskette drive to load the program. An alternative to the key diskette arrangement is available from Macmillan in the form of a hardware protection device. All of the software can be copied to the hard disk or to the diskette drive with the DOS COPY command.

The manual is a 2-inch, loose-leaf binder with 8½ by 11-inch pages. It includes a tutorial, a reference section, several appendices, and an index, all separated with tabbed dividers. A hard slipcase is included. Both the printing and packaging are excellent.

The tutorial is thorough and accurate. It guides the user through the essential features of ASYSTANT+. Although the tutorial assumes that the user already has some knowledge of data acquisition, it is suitable for use as a refresher for occasional practitioners, or as an introduction for a determined beginner. The tutorial can be completed in a reasonable amount of time.

The reference section is well organized, closely following the program's menus. It covers the simulated instruments in considerable detail. The user will seldom have to refer to the data acquisition hardware documentation if the hardware is controlled exclusively with ASYSTANT+.

One possible drawback is that the manual is definitely not a mathematics textbook. The advanced math functions available in the calculator are summarized only briefly. Users who occasionally require Bessel functions and fast Fourier transforms may need to keep an assortment of math textbooks handy. The sister product, ASYST, provides a more insightful tutorial for using the mathematical functions.

ASYSTANT+ adds realtime data acquisition capabilities to the ASYSTANT calculator, which rivals any general purpose computational tool, microcomputer-based or not, in terms of speed, ease of use, and functions. The data acquisition capabilities obviously do not match those of dedicated instruments. However, they do provide a comprehensive assortment of techniques for applications that can tolerate moderate sampling rates and provide these features at much lower cost than dedicated instruments. An ASYSTANT+ system is a well-balanced solution to moderate data acquisition needs and a high-performance solution to analysis needs.

ASYSTANT+: $895
Macmillan Software Company
866 3rd Avenue
New York, NY 10022
212/972-3960
CIRCLE 348 ON READER SERVICE CARD

Victor E. Wright is the manager of process engineering at Luckett & Farley, located in Louisville, Kentucky.