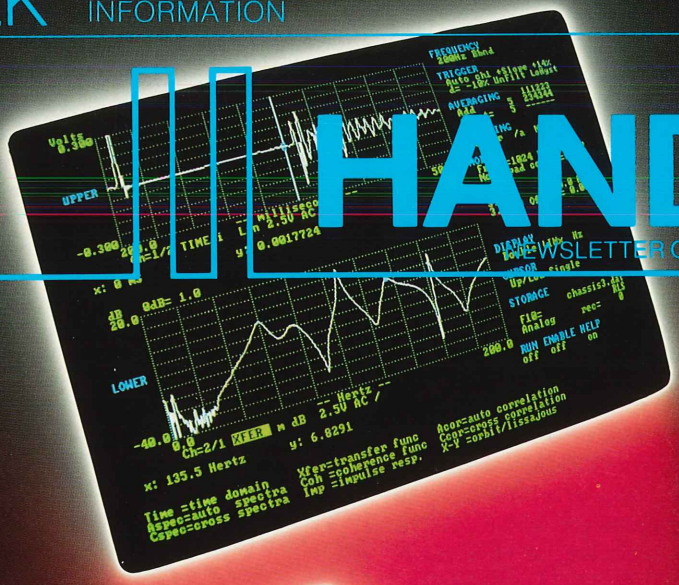
TEK APPLICATION INFORMATION

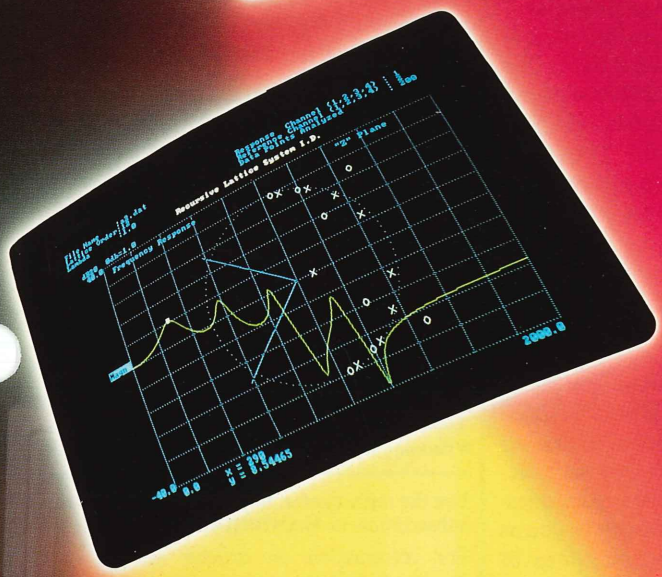
VOL. 13 NO. 3
FALL 1988

HANDSHAKE

NEWSLETTER OF INSTRUMENTATION AND INSTRUMENT SYSTEMS

A New Dimension in Signal Analysis





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Q I would like to learn more about the FFT and it's application to signal processing. Can you recommend a good reference book on the subject?

A While there are a variety of books on this topic, one that I like is **THE FFT: Fundamentals and Concepts** written by the former editor of **HANDSHAKE**, Robert W. Ramirez. This book is both complete and easy to understand. But what I like best about this book is that it takes a non-mathematical approach to this complex topic.

Here's some further information on this book from the publisher:

> "This easy-to-follow guide shows you how to use Fourier theory in digital implementations and the FFT in accurate measurement applications! Make use of a waveform digitizer and an FFT algorithm to gain an "intuitive feel" for Fourier analysis. With minimum math, and over 100 drawings and waveform photos, it graphically develops basic Fourier series, transform theory, and waveform digitizing so you can see actual results of the FFT process. Plus, you'll find broad coverage of distortion analysis, vibration analysis, transform function estimation, and other practical uses of the FFT. And, a sample FFT algorithm written in BASIC allows you to evaluate the FFT for your specific applications."

THE FFT: Fundamentals and Concepts is published by Prentice Hall. You can order copies from your local book store; Prentice Hall reference number is 31438-5. Or, you can order directly from Prentice Hall by calling 201-767-5937.

A. Dale Aufrecht
HANDSHAKE *Editor*

Q The safety article in the Spring 88 **HANDSHAKE** was very timely. I would like to reprint it in our company engineering bulletin.

Customer name withheld

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A. Dale Aufrecht
HANDSHAKE Editor

Questions?

Do you have a question on signal measurements? Send it to **HANDSHAKE** Q&A, M/S 02-382, P.O. Box 500, Beaverton, OR 97077, or use the Comments section of the reply card to send in your question. We'll get a personal answer to you as soon as possible and print questions of general interest in future Q&A columns. Your name and name of your company will be used with the printed question unless you specifically request that it be withheld.

A preview of the Winter HANDSHAKE

The Winter 1988/1989 issue of HANDSHAKE will feature a new series of 10 GHz digital sampling oscilloscopes with 136 channel and differential time domain reflectometry (TDR) measurement capabilities. The Tektronix 11800 Series provides an easy-to-use, comprehensive measurement system for manufacturing and design engineers to quickly and easily design, test, and produce high-speed digital systems.

Mark Tilden, Laboratory Instruments Division Design Engineer on the 11800 Series, will discuss basic sampling concepts, when to use sampling, and the sampling capabilities designed into the 11800 Series. Accompanying articles will describe sampling concepts in more detail and show an application using the multi-channel TDR capabilities of the 11800 Series.

If your application leaves no room for error, the 11800 Series is the measurement tool you've been waiting for. If your need for information on the 11800 Series is immediate, contact your local Tektronix Field Office or representative for information on this exciting new product.

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FOR MORE INFORMATION:

United States readers can use the postpaid reply card in this issue to request a free subscription to HANDSHAKE or more information on products described in this issue. For product prices and information, call the Tektronix National Marketing Center 1-800-426-2200.

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A look inside

The 2630 Fourier Analyzer featured in the article **Low-frequency analysis with the Tektronix 2630 Fourier Analyzer** introduces a new measurement area for Tektronix — low-frequency Fourier analysis. Based upon the familiar Fast Fourier Transform (FFT) often used in signal processing, this new product from the Signal Analysis Unit opens many new application areas.

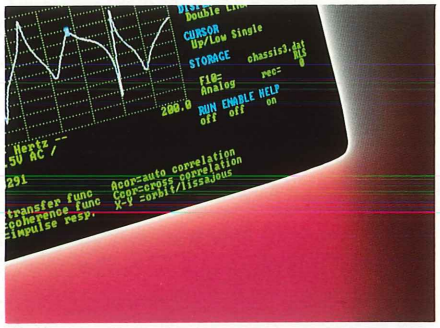
Several new products and applications in this issue focus on manufacturing test. **Making test procedure generation quick and EZ** describes how the EZ-TEST PC Test Procedure Generator can revolutionize your test development strategies. **Automated impedance characterization and control** describes a procedure for measuring the impedance of circuit boards during manufacturing as well as documenting test results. The article **Automated manufacturing test systems for resource-limited companies** provides a case-history of how Tektronix helped a manufacturing company develop a functional test system custom-tailored to their specific needs.

As usual, we have a variety of new products to introduce to you in this issue: An optical sampler to directly measure optical signals to bandwidths of 6.4 GHz, new analog scopes with advanced measurement features, a powerful DSO that you can hold in your hand, new digitizer capabilities in the RTD 710A, and new cards to bring added performance to the TSI 8150 Test System Interface.

We hope you find something in these pages to solve your measurement problems. For help with any of your test and measurement applications or just to talk about your measurement needs, contact your local Tektronix Field Office or sales representative. They'll be glad to help you. And tell them you read about it in **HANDSHAKE**!

A. Dale Aufrecht
HANDSHAKE Editor

For information or prices on products described in this issue, call the Tektronix National Marketing Center 1-800-426-2200



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Low-frequency analysis with the Tektronix 2630 Fourier Analyzer

Dan Blick
Applications Engineer
Signal Analysis Unit
Tektronix, Inc.

The Tektronix 2630 Fourier Analyzer and the Tektronix PEP 301 Systems Controller team up to provide a powerful analysis system (shown with the HC100 Color Plotter).

Are you a mechanical engineer trying to design a stronger, lighter structure? Or a test engineer who's trying to find bad speakers or defective disk drives on a production line? Are you searching for the source of a vibration problem?

If your work involves vibration analysis, frequency response measurements, modal analysis, control system development, machinery monitoring, acoustics, or one of many other low-frequency applications, you should know about the Tektronix 2630 Fourier Analyzer. The 2630 is a two- or four-channel system for data acquisition and analysis up to 20 kHz. It digitizes analog signals and uses the Fast Fourier Transform (FFT) to convert them from the time domain to their frequency domain representation.

The 2630 is unique among analysis systems. Instead of being a monolithic instrument, it's actually a high-performance peripheral that connects to the Tektronix PEP 301 Systems Controller or any IBM PC/XT/AT, IBM PS/2, or compatibles over a standard serial interface.

This PC-based architecture provides many important benefits: First, it gives users easy access to a wealth of third-party analysis software, printers, plotters, net works, and utilities. It also provides for a high degree of programmability, so the 2630 can be customized for a variety of applications. And since the PC provides the display, control panel, and mass storage, your analysis system can be tailored to your own needs and budget. You can choose a low-cost XT-compatible, a laptop computer for portability, or the Tek PEP 301 Systems Controller for high performance (see **More power for your measurements** in the Winter 1987/88 **HANDSHAKE** for information on the PEP 301).

The 2630 isn't just a data acquisition system that does some FFTs. It's a high-quality signal processing system whose design is streamlined and optimized for accurate frequency domain measurements. Included are precisely matched, built-in anti-alias filters, and several high-speed digital signal processors for digital filtering and FFTs. This fast processing enables measurement results to be displayed in the frequency domain, on-line, immediately.

Instrument or programmable system

The 2630 is an exceptionally versatile Fourier analyzer that can act either as an easy-to-use instrument or as a programmable Fourier analysis system. As an instrument, it automatically acquires and analyzes time-domain data using a variety of selectable analysis functions. Typical functions include spectral densities for measuring frequency components of signals, transfer functions for measuring the frequency response of systems, correlation functions for time delays, along with coherence, impulse response, and X vs Y functions.

The software that runs on the PC and the 2630 to perform these functions is called the Instrument Program. It comes standard with each system and it turns the 2630 and the PC into a powerful FFT analyzer immediately — without any programming. The Instrument Program lets the 2630 do all of the number-crunching, so its performance is independent of the speed of the PC. Figure 1 shows a typical display produced by the Instrument Program.

By itself, the Instrument Program is comprehensive enough to meet the measurement needs of many users. But for those with more advanced requirements, we offer the optional TurboPac Application Library. TurboPac is a collection of high-level routines for data acquisition, analysis, and interactive displays — all callable from Borland's Turbo Pascal — that turn the 2630 into a powerful and versatile Fourier analysis system. This gives engineers in research, development, production testing,

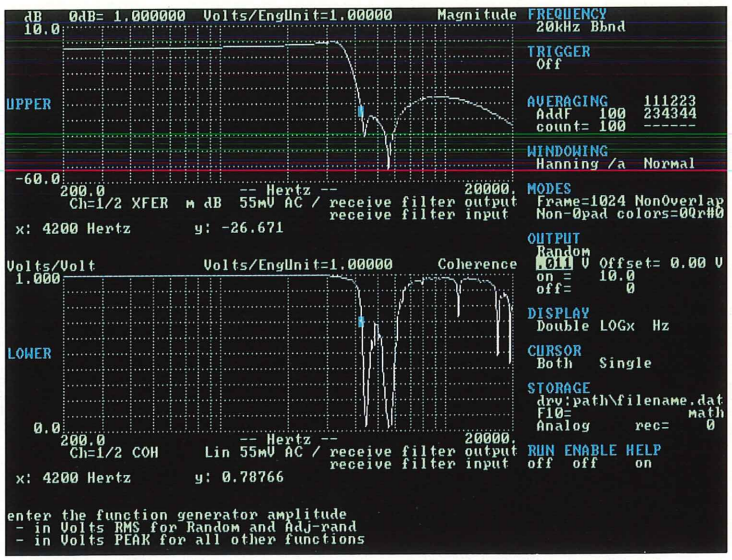

Figure 1. *A typical Instrument Program display. The Instrument Program serves as the control panel for the 2630.*

and consulting all the tools they need to do their own special analyses.

TurboPac also contains a growing collection of programs that are ready-to-run. Included are programs for general array calculations, system identification, ⅓-octave acoustic analysis, swept sine testing, waterfall displays, translation of data to other file formats, and a variety of others. The source code for these programs is provided so you can use them as examples, or you can modify them to meet your own special requirements.

System architecture

The block diagram in Figure 2 shows the architecture of the 2630. The analyzer consists mainly of an analog input system, an optional analog output system, an array processor, and a main processor. The main processor receives commands from the PC, orchestrates the operation of the subsystems, performs a bit of number-crunching, and sends data back to the PC over a high-speed serial link.

An input signal can come through the front-panel input connector, or through an internal connection from the optional output channel. External signals can be either AC or DC Coupled. DC coupling passes all offsets as well as the very low-frequency components, while AC blocks all signals below a low-frequency cutoff of 0.8 Hz.

The input signal is then connected to a preamplifier with software-selected settings from 55 millivolts to 10 volts. An overload test is made on the data before it is passed through a nine-pole analog low-pass anti-aliasing filter. All channels are then sampled simultaneously at a rate of 51.2 kHz with a 12-bit fully-linear digitizer.

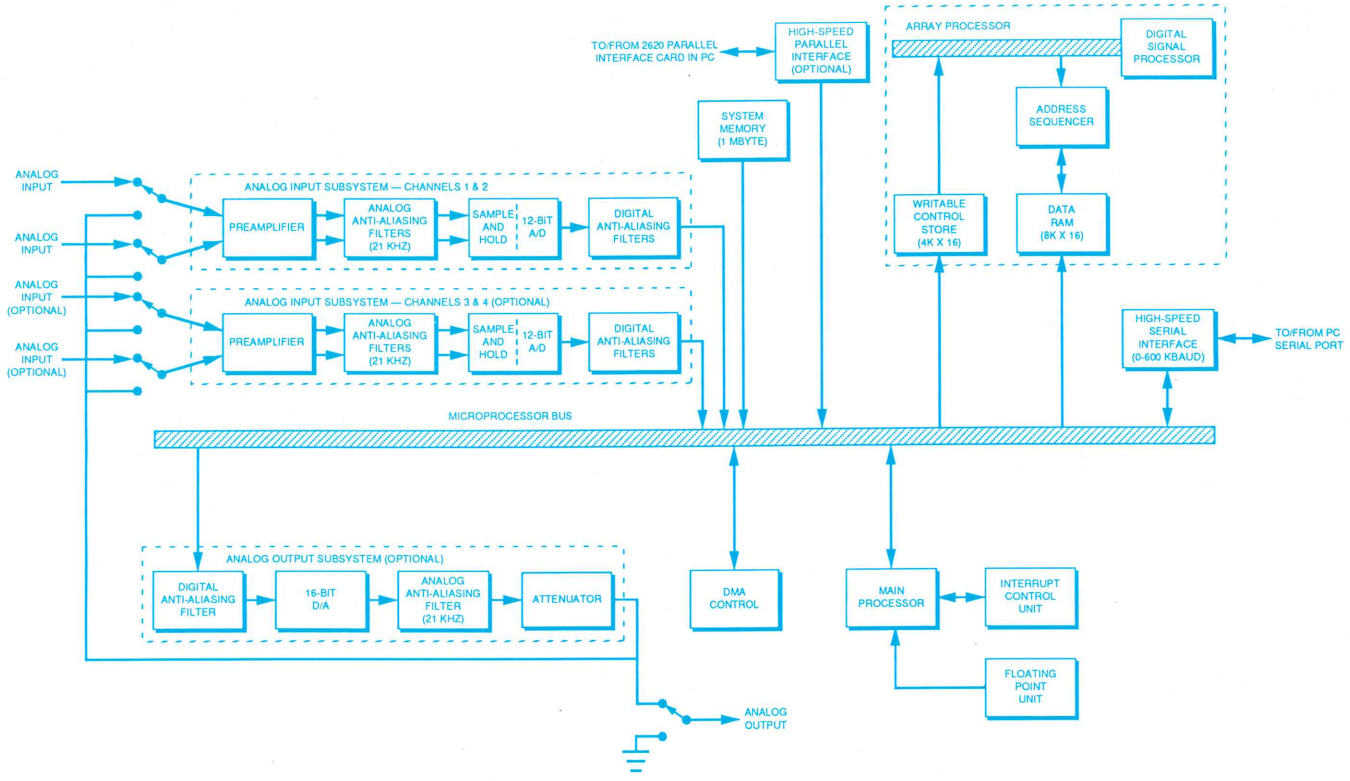

Figure 2. *Block diagram showing the 2630 architecture.*

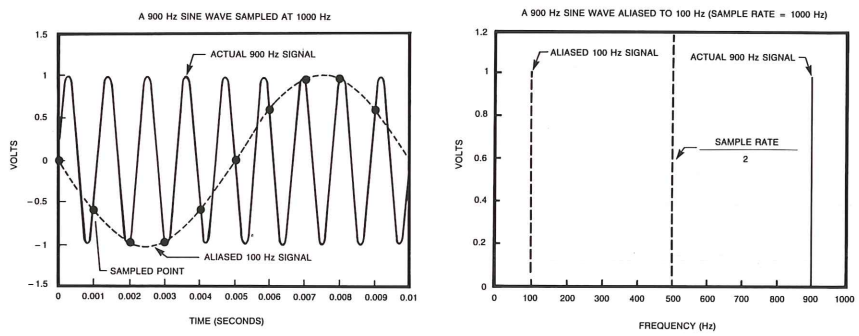

Figure 3. *The unwanted noise signal at 900 Hz is sampled at 1000 Hz. The result is an apparent, or aliased signal, at 100 Hz. Errors of this type are eliminated by built-in anti-alias filters in the 2630.*

Next, a second overload test is made, this one on the digital data. The samples are held in a set of FIFO registers which feed digital low-pass anti-aliasing filters. The effective sampling rate is reduced out of these filters in proportion to the bandwidth. Settings can be selected from 10 kHz down to 5 Hz. Sampling rate is always maintained at 2.56 times the selected bandwidth.

The analog low-pass filtering is critical in Fourier analysis because of the phenomenon of aliasing. Aliasing occurs when you try to sample signals that have frequencies greater than one half of the sample rate. If these signals aren't filtered out, they will appear as lower frequencies (aliases) in your frequency domain analysis (see Figure 3).

The analog filters in the 2630 roll off at more than 125 dB/octave, starting at 21 kHz; this insures that all frequency components above the Nyquist frequency of 25.6 kHz (51.2 kHz/2) will be filtered out.

Optional digital signal processors are available for bandpass (zoom) filtering. Zoom is useful when additional frequency resolution is required; with it, the analyst can set a center frequency from 5 to 19,995 Hz and a bandwidth anywhere from ±10 kHz down to 5 Hz. The number of frequency lines in this bandwidth can be varied from 25 to 1600.

The combined analog and digital filters are matched to within ±0.2 dB in amplitude and ±1 degree of phase shift. All possible aliases are guaranteed to be attenuated at least −75 dB in the usable spectral lines. The magnitude and phase matching is very stable and can be further improved through the use of software calibration.

The filtered digital data is moved via direct memory access (DMA) to the array processor, where high-speed FFT processing and windowing take place. The array processor takes 28 milliseconds to do an FFT with windowing on a 1024-point record of real data.

The FFT algorithm used in the 2630 is an adaptation of the Cooley-Tukey method. One of the key enhancements to the original algorithm is that the three most significant bits in the array processor are constantly monitored so the possibility of numerical overflow can be detected as early as possible. This is more time-efficient than waiting for an overflow to occur, and provides the maximum dynamic range for the FFT.

The spectral windows are implemented by convolving a five-point windowing function with the complex frequency-domain FFT result. Nine different spectral windows are offered, along with three different exponential windows. The exponential windows are applied in the time domain, and serve to increase the apparent damping of a lightly-damped transient response so that spectral leakage errors are minimized. Also, "force" windows can be applied to an input transient signal to eliminate noise in the time history.

A 32-bit microprocessor and math coprocessor convert the integer FFT result into a floating-point array so that the requested function can be calculated. The 2630 knows everything about the display on the PC — X and Y limits, scaling, etc. — so it calculates the vertical offset (in pixels) for each X-axis pixel in the display. For each display, a packet of 400 bytes (each vertical offset takes one byte) is sent from the 2630 to the PC over the serial interface. The PC then draws the appropriate vectors to graph the function. This architecture enables the 2630 to take maximum advantage of its internal processing power while minimizing the computational load on the PC.

The optional analog output system runs in parallel with all other parts of the system. It provides random noise, pseudo-random bursts, sine, square, triangle, sawtooth, and impulse waveforms for system stimulus or for educational purposes. Even arbitrary signals, either measured or user-defined, can be sent to the analog output channel. These signals are stored in the output system's memory, sent through a D/A converter, a 21 kHz low-pass filter, and an attenuator. The low-pass filter is identical to the input filters except for a sin (x)/x correction that accounts for the zero-order hold of the D/A converter.

An optional high-speed parallel interface is also available which allows time-domain data to be written directly to a file on a PC hard disk or RAM disk. This interface allows data to be written to the disk at 25.6 K samples/second on a standard IBM PC/AT — that's fast enough to record one channel at the 10 kHz bandwidth, or two channels at 5 kHz. Higher data rates can be achieved with faster hardware. The amount of data that can be gathered at any time is limited only by the capacity of the storage device. Once recorded on the disk, this data can also be played back through the analog output channel.

Application areas

Following is a brief overview of a few of the many application areas for which the 2630 Fourier Analyzer is well suited.

Modal analysis. Experimentally determining the vibration frequencies and deflection patterns of objects is an important part of the mechanical design process. Known as modal analysis, it enables designers to visualize different parts of a structure, such as an electronic chassis, moving relative to each other at each resonant frequency. When large deflections are detected in critical areas, they can be reduced by using the results of the analysis to guide structural modifications.

The first step in performing a modal analysis is to measure the frequency response functions (FRFs) between the force input and the acceleration response at various points on the test structure. The 2630 is optimized for this type of measure-

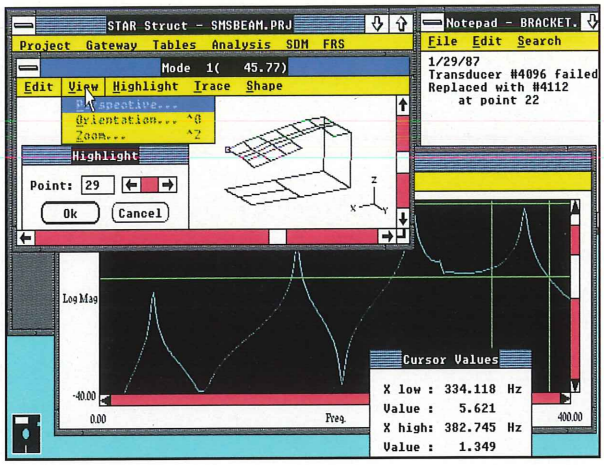

Figure 4. *Typical display when using the STAR System for modal analysis.*

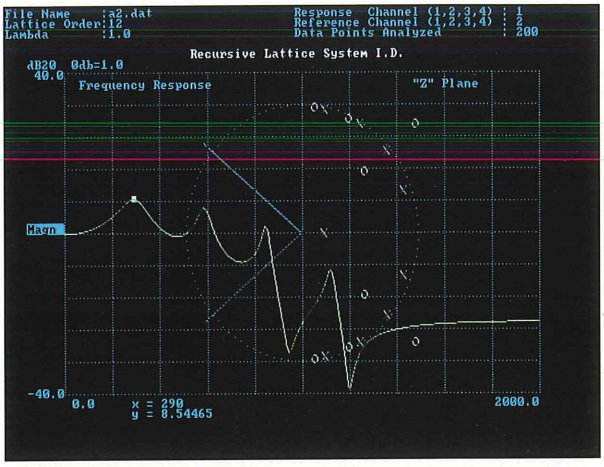

Figure 5. *Typical control system modeling display. This Z-plane pole-zero model was developed using the RLS application in TurboPac.*

ment; its high-performance acquisition and analysis capabilities help to estimate the response functions accurately, and the four-channel option enables three FRFs to be measured simultaneously.

Since each point on a structure can move in three directions, three FRFs are normally measured for each point. A four-channel system allows all of these functions to be measured at once instead of individually, so measurement time can be reduced by a factor of three.

These frequency response measurements are passed to a modal analysis program. This program determines the resonance frequencies and damping factors, and then calculates and displays the corresponding mode shapes, or deflection patterns, with real-time animation. Some modal analysis packages also offer structural modification capabilities — they let the designer add stiffeners, dampeners, or additional mass to the structural model so that the effect upon the resonance frequencies and mode shapes can be determined.

One such modal analysis program, the STAR System from Structural Measurement Systems, Inc., is a full-performance modal analysis program for the PC. Figure 4 shows a typical display from this system. The STAR System is very easy to use since it runs under Microsoft Windows. In addition, it has optional packages for structural modification and forced response simulation. The combination of the 2630, the PEP 301, and software like SMS STAR makes accurate modal analysis affordable for many mechanical designers.

Control system design. The advanced measurement capabilities of the 2630 also make it an indispensable tool for control system design and analysis.

First, the Recursive Least Squares (RLS) system identification program in the TurboPac Application Library allows the designer to develop pole-zero models for the components of the control system. This highly accurate algorithm uses time-domain input/output data measured by the 2630 to characterize dynamic systems in either continuous or discrete time (see Figure 5).

Second, these pole and zero locations can be written to a DOS file and read by control system design packages like PC-Matlab, MATRIX$_X$, or CTRL-C. These programs provide extensive libraries of design and simulation tools for digital or continuous systems, and classical or modern design methods. PC-Matlab and the 2630 combine to turn the PC into a complete control system design workstation.

The 2630 is also used to evaluate the performance of control systems. Frequency response functions can be measured in a variety of different ways to suit the application. In addition to the conventional frequency response analysis with random excitation, there's also swept-sine testing, closed-loop to open-loop mappings, and advanced three-channel measurement techniques which minimize the effects of disturbances and sensor noise.

Arbitrary signal generation (included with the optional output system) allows the excitation signal to be tailored to a particular measurement problem. Signals can be defined in either time or frequency domain, or they can be derived from previously measured data. You can, for instance, create an output signal which has high energy at frequencies where the closed-loop system has low gain. This increases the signal-to-noise ratio at those frequencies and greatly enhances the accuracy of the measurement.

The measurement capabilities of the 2630 and its links to control system design packages help to close the gap between theoretical analysis and the behavior of real-world systems. This helps to shorten development time and optimize control system performance.

Production testing. The 2630 is ideal for making fast, accurate measurements and quick decisions on the production floor. The TurboPac Application Library provides all the tools required to set up pass/fail production tests based on frequency- or time-domain measurements.

The frequency response of loudspeakers, servo systems, transducers, or amplifiers can be measured, and the units whose responses are outside of a given tolerance can be rejected accordingly. Noise spectra can also be measured to find defective motors, bearings, pumps, or any other fault indicated by noise or vibration.

Sometimes tests are required to check the resonant frequency and damping ratio for items like vibration isolation mounts, shock absorbers, and damping materials. The RLS system identification algorithm can be used in cases like these to calculate

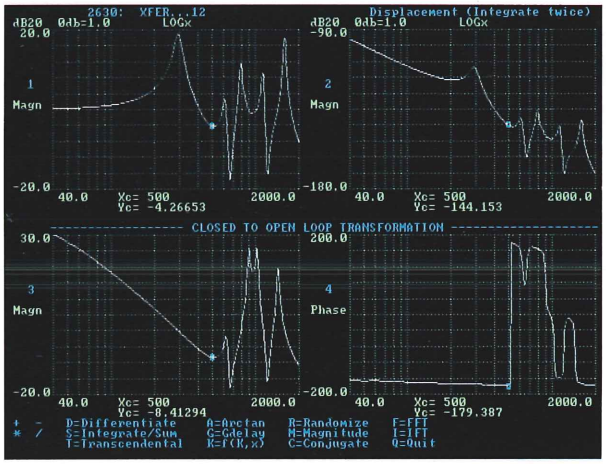

Figure 6. *Sample display from MATH program for general array calculations. Array in window 1 is integrated twice to produce the array in window 2. Open-loop transfer function provides magnitude and phase arrays in windows 3 and 4.*

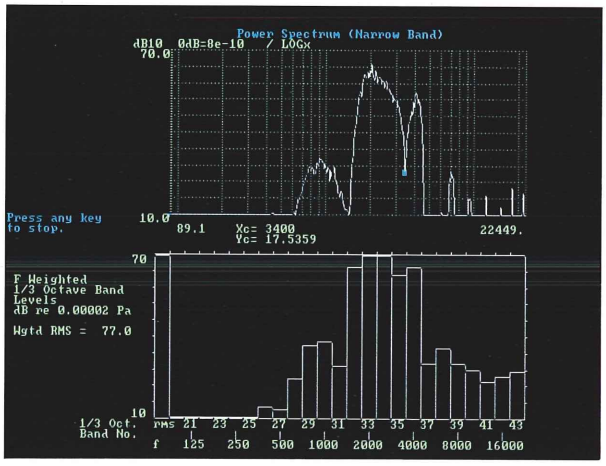

Figure 7. *Typical display from acoustic analysis. Display shows the results of a jet flyover test in narrow-band (top) and ⅓-octave (bottom) format.*

frequency and damping parameters more quickly and accurately than FFT-based methods.

Since the 2630 is PC-based, these production tests can include data from other test equipment and inputs from other devices such as bar code readers. The test information and results can also be automatically written to a database file or to another computer over a network. The combination of the 2630 and the PC provides an inexpensive way to increase product quality and reliability through the automation of production testing processes.

Vibration analysis. One of the most popular uses of a Fourier analyzer is in vibration analyses. The 2630 can be used to measure vibrations inside automobiles or airplanes, on vibration test fixtures, on pipes, on machines, or on anything that vibrates.

Fourier analysis is essential for characterizing vibration signals. Seeing the frequency content of vibrations gives valuable insight into their possible causes and effects. But Fourier analysis is much more than acquiring some data and doing a Fourier transform. It requires averaging, windowing, anti-alias filtering, and a wide dynamic range so that even small vibration components can be distinguished from the noise.

All these things, and many others, are an integral part of the 2630. And in addition to making accurate measurements, the 2630 makes it easy for engineers to work with vibration data. The MATH program in TurboPac does quick array calculations (See Figure 6). TurboPac programs can be used for custom analysis, and since the data is already in the PC, there's easy access to a wide range of third-party analysis packages.

Accurate measurements, analysis flexibility, and a small, lightweight package help make the 2630 an exceptional value for vibration analysis.

Acoustics. The 2630 is an extremely useful tool for a variety of acoustical applications. The Instrument Program offers power spectra for measuring the frequency content of acoustical signals; transfer function analysis for determining the dynamic characteristics of rooms, walls, speakers, amplifiers, and microphones; and correlation functions for measuring propagation delays.

In addition the TurboPac Application Library provides a program for four-channel ⅓-octave analysis (see Figure 7) and the ability to do cepstrum analysis, Hilbert transforms, and many other useful functions for acoustic analysis.

Machinery monitoring. Another application for the 2630 is machinery health monitoring. Analysis of the vibration signals near a bearing can indicate that it may soon fail. A monitoring program that uses a Fourier analyzer can result in tremendous savings on maintenance costs and helps to avoid excessive down time.

Two TurboPac programs can help in the analysis of rotating machinery: One labels the peak frequencies in a measured spectrum; the other takes a series of spectral measurements and graphs them in a "waterfall display" to show how the vibration spectra change over time.

Summary

The Tektronix 2630 Fourier Analyzer is a very versatile Fourier analyzer that provides high performance and excellent value for a variety of mechanical, electromechanical, and electrical applications. Its PC-based architecture not only provides unparalleled flexibility and easy access to a wide range of third-party software, peripherals, and utilities, but it also substantially lowers the cost of the system.

Want to know more?

We could only give you a small glimpse into the many capabilities of the 2630 Fourier Analyzer in this article. If you would like more information, please contact your local Tektronix Field Office or sales representative. U.S. readers can call the Tektronix National Marketing Center toll free — 1-800-426-2200 — for information, prices, or to place an order. And be sure to tell them you saw it in **HANDSHAKE**.

For a brochure on the 2630 Fourier Analyzer or the PEP 301 Systems Controller, check the appropriate box on the reply card in this issue.

Making test procedure generation quick and EZ!

Steve Peterson
Software Solutions Product Marketing Manager
Measurement Systems Division
Tektronix, Inc.

Tektronix EZ-TEST PC Test Procedure Generator provides productivity enhancements to dramatically reduce ATE software development time and costs.

In today's manufacturing test environment, a typical automated test procedure can require 10,000 or more lines of code — code detailing instrument front-panel settings, measurement acquisitions, comparison against limits, procedure flow control based on the pass/fail results of these comparisons, etc. — all in a logical sequence.

Manual entry of this many lines of code, even with the computer-based text editors in common usage, can easily require a year or more of very expensive, skilled labor. Tedious, repetitive coding of front-panel setups, measurement acquisitions, test limits, and branching consumes a major portion of a programmer's time — time that could be better spent in value-added tasks. And then there's debugging. Debugging test program code often requires up to 50% of the total software development time.

As a result, many manufacturing test departments are stuck with a test development backlog of anywhere from several months to several years. In some cases, outdated manual testing methods are still being used simply because the software development time and cost associated with automating test procedures are too high.

First steps toward a solution

In recent years, manufacturers of programmable test instruments have introduced software tools designed to assist with automated test procedure generation. The goal has been to reduce dependence upon costly, and often hard to find, skilled programmers; to reduce the amount of tedious primitive-level coding required of a programmer; and to provide automated test program generation tools that guide even inexperienced programmers through the test procedure generation process — thereby reducing not only the many hours needed to complete test development, but also the cost of development.

However, the majority of these software tools still rely on a large body of manually generated code. What's needed is an environment where a test development engineer of any programming skill level can sit down and generate a test procedure using English-like commands, and let the computer work at the more primitive coding level to automatically produce a compiled version of the procedure.

Tektronix EZ-TEST PC Test Procedure Generator — the real solution

Tektronix EZ-TEST PC Test Procedure Generator is a high-level interactive test procedure development environment that produces automated test procedures in less than a third of the time it takes with ordinary coding methods. It allows the programmer to work in a high-level interactive environment to generate test procedures, while the controller provides automatic code generation. EZ-TEST PC makes it possible for programmers and non-programmers alike to generate entire test procedures without having to write a single line of code.

EZ-TEST PC runs on the Tektronix PEP301 Systems Controller, or any IBM-PC compatible controller configured with GURU — the Tek GPIB interface — and 640 kbyte memory, 10 Mbyte hard disk, and CGA graphics. The complete software package consists of EZ-TEST PC 2.0 software, Microsoft QuickBASIC 4.0 compiler, and GPIB interface software for QuickBASIC.

A menu-driven format lets the test development engineer create, revise, and easily debug complete test procedures with all of the test instruments and the Unit-Under-Test (UUT) on-line. Each menu is presented in clearly readable English. The developer only has to respond to prompts with item selection and fill-in-the-blank answers. This keeps attention focused on the test procedure, not on language syntax.

EZ-TEST PC cuts test program development time even further by eliminating the need to manually write test code. Even inexperienced test engineers can produce fully functional test procedures in hours, not weeks.

EZ-TEST PC features an open systems architecture to provide a great degree of program flexibility. Tek provides all source code so that custom modifications can be made by experienced users, giving them the level of control they prefer but with the development-time savings of using a higher-level tool to accomplish their goals. At runtime, EZ-TEST PC directs all of the GPIB instrumentation to supply the stimulus, switching, and data acquisition required for each test step. In addition, on-screen prompts can be provided to help the system operator with any manual tasks related to the test. High resolution graphical images can be incorporated into the procedure to provide visual aids for the operator.

And EZ-TEST PC supports a host of GPIB instruments from Tektronix, Fluke, Hewlett-Packard, Wavetek, and other vendors.

Four programs in one

The EZ-TEST PC software system is actually four programs in one: A generator program "EZGEN", a QuickBASIC language translator program "EZTRAN", and a test executive program "EZEXEC". In addition, EZ-TEST PC includes a runtime library "RUNLIB" which simplifies the test procedure code structure by modularizing test functions, and a Microsoft QuickBASIC editor, compiler, and linker for customizing test programs. Figure 1 shows the functional relationship of these components.

EZGEN is used to create, modify, and debug a test procedure and interpretively execute it — either from beginning to end, or one step at a time. EZGEN also provides ancillary functions used before test procedure generation and after test execution — functions such as preparation of graphics files to be used in tests, preparation of switching matrices, displaying digitized waveforms, and viewing test results graphically.

EZTRAN converts the test procedure created with the generator into QuickBASIC source code. When compiled and linked with RUNLIB, this source code runs under control of the test executive, EZEXEC.

Microsoft QuickBASIC 4.0 compiles the source code test file produced by EZTRAN and links it with the runtime library. It also provides the coding environment for custom modifications to the test source code and the runtime library modules.

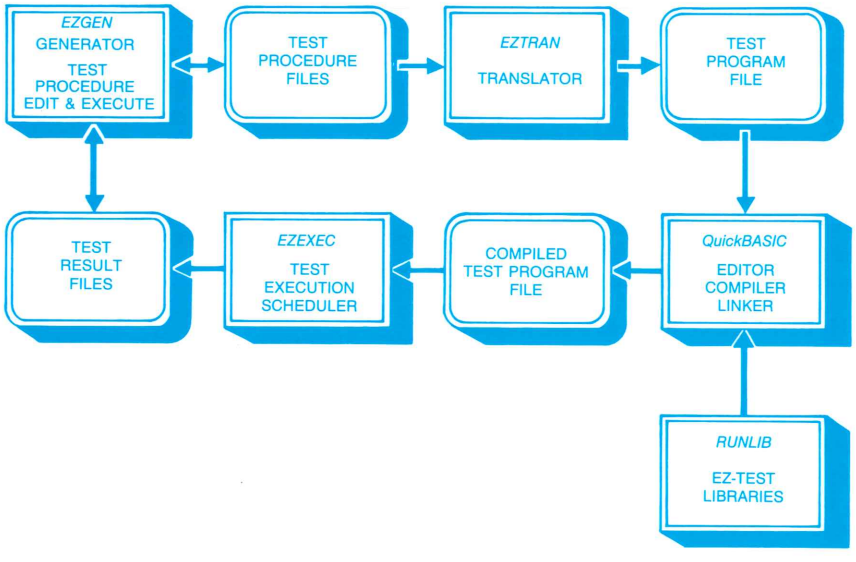

Figure 1. *System elements of Tek EZ-TEST PC Software.*

EZEXEC is used by the test operator to schedule tests and set up options for logging data during test runtime. EZEXEC also allows test modules to be batched together to form test sequences.

Step-by-step through EZ-TEST

The generator program, EZGEN, guides the test developer through the test procedure generation process with a variety of menus and prompts. Using the Edit Menu in EZGEN, the developer defines, modifies, and debugs the test procedure with all of the required test instrumentation on-line. The test procedure is interpretively executed with the Execute Menu.

But before beginning an edit session with EZGEN, the test engineer must first connect all GPIB instrumentation required for the test and configure them with non-conflicting GPIB addresses. Then, with EZ-TEST PC loaded and running, EZGEN automatically scans the bus and builds a table of available instruments. This table indicates the name of each instrument and its address (see Figure 2).

With the instruments on-line and identified, the test engineer sets up each step of the procedure at the instrument front panels and then requests that EZGEN "learn" these settings with the settings query command — "SET?". EZGEN uses the query/readback capability of Tektronix instruments (and instruments from some other vendors) to learn instrument setups directly from the instrument hardware.

Instrument settings strings received from each instrument (or entered by the developer) are stored in a data table. At runtime, these settings are interpreted from the settings data table and sent back to the instrument for execution of each step.

Instruments which do not have the query/readback capability can be programmed by entering device-dependent command strings as text via the edit screen. These command strings are immediately sent to the instrument to validate proper coding and hardware operation.

EZGEN allows broad functionality

A wide range of functions can be selected from the structured menus of EZGEN in the course of defining each test step. They include: Instrument setups, measurement acquisitions, stimulus-response tests, waveform acquisitions, waveform pulse parameter extraction, data transfers between instruments and files, wait states, measurement limits, conditional and non-conditional branching, operator text prompts and graphics displays, operator inputs, and operator UUT adjustments.

Each function that the developer selects uses a resource or group of resources within the system. The resources may be the computer keyboard and display screen, test instrumentation, disk files, or the system operator.

Once a procedure has been created, it can be executed, debugged, printed and stored. The operator may run the entire procedure from beginning to end, or step through the procedure one step at a time to verify runtime behavior. Any procedural errors found can be quickly corrected without leaving the program generator environment.

Loop steps. An especially useful function is the loop step. The loop step allows the developer to set up both a stimulus device and a measurement device and then automatically step the stimulus device through a range of values. This powerful feature automates the process of setting up stimulus/response tests.

For example, a Tek FG 5010 Programmable Function Generator can be set up to step through a range of frequencies in order to stimulate an amplifier circuit node — say between 100 Hz and 100 kHz in 31 increments. EZ-TEST automatically calculates the logarithmic increment size, resulting in 10 frequencies per decade. A Tek DM 5010 Programmable Digital Multimeter can then measure the results at the amplifier output.

EZ-TEST PC lets the test developer set up PASS/FAIL limits at each step. In addition, limits can be established as either static (one set of values — high and low — for the whole range) or dynamic (high and low values which change in relation to stimulus changes). The test data acquired in a stimulus/measurement loop step can be plotted to show how actual test data compare to PASS/FAIL limits as shown in Figure 3.

Graphical adjustment steps. EZ-TEST PC has the unique ability to incorporate operator adjustments of the UUT within the test procedure while simultaneously assisting the operator with a real-time graphical display of the adjustment results. When an adjustment step of this type is executed, the computer monitor displays a simple one-line bar graph with an indicator that moves back and forth as the measured real-time output changes (see Figure 4). The bar graph can also display preprogrammed nominal and limits values. The operator adjusts the applicable control until the display indicates that the measurement is within limits.

Pulse parameter measurements. EZ-TEST PC supports most Tektronix digitizers and digital-storage oscilloscopes (DSOs) for acquisition and measurement of waveform pulse parameters. This permits PASS/FAIL testing of complex waveforms with amplitude and time parameters either calculated by the digitizer or calculated in software after a waveform has been acquired. For example, the histogram method may be selected to determine pulse top and bottom levels, mesial, proximal, and distal amplitudes specified as percent of amplitude, and then width and risetime measurements acquired and compared to PASS/FAIL limits.

Translating and compiling the test procedure

The translator program, EZTRAN, processes the test procedure and produces an output file containing a QuickBASIC source-code program. The translator can convert a 200-step procedure into a QuickBASIC file in about 60 seconds on a hard disk system, producing an average of 20 lines of source code per test step. The actual number of lines of QuickBASIC source code depends upon the type of test step and length of the device-dependent command string sent to an instrument in the step.

The compiled test code includes a subprogram containing the procedure code which makes calls to modules in the runtime library. These RUNLIB modules are coded versions of the test functions that are included in the generator program.

Handling the code. Instrument front-panel settings may be in ASCII or binary depending upon instrument protocol. ASCII front-panel settings data is stored as literal strings within the test code.

Non-ASCII settings data are handled in

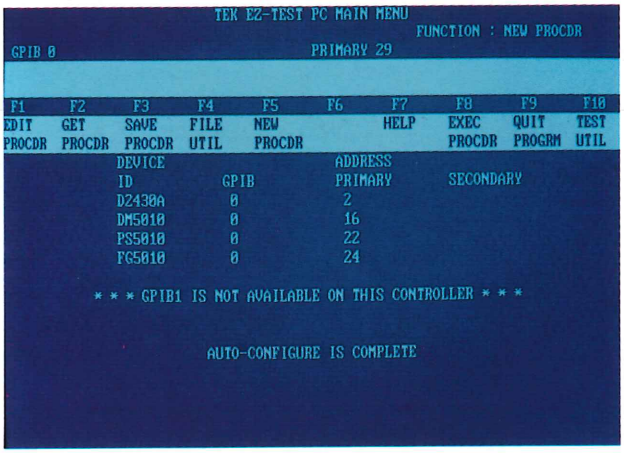

Figure 2. *EZGEN scans the bus and automatically builds a list of available instruments along with their GPIB addresses.*

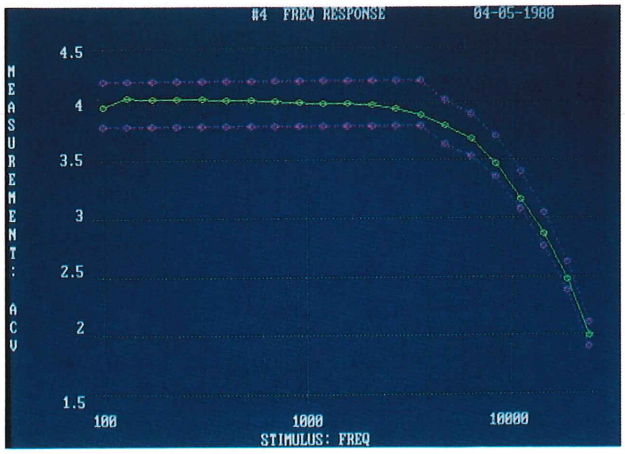

Figure 3. *Plot of test data acquired in a typical loop step.*

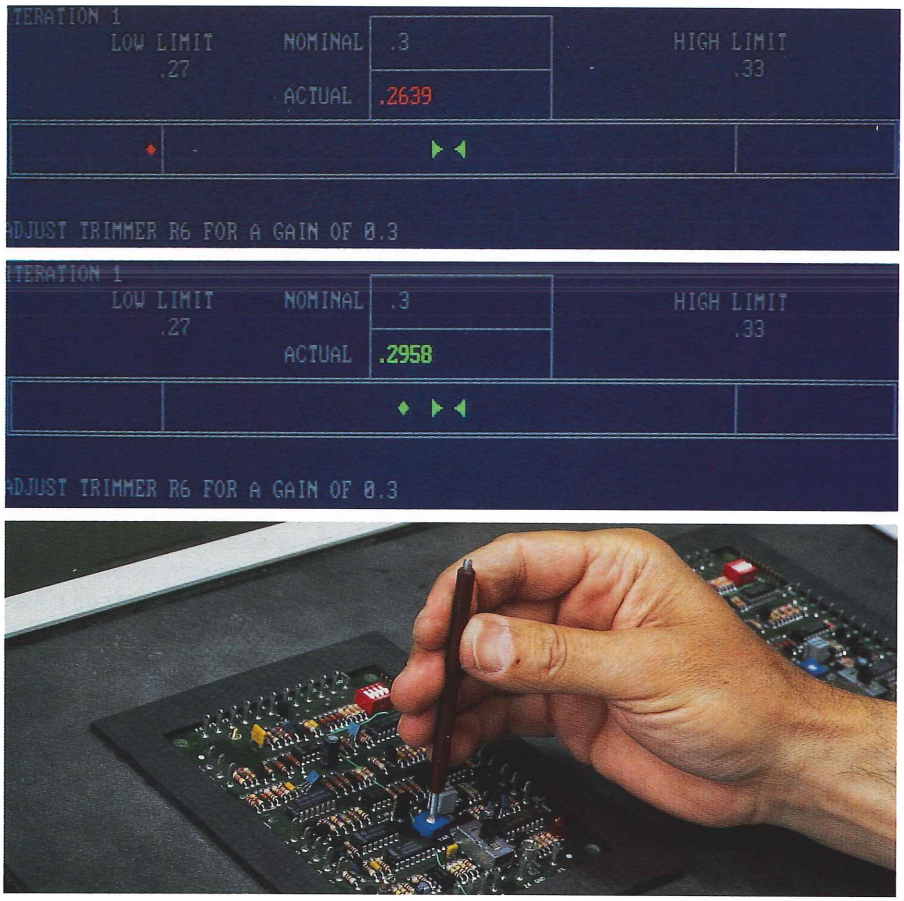

Figure 4. *Adjustment steps are supported by a real-time on-screen display. As shown here, the operator adjusts the UUT until the cursor lines up with preprogrammed nominal adjustment markers.*

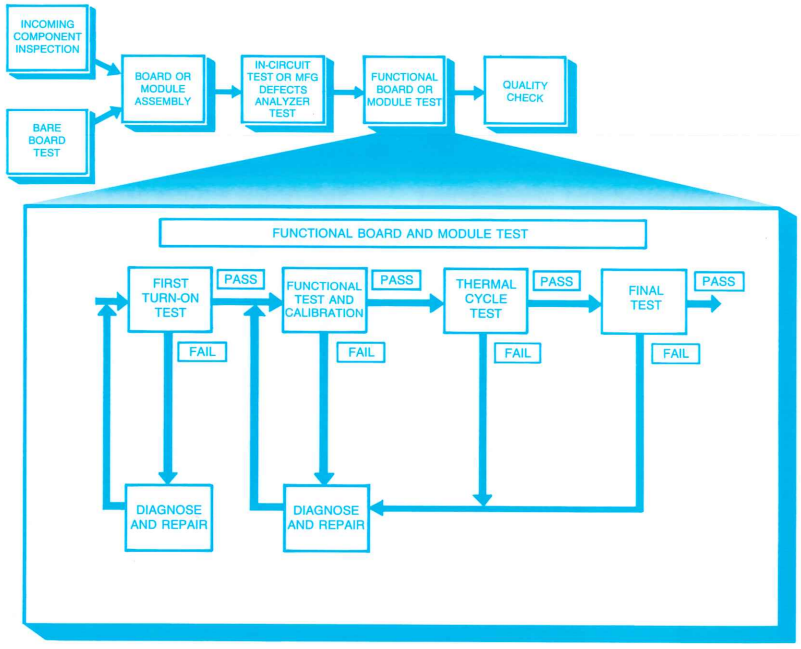

Figure 5. *Each box in the diagram denotes a test sequence comprised of a combination of test procedures. Each procedure may be used in any number of test sequences.*

a DATA statement with an associated READ statement. The DATA and READ statements fill an output buffer string that is sent to the instrument at runtime. As an alternative, instrument settings can be stored as disk files and called in when needed. This saves program space and may simplify software maintenance.

Once the translator has produced the source code file, it automatically invokes the QuickBASIC compiler and linker to produce an executable file. EZ-TEST PC does it all automatically without programming expertise or manual coding. And the compiled, executable test program performs exactly as it did when interpretively executed by the generator.

Customizing the procedure. The QuickBASIC editor can be used to make custom modifications to the test program source code file and to the EZ-TEST PC runtime library modules in order to perform any special operations that EZGEN cannot perform through its menu selections. Experienced programmers can easily enter new source code and modify the translated code to provide the sophistication and subtle requirements that a particular test may require. The translator makes individual test steps easy to identify, and clearly labels the various setup parameters for each step.

The runtime library modules are provided as fully documented source code files as well as linkable libraries with complete instructions for rebuilding or modifying them if source code changes are made. The user may add additional code modules to the library as needed — even modules written in Microsoft C.

QuickBASIC 4.0 incorporates a user interface which includes a syntax-checking screen editor, an immediate mode window so that developers can try out code before including it in the procedure, an excellent set of debugging tools, and an extremely fast compiler.

Building a test sequence. Typical manufacturing test environments incorporate a number of test sequences at different stages in the manufacturing process. Each test sequence is comprised of a test procedure (or group of procedures) chained together in a logical order. Figure 5 shows a block diagram of a typical manufacturing process. The test executive — EZEXEC — allows the test developer to

schedule the coded test procedures produced by the translator and the QuickBASIC compiler and then execute them.

An individual test procedure can be used in any number of test sequences. This promotes reuse of test procedures where needed. For example, a short procedure which tests continuity and applies power to a UUT may be needed for each of the test sequences shown in Figure 5 — from the First Turn On Test through to the Final Test sequence.

EZEXEC is invoked from the DOS command line by calling up the filename arguments for specific test procedures in the order chosen for the complete test sequence. EZEXEC can also be invoked directly from a DOS batch file. The batch file approach is a convenient way to organize a sequence of test procedures under a file name associated with the sequence name. All test data gathered during test execution is handled by EZEXEC and can be sent to a disk file, to the display screen, or to a printer.

Utilities expedite testing

EZGEN provides a utility menu which incorporates a number of features that facilitate testing: Graphic prompts, improved maintenance of switching functions, test data browsing capabilities, capture of waveforms from Tektronix digitizers and DSOs, pulse parameter analysis on stored waveforms, and conversion of test data to the Data Interchange Format (DIF) for statistical analysis.

Procedure clarification with high-resolution graphics. The utility menu provides an interface for screen graphics created with Microsoft Windows Paint and PC Paintbrush, giving users the ability to incorporate board layout diagrams and graphic prompts within a test procedure. Graphic diagrams and prompts created with these programs can be quite useful for the test system operator. For example, a picture can show where connections are needed between the test system and the UUT. Or you can show the location of adjustments or communicate important information about the test.

This feature is particularly useful in situations where the operator must make adjustments to the UUT, such as adjusting a control. A picture file can be presented on screen with the appropriate control highlighted, or with an arrow indicating in which direction it must be turned (see Figure 6). EZ-TEST PC supports high-resolution EGA, CGA, and Hercules Monochrome Graphics displays.

Switching support. EZ-TEST PC supports the TSI 8150 Test System Interface by providing a utility to aid in generating switch configuration files. Using the utility menu, the test developer no longer needs to hand-enter the specific device-dependent commands for every action needed on the scanner cards.

The switch-configuration file defines the switching used to interface the test system instrumentation to the UUT. EZGEN uses this file when switch paths are to be closed or opened between the UUT and the test system. The file clearly defines the names of switch paths for specific relays within the switching matrix.

Using the utility menu, the test engineer defines a "map" which labels physical switches with "logical" names and groups of switches with "group" names (see Figure 7). This mapping permits grouping of commonly named switch paths. For example, power connections on a UUT could be given logical names such as "+5VDC" and "GND", and then grouped together under a single group name such as "LOGIC PWR". All that is needed to connect power to the UUT is the EZGEN command "CLOSE LOGIC PWR". Large matrices of switches on multiple switch cards can be easily configured by referring to groups of switches defined in the configuration file. This grouping greatly improves the readability of the code and saves massive amounts of debugging time.

Statistical quality control. Test data can be converted to the DIF file format which can then be imported into spreadsheet programs such as EXCEL, FRAMEWORK II, and LOTUS 1-2-3 for statistical evaluation and custom formatted printouts. Using the statistical analysis functions provided by spreadsheets, data collected on individual device tests or processes can be analyzed for deviations from the norm. Faulty manufacturing processes can be corrected before they get out of control. There's less wasted effort on the manufacturing floor, less scrap material, and less time involved in diagnostics and salvage.

Digital waveform capture. EZ-TEST PC has the ability to capture waveforms using most Tektronix digitizers and DSOs. These waveforms may be converted to the Tektronix standard ADIF file format for later retrieval and evaluation with the Tektronix Signal Processing and Display software (SPD). (See **ADIF — The Analog Data Interchange Format** in the Winter 1987/88 **HANDSHAKE** for details on ADIF.) Waveforms acquired as test data can be processed to produce a complete set of pulse parameters.

Limited debugging required

With EZ-TEST PC, test procedures are produced with the hardware and the device to be tested on-line, so test procedure development and debugging tend to occur

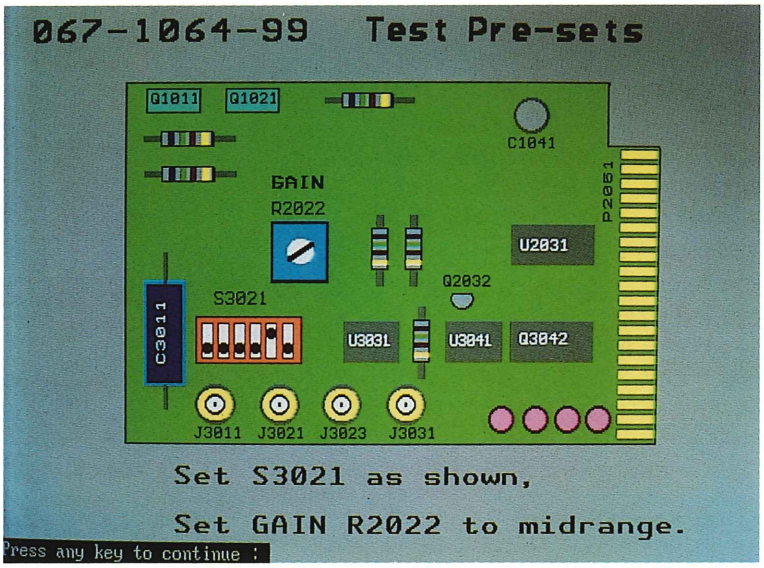

Figure 6. *A typical electronic circuit board picture produced with PC Paintbrush is shown here with the test presets labeled for easy component locating.*

```
TSI 8150 Configuration
ID TEK/TSI8150,V81.1,FV1.0,F1:NONE,F2:NONE,F3:NONE,F4:NONE,F5:NONE,F6:NONE,
R1:SCANNER/GENERAL PURPOSE:V1.1,R2:SCANNER/GENERAL PURPOSE:V1.1,R3:NONE,
R4:NONE,R5:SCANNER/COAXIAL:V1.1,R6:NONE;

Logical to Physical Map
 Entry        Logical        Physical designation
-------------------------------------------------
   1          +5VDC          R1 A1
   2          GND(+5V)       R1 A2
   3          +15VDC         R1 A3
   4          GND(+-15V)     R1 A4
   5          -15VDC         R1 B1
   6          +15V_SENSE     R1 B2
   7          -15V_SENSE     R1 B3
   8          J302_VCO_OUT   R5 A1
   9          J303_SQR_OUT   R5 A2

Group to Logical Map
 Entry        Group          Logical designation list
-------------------------------------------------
   1          LOGIC_PWR      +5VDC,GND(+5V)
   2          VCO_PWR        +15VDC,GND(+-15V),-15VDC,+15V_SENSE,-15V_SENSE
   3          VCO_OUT        J302_VCO_OUT,J303_SQR_OUT
```

Figure 7. *The switch configuration "MAP" file for the Tektronix TSI 8150 specifies how the test system instrumentation is interfaced to the UUT. Two tables, Logical-to-Physical and Group-to-Logical, define switch paths with meaningful names which are used in programming the TSI 8150 with EZ-TEST PC.*

simultaneously. Errors are detected immediately and corrected in the process of developing a test step. In fact, the user cannot proceed with the next test step unless prior steps have been performed correctly — the hardware simply is not set up to logically provide the required response.

When you consider the fact that it's not unusual for debugging operations to consume as much as 50% of test development time, it becomes very clear that a software productivity tool such as EZ-TEST PC — which can generate error free code the first time — will result in immense savings.

Productivity enhancement made EZ

EZ-TEST PC is the ideal productivity enhancement tool for test procedure generation. Whether you're a novice or skilled programmer, you can implement tests easily and in a third of the time it takes with other programming methods. And EZ-TEST PC generates the code for you, providing full flexibility if you need to add additional code with the QuickBASIC Editor.

For more information

Would you like a demonstration of how easy it is to generate test procedures using EZ-TEST PC? Check the appropriate box on the reply card in this issue for a demo disk showing EZ-TEST PC in action. Or contact your local Tektronix Field Office or sales representative for a demonstration at your site, on your equipment. U.S. customers can get information or order EZ-TEST PC software from the Tektronix National Marketing Center toll free — 1-800-426-2200. And be sure to tell them you read about EZ-TEST in **HANDSHAKE.**

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New catalog lets U.S. Customers "shop by phone" for Tektronix products

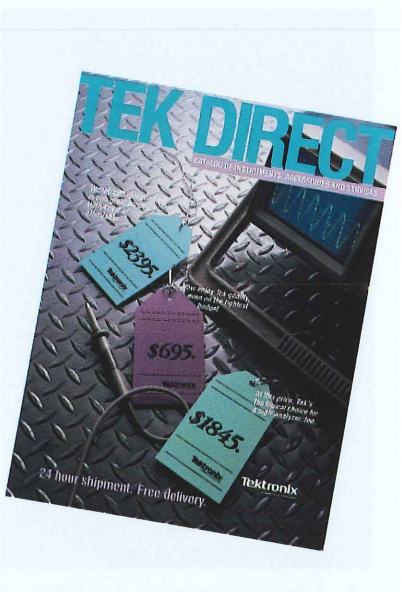
Tektronix introduces a convenient new way that U.S. customers can select and order our most affordable products — The Tek Direct Catalog.

This 24-page, full-color catalog includes 50 low-cost instruments and accessories as well as software, training aids, and testing services. It includes low-cost analog scopes, store/non-store scopes, logic analyzers, and Tek's latest automated scope, the 2247.

All products are fully described and illustrated for easy selection. A toll-free number is available for ordering, as well as for assistance in making choices and after-sale support.

Tek Direct phone customers also receive special benefits such as 24-hour shipment, free surface freight, a 30-day money back guarantee, and the option of charging purchases on Visa or MasterCard.

To receive a free copy of the Tek Direct Catalog, U.S. customers can write to Tek Direct at M/S 02-050, P.O. Box 500, Beaverton, OR 97077 or call 1-800-426-2200.



High-frequency measurement of optical signals

The S-42 Optical Sampling Head allows the direct measurement of optical signals using a 7S11 Sampling Unit or a 7S12 TDR/Sampler in a 7000-Series Oscilloscope.

Now you can make direct measurements on optical signals with the Tektronix S-42 Optical Sampling Head. This allows you to measure very high-frequency repetitive optical signals using sampling measurement techniques. A Tektronix 7000-Series Oscilloscope equipped with a 7S11 Sampling Unit or a 7S12 TDR/Sampler is required.

The S-42 can be used to analyze optical signals in the 1000 to 1700 nanometer wavelength range. The pulse response of the measurement system is less than 55 picoseconds (Full Width Half Maximum) which is equivalent to a calculated bandwidth of DC to 6.4 GHz. Figure 1 shows the pulse response of the S-42.

The S-42 also has a Mean Power Meter output which can be used with a voltmeter to measure optical power. Range is 5 nanowatts to 5 milliwatts (−53.0 dBm to +8 dBm) in two ranges. A front-panel overload indicator warns when the optical signal is too large for the selected range.

Optical waveform analysis

Characterization of opto-electronic devices such as laser diodes, light emitting diodes (LEDs), optical waveguides, optical detectors, and electro-optic modulators is becoming more important as applications for fiber optics in telecommunications expand. Measurements such as risetime, aberration, optical power vs drive current/voltage, modulation bandwidth, and sensitivity can now be made accurately and easily at high bandwidth.

In the development and characterization of opto-electronic systems such as fiber optic transmission networks and fiber optic sensor networks, the S-42 with a 7000-Series Oscilloscope offers unmatched bandwidth and optical waveform analysis capabilities.

The S-42 can also be used for process control, quality control, calibration, and troubleshooting in the manufacture of opto-electronic components and systems.

Add software for automated measurements

Several software packages are available for analysis of the acquired signals when used with the Tektronix 7854 Oscilloscope. One package, the 7854 Time and Amplitude Measurement Software (TAMS), is described elsewhere in this issue (see **Automated impedance characterization and control**). This program is available both for the IBM PC and compatibles or for HP Series 200 controllers.

Another useful program is ASYST which works on the IBM PC or compatibles. This package provides device-independent data acquisition commands, direct array manipulation, and direct reading and writing of Lotus 1-2-3 .WK1 and .WKS files. ASYST also includes drivers for many Tektronix scopes and digitizers.

Or you can use Tektronix Signal Processing and Display Software (SPD). This is a signal acquisition, processing, and display tool set with 196 functions designed for the IBM PC and compatibles.

For information

U.S. customers can call the Tektronix National Marketing Center toll free — 1-800-426-2200 — for information, prices, or to place an order for the S-42 as well as any of the software listed above. Or contact your local Tektronix Field Office or sales representative. And be sure to tell them you read about it in **HANDSHAKE**.

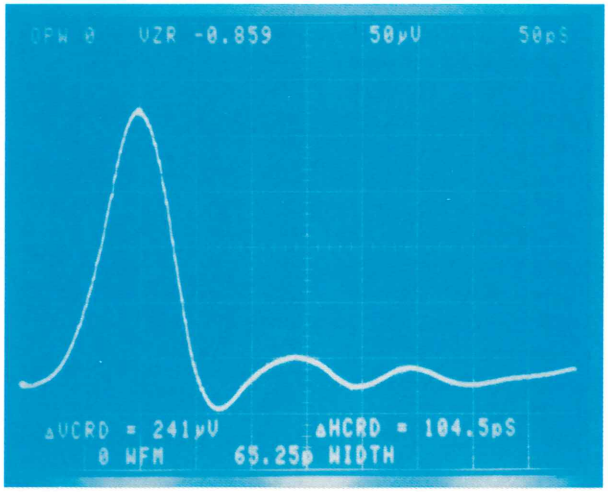


Figure 1. *Pulse response of the S-42 Optical Sampling Head in a Tektronix 7854 Oscilloscope with a 7S11 Sampling Unit. The optical source is a 1300 nanometer, 50 picosecond (FWHM) laser diode; the calculated response of the S-42 is* $((65.25)^2 - (50\text{ ps})^2)^{1/2} = 42$ ps.

Analog oscilloscopes gain new features

While some would tell you that the days of the analog scope are past, Tektronix believes these pioneer tools of the measurement world provide capabilities unavailable using any other measurement method. But today's new analog scopes aren't the same as what you may be using, or they aren't limited by previous restrictions on what an analog scope can do. These new analog scopes sport many features previously available only on the more sophisticated (and usually much more expensive) digital scopes. Features such as automatic one-button measurements, built-in counter/DVM capability, and the superior measurement capability of microchannel plate (MCP) CRT technology make today's analog measurements more convenient and more accurate.

Why analog oscilloscopes?

So why use an analog oscilloscope? The simple fact is that there are many measurements and applications where an analog oscilloscope is the best answer or, in some cases, the only answer.

Digitizing oscilloscopes are attractive because of benefits like digital storage, almost unlimited waveform manipulation capability, hardcopy output, comparison with a reference, digitized waveform output for computer analysis, etc., etc. The drawback, however, is that for equivalent bandwidth and channels, digital oscilloscopes are more expensive than analog scopes.

Digitizing oscilloscopes work best when the signal is fairly predictable. However, when the signal is constantly varying, the display from a digitizing oscilloscope can be almost incomprehensible. Some digitizing oscilloscopes offset this by using a point-accumulate mode which shows the outer limits of signal variations after many, many passes. But it still doesn't show the individual variations within these limits. In order to see and measure these variations, you need a fast analog oscilloscope with a bright, easy-to-read display.

Another general limitation of digitizing oscilloscopes, particularly at higher frequencies, is that the signal must be repetitive. Most digitizing scopes cannot capture single-shot signals with frequency components in excess of about 50 megahertz. Some specialty digitizers can perform up into the gigahertz range, but their price eliminates them from consideration in all but the most important and demanding applications.

For the foreseeable future, there is a need for real-time analog oscilloscopes. At the same time, there are applications where a digitizing oscilloscope may provide the best answer. That's why Tektronix doesn't lock you in to either analog-only or digital-only measurements but gives you a choice — analog or digital as the measurement demands.

The new 2400B Series and 11300A Series are our most recent efforts to make your analog measurements faster, easier, and more accurate. When looked at on a price vs performance basis, these new analog scopes are unmatched.

The 2400B Series

The 2400B Series provides the ultimate performance in portable analog oscilloscope measurements. Bandwidth has been increased to 400 MHz and they now provide automatic measurement of frequency, pulse width, risetime, fall time, time interval A-to-B, and voltage at the push of a button.

The 2400B Series features the ultimate in ease-of-measurement. Just attach up to four probes to the signal points of interest, press a button on the head of one of the probes, and within seconds you have a stable, automatically triggered display. You can still use the front-panel controls to set up specialized measurements such as delayed sweeps or to "fine tune" the display. Then, when you've achieved the desired setup, you can store it in one of 30 non-volatile memory locations for instant recall at the push of a button. Built-in sequencing allows you to step through the stored setups for semi-automatic testing without an external controller.

In addition to these features, the 2467B provides four centimeter/nanosecond visual writing speed so you can view high-speed, low-repetition rate, and even single-shot signals in normal room light without a viewing hood. This display capability is provided through the use of a microchannel plate CRT (see accompanying sidebar for an overview of MCP technology).

The 11300A Series

The 11300A Series oscilloscopes contain more measurement capability than any other analog oscilloscopes. The 11301A and 11302A Counter Timer Oscilloscopes combine high performance scope features with a 750 MHz counter timer for measurement capability to solve the most demanding problems. These two instruments are identical except that the 11302A uses MCP technology (see accompanying MCP sidebar) to achieve maximum writing speed for

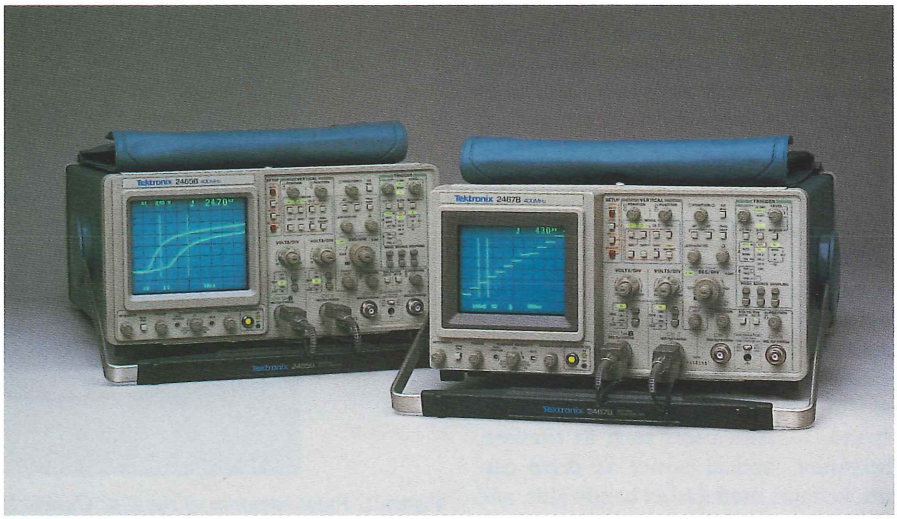


Figure 1. *The 2465B and 2467B Oscilloscopes provide new features for analog measurements.*

viewing single-shot phenomena at the full system bandwidth of 500 MHz. Bandwidth for the 11301A is 400 MHz.

The 11300A Series features plug-in flexibility and expandibility. You can choose from a variety of 11000-Series plug-ins to tailor the measurement system to your measurement need — today or tomorrow. The 11300A Series offers up to eight vertical input channels with an additional six inputs for trigger/counter measurements. The 11000 Series plug-ins provide vertical accuracy, offset capability, and overdrive recovery unmatched in the industry.

An integral counter timer in the 11300A Series provides two nanosecond single-shot resolution, gating capability for the counter and automatic measurements, and counter-view traces to indicate exactly what portions of a waveform are being measured. Sixteen automatic measurements include rise, fall, plus and minus aberrations, and true RMS, with the ability to display up to eight measurements at once. Save/Recall allows non-volatile storage of up to 11 front-panel setups, with sequencing control available at the probe button. Flexible holdoff control features allow locking on pseudo-random pulse trains for examining individual pulses in telecommunications testing. A new video triggering mode is now standard, featuring line and field identification.

Figure 2. *The 11301A and 11302A Oscilloscopes bring advanced analog measurements to the Tektronix 11000 Series.*

For more detail on the Tektronix 11000 Family, refer to the Winter 1986/87 **HANDSHAKE**.

Want to know more?

If your measurements demand the performance provided by today's analog oscilloscopes, contact your local Tektronix Field Office or representative for a demonstration of the 2400B Series or the 11300A Series. U.S. customers can call the Tektronix National Marketing Center toll free for prices or information — 1-800-426-2200. And tell them you read about these new analog scopes in **HANDSHAKE**.

What is a microchannel plate?

Microchannel-plate technology provides one of the major technological breakthroughs in the effort to increase CRT writing rate for the display of single-shot phenomena. A microchannel-plate CRT is quite similar to a conventional CRT. The major difference is the microchannel plate (MCP) located just behind the CRT phosphor screen. Figure A shows the details of an MCP CRT.

The MCP is a 0.050-inch thick glass plate with millions of tiny (approximately 25 micron), closely spaced holes (microchannels). These holes are offset angularly from the beam axis by about 15 degrees and are internally treated to promote the generation of secondary-emission electrons.

When the electron beam scans across the MCP, electrons enter the holes and strike the treated sides. This causes secondary emission within the channel which is amplified by further secondary emission as it moves down the channel. The amplified electron beam exits the channel and travels the short distance to produce a trace on the phosphor screen.

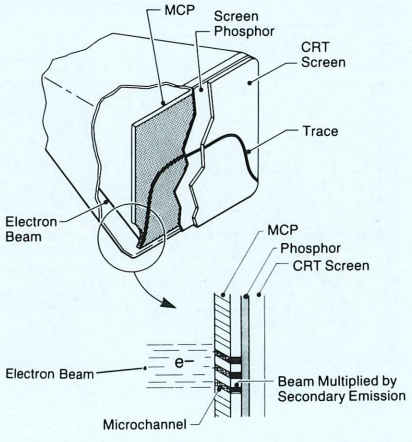


Figure A. *Detail of microchannel-plate CRT showing how electron beam is amplified.*

Because of the channel multiplication of beam electrons, trace brightness is increased, even for extremely fast traces that would otherwise not be visible on the CRT. Individual channels of the MCP saturate in regions of high trace intensity while maintaining full gain for less intense portions. This feature called "adaptive" intensity tends to normalize overall trace intensity between high and low repetition rate signals. Bright traces are limited to a safe viewing level while the intensity of dim traces is increased for good visibility.

The best of both worlds

The Tektronix 2467B, 7104, or 11302A Oscilloscope and the Tektronix DCS01 Digitizing Camera System provide a unique combination of technology for capturing and analyzing waveforms. The microchannel plate (MCP) display provides exceptional trace brightness for any type of waveform. Waveforms can be easily viewed in normal room light — even a single-shot waveform at the fastest sweep rates. Attach the DCS01 Digitizing Camera System and you can digitize the waveform and store it on computer disk or automatically analyze it for a wide range of parameters with the DCS01 software. Thus you can get the best of both worlds: Capture of fast transient waveforms and a digital record for further analysis, processing, or display.

The trace on the oscilloscope screen is captured by a CCD in the DCS01 in real time as it occurs. Then, the stored image is read and converted to digital values. As long as there is a visible trace (which there will be on an MCP), the DCS01 can capture it and convert it to digital values. Vertical resolution is 12 bits, which gives the highest bandwidth/resolution available for single-shot capture of waveforms.

Captured waveforms can be processed in a variety of manners depending on the DCS01 system configuration. A full system configuration allows "raw" video waveforms to be displayed on a video monitor, to be output to a video copier, or to be stored and processed by a Tektronix PEP 301 Systems Controller or other IBM PC compatible computers. Figure B shows a diagram of a full system.

DCS01 software provides menu-driven control of waveform transfer, PC screen graphics, and selection of waveform processing and analysis. Complete pulse parameter analysis is included in the software along with the capability to add subtract, multiply, divide, integrate, differentiate, scale, smooth, and offset waveforms. Information captured with DCS01 software can also be exported to other processing programs such as Tektronix Signal Processing and Display software for more extensive analysis including Fast Fourier Transforms, convolution, and correlation.

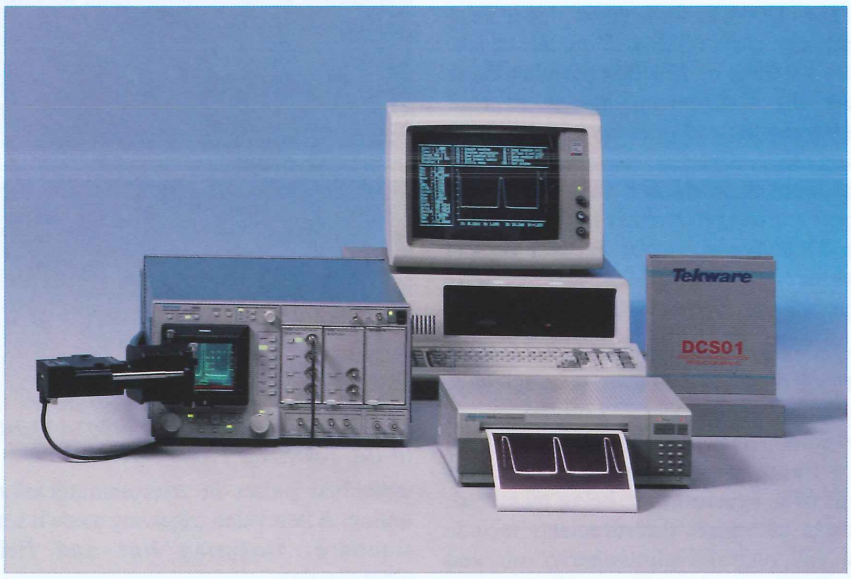


Figure A. *The DCS01 Digitizing Camera System turns an analog oscilloscope into a transient digitizer.*

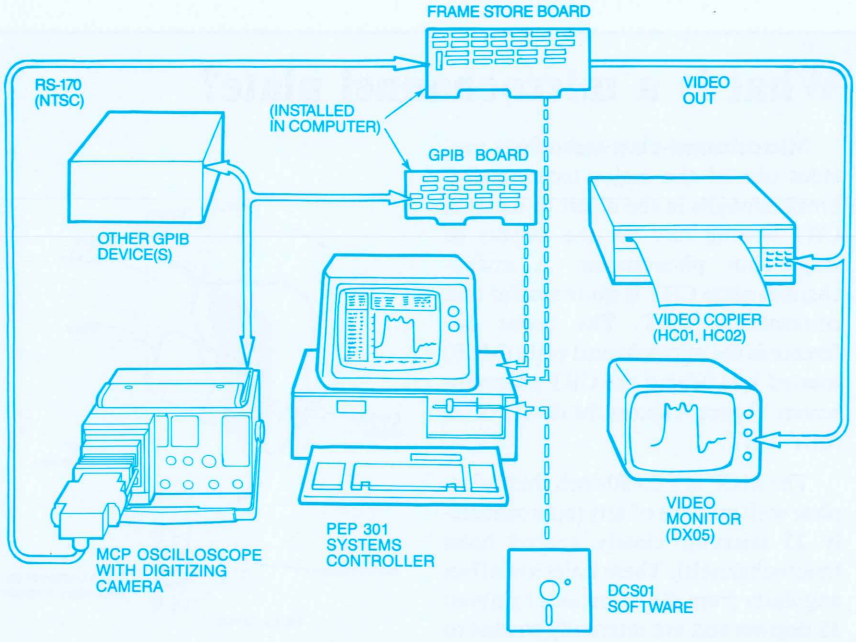


Figure B. *A full DCS01 system configuration provides waveform capture and processing, scope control over the GPIB, and waveform output to a video monitor or video copier.*

Small size, big DSO performance!

What can you do when your measurements demand digital storage oscilloscope (DSO) performance, but space in your service kit is limited? Or how can you safely make DSO measurements when you're on top of a utility pole? Or in a crowded access hatch? Or ...

The new Tektronix T200 Series offers DSO capabilities in a lightweight, handheld format. At the same time, the T200 Series offers features that you would expect only in larger, more costly instruments. Features like auto setup, display cursors, automatic triggering, signal processing, digital readouts, as well as a self-contained DVM/counter.

Operating these DSOs is as simple as their capabilities are advanced. Two choices of operator interface are offered: The T201 uses a calculator-type interface featuring left-to-right logical manipulations. The T202 provides a traditional oscilloscope interface. You can choose the interface that you're most comfortable with, but the measurement performance is the same for both models.

The Tektronix T202 Digital Storage Oscilloscope — DSO capability you can hold in your hand!

Three instruments in one

The T200 offers the capabilities of three test and measurement instruments in one compact unit: A 5 MHz dual-channel oscilloscope (2 MHz single shot) and 20 megasamples/second digital storage with 500 nanosecond resolution; Full-function digital voltmeter; A frequency/period counter. And all this in a package that's only 25.7 x 11.1 x 4.8 centimeters (10.1 x 4.4 x 1.9 inches) and less than 1 kilogram (1.9 pounds)! This makes the T200-Series the ideal addition to any service kit.

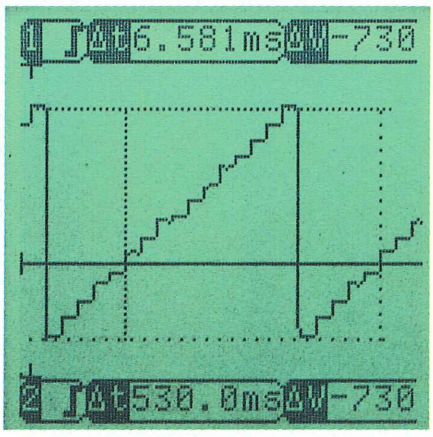


Figure 1. *The data line above the waveform shows that Channel 1 is triggered on the positive slope with a time of 6.581 milliseconds between horizontal cursors and 730 millivolts vertical difference between the Channel 1 and Channel 2 traces (display shown actual size).*

Waveforms and digital information are displayed on a 5.76 x 5.76 centimeter LCD display. The display is bright and clear, even under high ambient light conditions. All of the information about your measurement is shown on this display including deflection factors, triggering information, and the results of signal processing calculations or DVM/counter measurements (see Figures 1 and 2).

The T200-Series can be operated from an AC line or from an external battery pack mounted in the carrying case. Up to five hours of operation is available without recharging.

Want more information?

This is only a brief overview of the T200 Series. For complete information on these little scopes that pack a full-size punch, contact your local Tektronix Field Office or sales representative. U.S. customers can call the Tektronix National Marketing Center toll-free for information, prices, or to place an order — 1-800-426-2200. And tell them **HANDSHAKE** sent you.

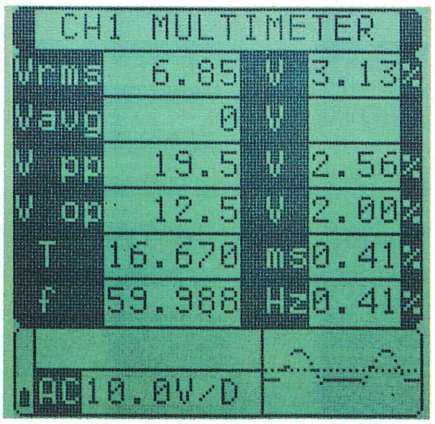
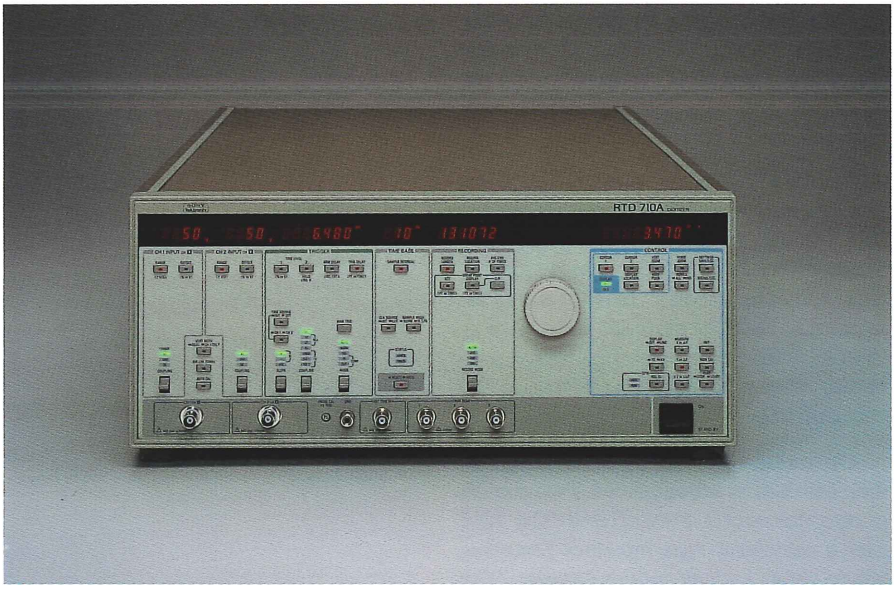


Figure 2. *In the DVM/Counter mode, a table of measured values is displayed. Note the reduced view of the waveform at the bottom of the display area.*

The RTD 710A Waveform Digitizer — new capabilities, new performance, new systems



The RTD 710A Waveform Digitizer combines 200 megasample per second digitizing with 10-bit resolution and 256k record length.

High resolution, accuracy, and speed

The RTD 710A Waveform Digitizer provides 10-bit resolution at sample rates up to 200 Megasamples per second (MS/s). In many applications such as high-voltage impulse testing, ultrasonics, and high-energy physics, the 10-bit resolution provides excellent dynamic range and four times the resolution of an 8-bit digitizer. The high-quality analog system provides accurate step response and rapid overdrive recovery, assuring signal fidelity.

The RTD 710A is an updated version of the RTD 710 Waveform Digitizer originally introduced in the Spring 87 issue of **HANDSHAKE.** Refer to this issue for general features and applications which are applicable to the RTD 710A.

Long memory and flexible recording

The RTD 710A has 256k words of waveform storage memory, providing long time windows with fine timing resolution. Memory may be allocated entirely to one channel or split to provide 128k per channel in dual-channel mode. In applications such as recording lightning strikes, hundreds of shorter records may be used to rapidly capture successive events in the Auto-Advance recording mode.

Direct output of A/D data

Some applications — such as disk and storage media development, video and imaging systems, and communications — demand extremely long record lengths. The direct A/D output feature of the RTD 710A supports virtually infinite record length. Optional memory cache products from Tektronix, the 9503 and 9504 Fast Data Cache (see Figure 1), provide either 4 megawords of additional storage or up to 32 megawords in 2 megaword increments. Other custom solutions are available from Tektronix to provide over a gigabyte of storage.

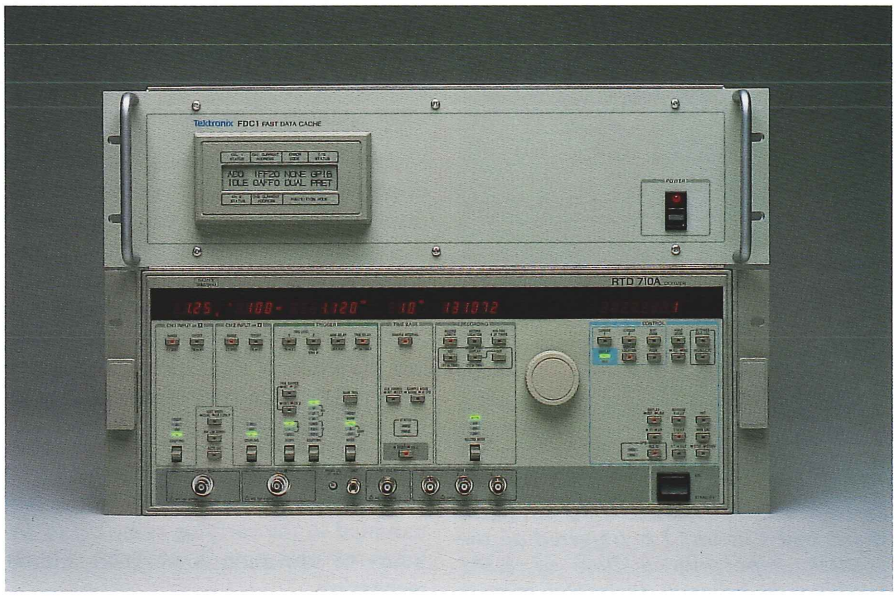


Figure 1. *The 9503 and 9504 Fast Data Cache products extend the record length of the RTD 710A to 4 megawords and 32 megawords respectively. This powerful combination delivers high-quality data in demanding transient applications.*

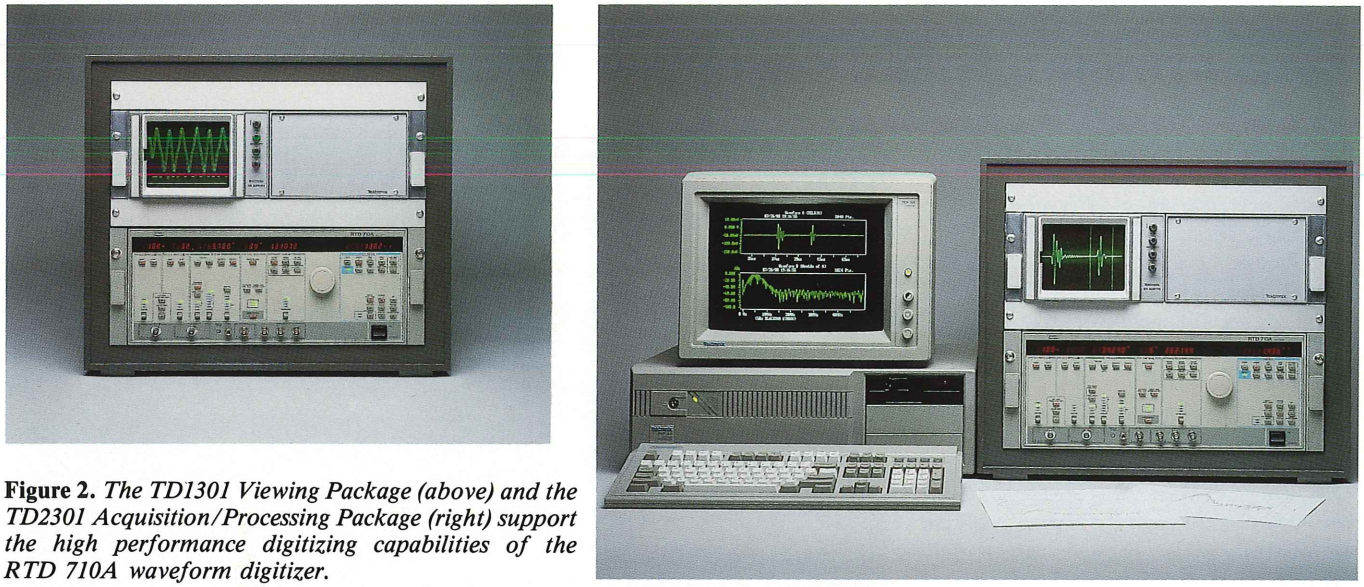


Figure 2. *The TD1301 Viewing Package (above) and the TD2301 Acquisition/Processing Package (right) support the high performance digitizing capabilities of the RTD 710A waveform digitizer.*

Internal or external sample clock

The ability to synchronize sampling with a system under test is very important in applications such as CCD development, radar, and multiplexed systems. The sample clock of the RTD 710A can be driven by an external source such as the shift clock in a CCD system or clocked-in bursts as in radar and particle accelerator applications. This provides efficient, precisely located sampling of the data of interest.

Other key features

On-board hardware signal averaging provides rapid improvement in the signal-to-noise ratio of repetitive events. Flexible triggering modes allow selective, confident capture of the signal of interest. The video trigger option supports line and field triggering and interlaced or non-interlaced scans to 1280 lines.

Interactive manipulation of cursors and waveform data provide local zooming, scrolling, and measurement. Direct output to HPGL-compatible plotters such as the Tek HC100 Color Plotter provides local hardcopy support.

RTD 710A Digitizer Systems

The TD1301 and TD2301 packages provide solutions to many measurement problems in research and development applications. High-performance digitizing coupled with flexible, efficient software and MS-DOS compatibility provide support for today's needs as well as future requirements.

The TD1301 Viewing Package (see Figure 2) supports the high-resolution transient digitizing capabilities of the RTD 710A. It provides an integrated viewing package with digitizer and monitor enclosed in an instrument cabinet.

The TD2301 Acquisition/Processing Package (see Figure 2) includes a Tektronix PEP 301 controller and interactive software. This package provides waveform capture, processing, analysis, display and storage. Instrument settings, measurement environments, and application macros can also be stored and recalled as needed.

The system software provided with the TD2301 contains broad support for waveform analysis and graphic display of results. An interactive mode is provided through a direct menu scheme. As familiarity increases and operations become more repetitive, the keystroke macro feature can be used to reduce many operations to a single menu selection. Collections of macros can be stored and recalled as needed to suit the measurement problems at hand. Each macro is assigned a user-provided description to facilitate selection.

The Tektronix PEP 301 controller provides excellent processing power for waveform analysis and high quality graphics for the TD2301 package. This high-performance MS-DOS compatible platform provides support for data collection and analysis, report generation, database management, and communications with other computing resources.

For details

To get more information on the RTD 710A Waveform Digitizer, Fast Data Cache products, or the TD1301 and TD2301 Digitizing Systems, contact your local Tektronix Field Office or sales representative. U.S. customers can call the Tektronix National Marketing Center toll free for information, prices, or to place an order — 1-800-426-2200. And be sure to tell them you read about it in **HANDSHAKE**.

Automated impedance characterization and control

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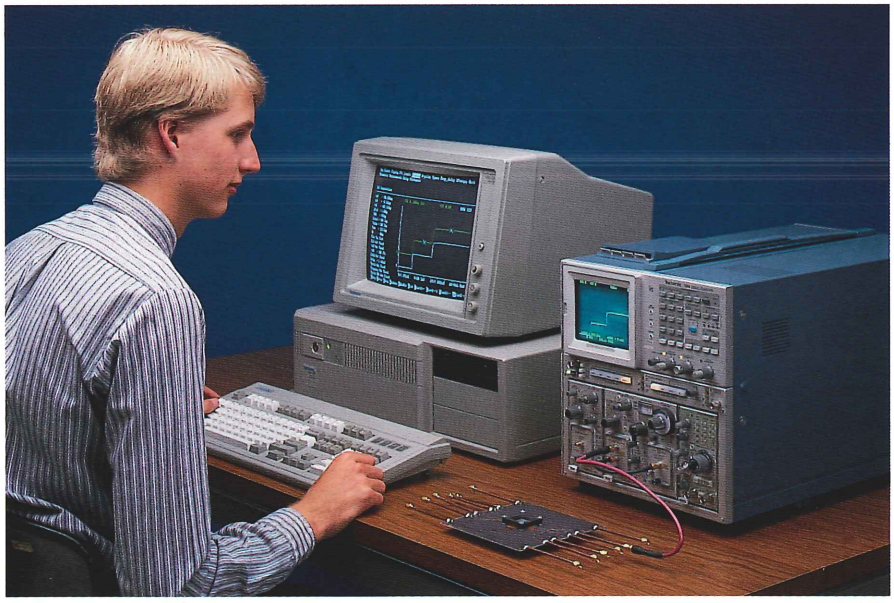
7854 Time and Amplitude Measurement Software (TAMS) extends the usefulness of the 7854 Oscilloscope by adding program editing capability, program storage, data logging, as well as statistical analysis and graphic display through standard PC-based spreadsheets.



Today's high-density, high-speed electronic circuit boards require close process control to insure line impedances are met or matched for proper circuit operation. During circuit board design, runs can be characterized for impedance. Line width and height can be changed to bring impedances within design tolerances. However, variations in manufacturing processes can result in changes which lead to improperly operating circuits. It's necessary not only to verify that a currently manufactured circuit board meets the design tolerances, but also to monitor the board manufacturing process to provide feedback on its stability. This allows an operator to control the manufacturing process instead of merely testing the output for good boards.

Effective process control not only requires the easy and repeatable acquisition of control data but also the maintenance of the database created, its analysis, and presentation of the results in a timely and useful fashion. Stand-alone or programmable measurement instruments have been readily available to make the required measurements. With the introduction of the IBM PC, low cost solutions exist for the creation, analysis and maintenance of a measurement database, as well as presentation of the results. Industry-standard spreadsheet packages or databases such as Lotus 1-2-3, Framework II, etc., provide a beginning level of analysis and report generation capability. Traditionally missing has been software to link the measurement instrument to the database. Users have had to either hand enter the data or write their own data acquisition and analysis routines.

The 7854 Time and Amplitude Measurement Software provides a pre-packaged application solution to these data acquisition and data logging needs. In addition, it provides for expanded waveform analysis and 7854 program development. Combined with the Tektronix PEP301 IBM PC compatible Systems Controller, it makes a fast, cost-effective characterization or process-control station.

The challenge

To illustrate, let's look at a typical application of the software. A circuit board manufacturer needs to verify and monitor the production of high-speed digital logic circuit boards. It's vital to insure that a 50-ohm environment is maintained on each board. Because of the volume involved it's also important to provide timely feedback on how each manufacturing lot of circuit boards varies in impedance value. A low cost and easy to use system is desired. Since the measurement station will also be used for board characterization during prototype development, flexibility is also important.

The measurement

The 7854 Waveform Processing Oscilloscope with a 7S12 TDR/Sampler, S-52 Pulse Generator Head, and S-6 Sampling Head has been a standard for circuit board TDR testing. The 7854 has on-board processing capabilities which can be used to make impedance measurements, distance-to-fault calculations, or automatic compensation for errors. **Making automated TDR measurements** in the Summer 1986 **HANDSHAKE** describes use of the 7854 in TDR applications in more detail.

Test "coupons" (special test tabs) on each circuit board provide an easy and repeatable way to measure impedances and board run lengths. The 7854 internal processing capabilities are used to compute the impedance of the measured circuit board run. Dual cursors are used and can either be positioned by the operator or pre-positioned using the 7854 programming capabilities. Cursor 1 is placed at the 50-ohm reference and cursor 2 is placed out to the end point of the measurement. (Figure 1 shows the cursors on an "open" ended TDR, before the cursor positions are set correctly.)

The program shown in Figure 2 was entered off-line using the TAMS software and saved to disk. Comments were added to improve readability of the program. The

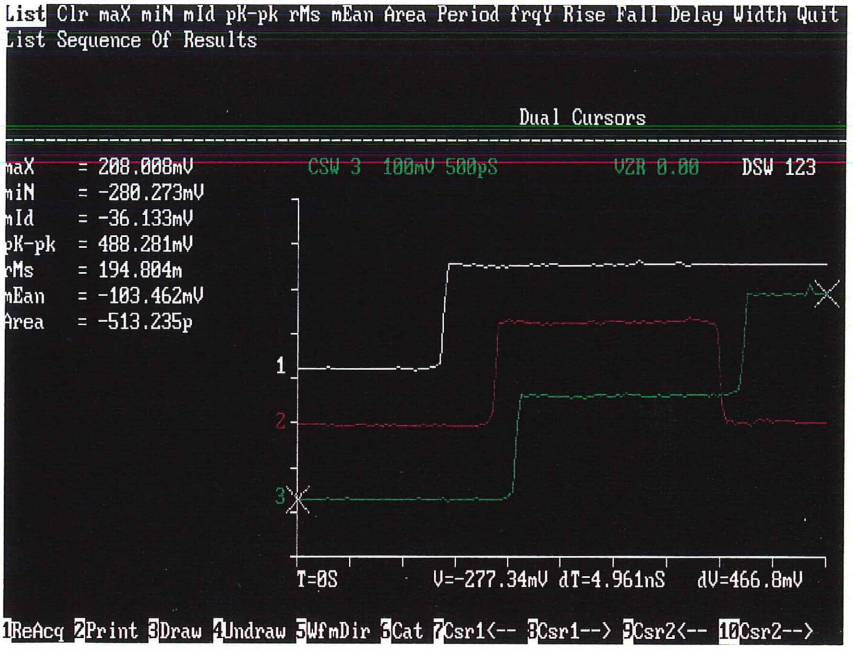


Figure 1. *Example TDR waveforms. Top waveform, matched impedance; Center waveform, short; Bottom waveform, open. Shown from Manual Pulse Parameters menu of 7854 TAMS.*

comments are automatically stripped off when the program is downloaded to the 7854, but appear in listings and screen editing. Off-line editing and program storage allows for easy access to programs for future board measurements.

The "SENDX" command in the program instructs the 7854 to send the contents of the 7854 X register to the controller. With data logging enabled in the 7854 TAMS software, this data value (the computed impedance) is automatically logged to a disk file. The logged data appears as ASCII text in the data file and can be imported into spreadsheet packages such as Lotus 1-2-3 or Framework II. In this example Framework II was used because of its integrated spreadsheet, database, and word processor.

The analysis

A spreadsheet was created and the data imported into it. Each column was set up to contain test data from one lot of circuit boards — in this case, each lot consists of ten circuit boards with one impedance measurement per board. Then, this raw data is processed to calculate the minimum, maximum, mean and standard deviation. Built-in spreadsheet functions make computation of statistical functions very fast and easy.

```
L00                    ; Label 0 — Start of program
0 ENTER 6 >CNS         ; Put 0 into constant register 6
L02                    ; Label 2 — Beginning of loop
AQR                    ; Acquire 64 waveforms and average
64 AVG
STORED                 ; Display the stored waveform
CRS2-1                 ; Turn on cursors 1 and 2
STOP                   ; Halt program to allow placement of cursors
1 ENTER VCRD +         ; Compute the formula: (1 + x )/(1 − x) where x is the
1 ENTER VCRD − /       ;  vertical cursor difference
50 *                   ; Multiply by the reference impedance (50 ohms)
SENDX                  ; Send the result to 7854TAMS
6 CNS 1 + 6 >CNS       ; Increment the constant register and repeat loop
6 CNS 10 IF X=Y STOP   ;  10 times
2 LBL GOTO
STOP
```

Figure 2. *7854 program to compute and log impedance values.*

The presentation

Using the integrated word processing and graphing functions, the final report shown in Figure 3 was generated. The graph is particularly useful for visibly monitoring trends. The mean value gives an indication of long term trends. If the mean value of the impedance slowly drifts out of set specifications over time, it could mean trouble. Although the standard deviation reflects both long and short term changes, it's used more to predict trends occurring in the near future. By using spreadsheet macros (command strings), it becomes quick and easy to process new test data and generate updated reports.

Conclusion

In today's competitive environment, a key advantage is the ability to measure and control manufacturing processes. Tektronix 7854 oscilloscopes provide outstanding measurement capabilities. Tektronix application software and IBM PC compatible controllers provide an unsurpassed level of systems integration and performance.

Want information?

For a demo disk showing the capabilities of 7854 TAMS on your IBM PC computer or compatible, check the appropriate box on the reply card. For more information or to order 7854 Test and Measurement Software, contact your local Tektronix Field office or sales representative and ask for S42P202. U.S. customers can call the Tektronix National Marketing Center toll free for information or to order — 1-800-426-2200.

A similar software package is available for the HP Series 200 controllers. Ask for information on S42H202 or check the box on the reply card.

ABC Manufacturing
Process Control Department

Subj: Weekly production report
August 1,1988

A series of four lots of impedance data were gathered in order to study this week's manufacturing performance. Each lot consists of ten measurements, with statistical information listed below.

	Data One	Data Two	Data Three	Data Four
	50	51.30	48.96	50.49
	50.34	48.93	50.38	48.32
	51.29	50.67	52.04	49.63
	49.97	51.29	51.70	46.11
	50.03	51	50.82	51.20
	49.24	49.84	51.27	50.75
	50.92	48.21	49.71	51.38
	50.18	50.25	51.35	50.52
	49.53	49.31	50.99	50.79
	51.01	51.57	51.57	51.07
min	49.24	48.21	48.96	46.11
max	51.29	51.57	52.04	51.38
mean	50.25	50.24	50.88	50.03
st. dev	.65	1.14	.95	1.64

The above data is then plotted in the standard Process Control analysis form. Notice that the mean does stay within the necessary limits, 48-52 Ohms. Although the standard deviation may indicate possible problems in the future, manufacturing output continues to be optimal.

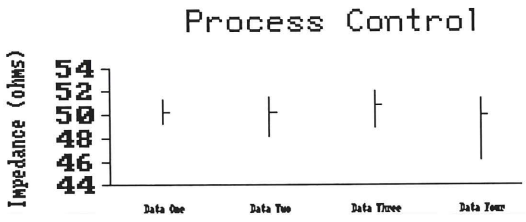


Figure 3. *Example report generated using Framework II based on data from 7854 TAMS.*

What is 7854 TAMS?

TAMS is an acronym for Time and Amplitude Measurement Software. Originally designed for the Tektronix 7D20 Digitizer, it has now been completely reorganized and upgraded to work with the Tektronix 7854 Waveform Processing Oscilloscope. The most appealing quality of this software is its ability to link the 7854 to the Tektronix PEP301 Systems Controller (or IBM PC compatible computers).

7854 TAMS provides the following benefits for 7854 users:

- **Increased capability:** Provides color displays with EGA graphics support; storage/retrieval of waveforms to/from disk via controller; quick FFT computation and display from built-in waveform parameter routines
- **Increased flexibility:** Requires no additional equipment except controller; uses current 7854 program library routines; logs data to disk via controller; exports data to spreadsheets for statistical and graphical analysis
- **Simplified operation:** Uses familiar Lotus 1-2-3 user interface for fast and easy learning; displays data immediately on-screen from acquired waveforms or computed FFT; calculates pulse parameters with a single key stroke
- **Increased efficiency:** Write or update programs easily with built-in program editor; store/recall programs on disk for later use which eliminates re-keying

The waveform processing capabilities of 7854 TAMS are modeled after those of the 7854 oscilloscope itself. Thus, data acquired with the 7854 can be reprocessed at a later time without any loss of accuracy or need for the original instrument or test setup.

TAMS can display up to six waveforms on the computer screen at once, using either CGA or EGA. (With EGA, each trace is assigned a different color.) Each waveform can also be given a 40-character description when saved to disk. Then, the waveform itself can be down-loaded or up-loaded to or from the 7854, computer, or disk.

With the 7854 TAMS program editor, writing programs becomes quick and simple. Quick, because the editor module can be run either as a stand-alone unit or as an option inside of TAMS. Simple, due to the "assisted syntax" method of entry where only enough letters need to be typed to distinguish the keyword from any other keywords. Like waveforms, programs can be easily transferred between disk, computer, and oscilloscope. At last, 7854 programs don't have to be completely re-entered when the power fails or the 7854 is shut off!

Besides program and waveform storage, TAMS has another way to permanently record important information to disk. The data logging capability provides for two methods of storing information in a less structured format. The first option simply opens a file and logs the appropriate on-screen facts with a single keystroke. Each data record can then be labeled to make later referral clear and easy. (See example in Figure A. Note the time and date stamps in the file.)

Another way to log results is by placing a "SENDX" command in any 7854 program. Once TAMS initiates the program, the data produced by the program will be sent to the computer and stored in a disk file. Since all logfiles are stored in ASCII format, it's very easy to import the data into a spreadsheet program, such as Lotus 1-2-3 or Framework II, and then analyze it statistically and/or graphically (see accompanying article).

7854 TAMS also includes a full set of pulse parameter routines. Each variable is computed using histogram analysis between the limits determined by the cursors. Furthermore, automatic propagation delay, FFT, and screen dumps to the printer are available with the stroke of a key. Figure B shows an example of a propagation delay measurement.

With all these features, 7854 TAMS is the best choice for integrating the 7854 Programmable Oscilloscope with the PEP301 Systems Controller (or other IBM PC compatible controller).

```
Thu Jul 28 14:46:17 1988
-----FFT CURSOR VALUES-----
CSW: CSW 3 100mV 500pS     VZR 0.00
FFT: 0 dB at 203.2MHz (175.2mV peak)
----------end log record 1
-----WAVEFORM CURSORS-----
CSW: CSW 1 100mV 500pS     VZR 0.00
CUR: T=0S V=18.55mV dT=4.961nS dV=238.28mV
----------end log record 2
-----SELECTED PULSE MEASUREMENTS-----
mEan = 189.353mV
rMs = 216.234m
pK-pk = 247.07mV
miN = 14.648mV
maX = 261.719mV
----------end log record 3
-----PROP DELAY DATA-----
             Wfm-1       Wfm-2
Wfm#         1           2
Level        50%         50%
Slope        +           +
T            1.36nS      1.85nS
V            138.18mV    10.74mV
dT           4.961nS     4.961nS
dV           238.28mV    5.86mV
Prop Delay = 494.514pS
----------end log record 4
-----end of log file
Thu Jul 28 14:53:00 1988
```

Figure A. *Example contents of an on-screen facts logged data file.*

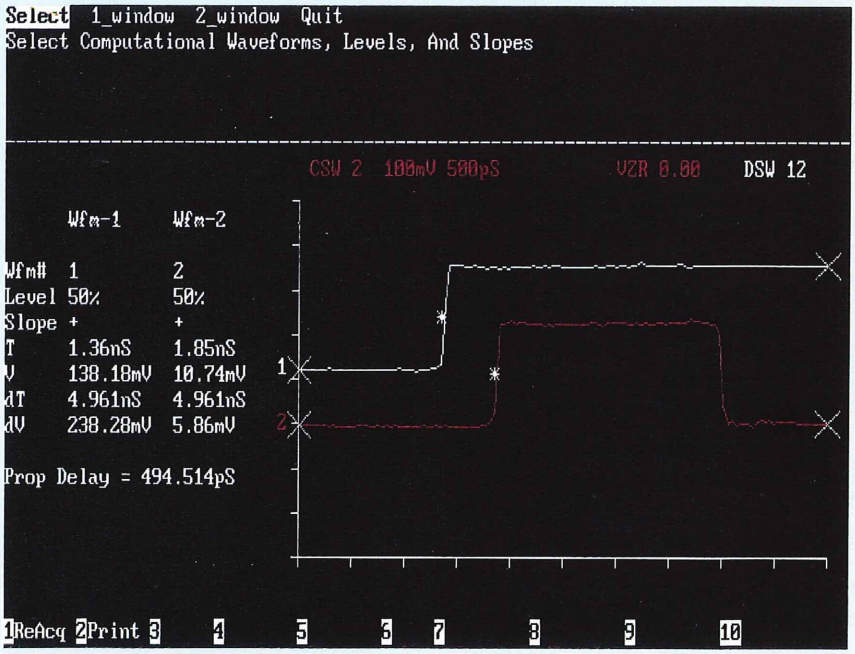
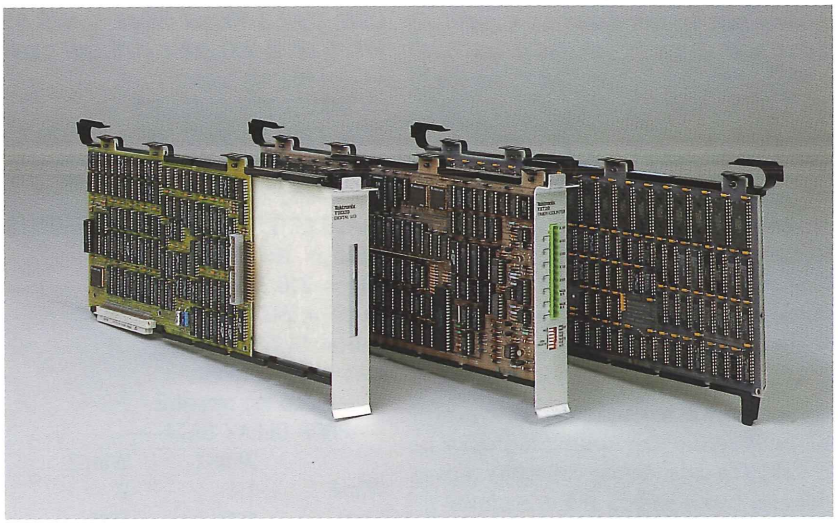


Figure B. *Example of propagation delay measurement using 7854 TAMS.*

Card-modular test systems — the TSI family evolves

Sid Blachford
TSI 8150 Product Marketing Manager
Measurement Systems Division
Tektronix, Inc.



Three new cards extend the capabilities of the TSI 8150 Test System Interface. Left, TSD20 Digital I/O Assembly; Center, TST20 Timer/Counter Assembly; Right, TSM20 Memory Assembly.

Today's test equipment users and manufacturers face an ever-growing need for flexibility and compactness. Just-In-Time (JIT) manufacturing, increasingly complex circuit boards, use of surface-mount technology (SMT), and competitive cost pressures are but a few of the factors fueling this demand. Recent adoption of the VXI Bus modular instrument standard by several leading test equipment manufacturers, including Tektronix, is an indication of a strong industry trend towards "instrument-on-a-card" modularity.

Test equipment users can take advantage of this instrumentation approach now. A little over two years ago, the TSI 8150 Test System Interface was introduced as the "missing link in ATE" (see the Summer 1986 **HANDSHAKE**). The TSI family of products offers a complete solution to test system switching, interfacing, and DUT fixturing needs. Now, the TSI product line is being expanded to include many of the instruments needed for complete, low-cost systems.

Currently being introduced are a 2 MHz, dual 16-bit digital I/O assembly (TSD20); a 2 MHz, 256k x 16-bit static memory assembly (TSM20); and a timer/counter assembly which has five timing generators and universal counter capabilities (TST20).

These new instrumentation assemblies plug directly into the TSI 8150 main interconnect board. As with other TSI components, all power and control is taken from the mainframe. It's important to note that these new instrumentation assemblies work only in the TSI mainframe, **not** in the TSX 8140 Expansion Chassis. Also, TSI 8150 firmware version 3.0 or later is required for operation. (An upgrade kit is available; contact your local Tektronix Service Center for details.)

Unlike the TSI 8150 switching cards and modules, relay drivers, and the TSD42 Digital Interface, these assemblies do not require a TSS40 Scanner Control Assembly. Note that these instruments are referred to here as "assemblies," not "cards" or "modules." Another clue that these are complete instrument assemblies is in the nomenclature. Cards and modules that require a TSS40 Scanner Control Assembly all carry a 4X-series nomenclature, while instrument assemblies have a 2X-series designation.

TSD20 Digital I/O Assembly

The TSD20 Digital I/O Assembly provides an interface between the device-under-test (DUT) and TSI 8150 components. Through the TSI 8150, this interface is extended to the rest of the test system. The TSD20 also provides static and dynamic magnitude comparison functions. TTL logic levels are used throughout.

The TSD20 is useful in applications such as:

- Providing a digital stimulus to the DUT
- Sending digital data over a high-speed data link to a computer (using a "personality" module)
- Low-speed logic analyzer with pattern generation, comparing digital data coming from the DUT (at speeds up to 2 MHz)
- Comparing digital data with long record lengths (in conjunction with the TSM20 Memory Assembly)

The TSD20 acts as an input or output to the GPIB through the TSI 8150 local controller data bus (LC DATA in Figure 1). In addition, the local controller data bus provides access to other cards, modules, and instruments being controlled by the TSI 8150. The TSD20 also has access to the TSI 8150 high-speed bus (HSBUS), which provides further interface to TSI components (such as the TSM20 memory assembly).

The assembly has two ports, designated Port A and Port B. Each port provides 16 data input/output lines, plus two handshake lines, control signals, and power. Having separate handshake lines lets the two ports be individually set to input or output data. Data transfers can be asynchronous using the handshake lines, synchronous being clocked with the trigger bus, or through GPIB commands.

Data transmission rate is 2 MHz maximum for 16 bits, using both TSI 8150 internal HSBUS channels. 1 MHz is the max-

imum rate for 32 bits, or whenever using one HSBUS channel.

The TSD20 can perform magnitude comparisons in which input or output values on Port A are compared to a reference value. The compare functions available can then generate a trigger to the internal trigger bus, or an SRQ to the GPIB, when a compare condition is met. This feature can be used to place the TSI 8150 into a "stop" state in which TSI operation is suspended. A typical application would be performing a long pattern match. The incoming data would pace the system using the handshake lines on Port A. If a mismatch occurs, the comparator would generate a STOP REQUEST, which would inhibit the pattern advancement, and generate a SRQ to allow the system controller to interrogate where the mismatch occurred.

One or two compare values can be used. Two compare values can create a window in which a Port A value is compared against upper and lower limits. Single-value compare functions are: $>$, $<$, $=$, $\leq$, $\geq$, and $< >$ (not equal). Two-value compare functions are $< / >$ (out of window, exclusive) and $\leq / \geq$ (out of window, inclusive). Any of the 16 input bits can be masked as "don't care."

Compare values can be static, constants that do not change over time, or they can be dynamic, changing with each Port A value. Four comparison modes are thus possible: Static with single limit, static with two limits, dynamic with single limit, and dynamic with two limits. For dynamic comparisons, the compare values are loaded from a TSM20 Memory Assembly over the HSBUS. When dynamic comparison is being used, only Port A is available.

The TSD20 has a provision for accepting signal conditioning cards. User-developed specialty interfaces, or "personality" modules, slide into a carrier plate, similar to the way scanner and relay driver cards slide into a TSS40. To assist the user in implementing these, the TSD20 includes an interface card which incorporates a prototype area for mounting custom circuitry, and connectors which mate to the TSD20.

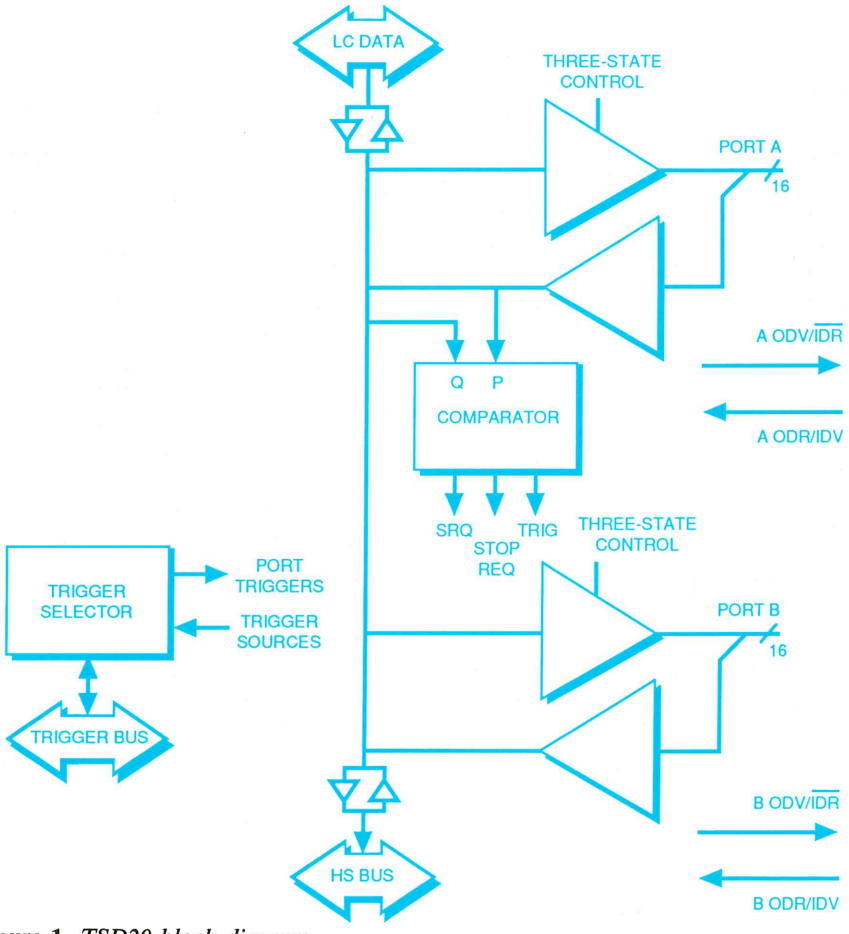


Figure 1. *TSD20 block diagram.*

TSM20 Memory Assembly

The TSM20 Memory Assembly provides additional memory for TSI 8150 components and other system components requiring additional memory. It is designed to operate over the TSI 8150 internal high-speed bus. Read/write access can also be gained over the GPIB via the TSI 8150 local controller data bus. The primary intended use of the TSM20, however, is as additional memory for other TSI 8150 components, such as the TSD20 Digital I/O Assembly.

Each TSM20 has 256k 16-bit words of 2 MHz static memory. Up to 120 files can be defined in the directory for each memory card, as long as the total space used by all the defined files does not exceed the 256k words available.

The TSM20 allows two files to be open at the same time, each running at 1 MHz. (In order to run at 2 MHz, only one file can be open.) The two files are referred to as the ODD channel file and the EVEN channel file. These files can be made cyclic (to operate as circular buffers).

If more than 256k words are needed, up to four additional memory assemblies can be inserted into the same TSI 8150 main interconnect board and chained. All memory in the same main interconnect board appears to be resident in the same slot. This allows the two possible open files to run independently across card boundaries and to be cyclic. Firmware keeps track of the addressing, freeing the user from keeping track of multiple directories.

TST20 Timer/Counter Assembly

The TST20 Timer/Counter provides programmable timing generators to give the TSI 8150 more timing channels and enhanced timing resolution. A totalizer provides up/down counting of events that occur internal or external to the unit. The TST20 can also measure time parameters of internal and external signals, and elapsed time from one event to another. Figure 2 shows a functional block diagram of the assembly.

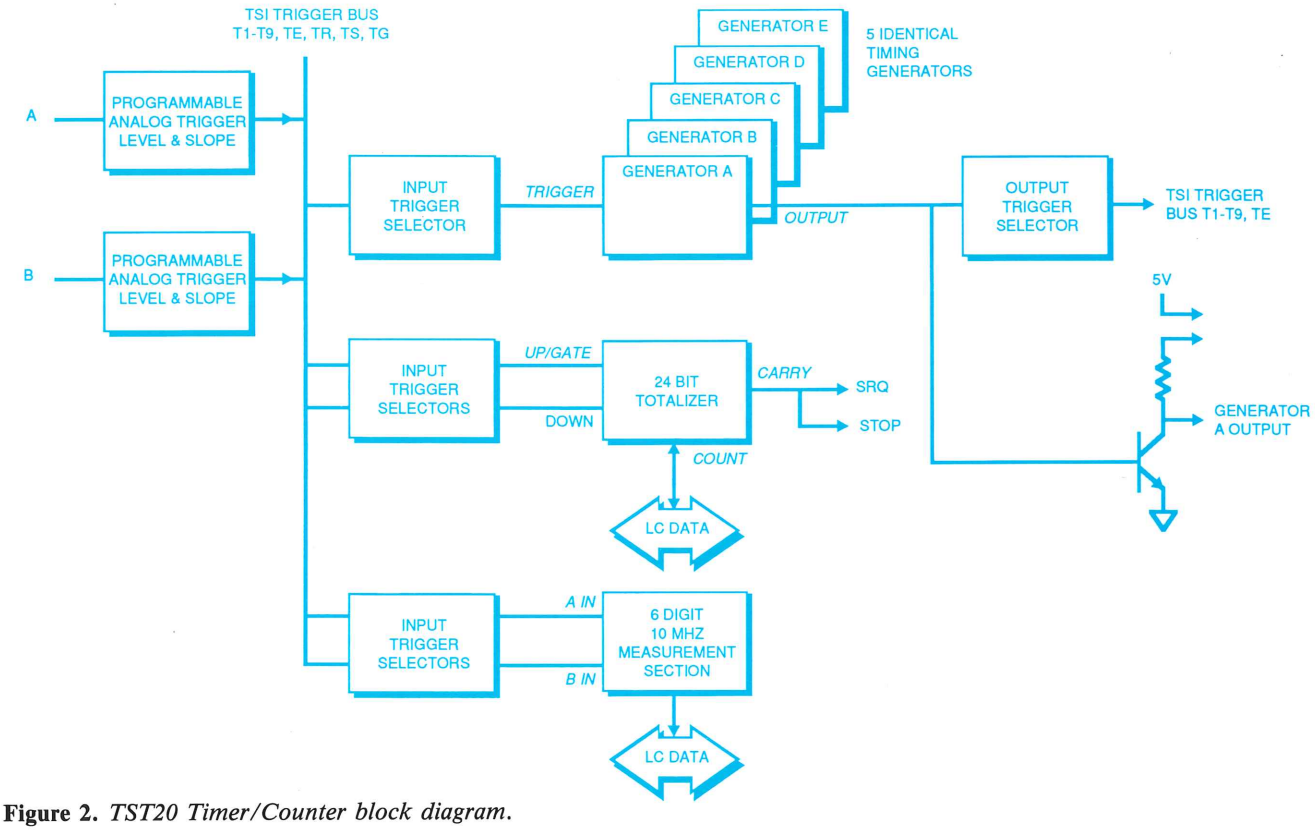


Figure 2. *TST20 Timer/Counter block diagram.*

The TST20 will prove useful in applications such as:

- Providing precise timing pulses for triggering other instruments in the TSI 8150
- Providing timing generation and universal timer/counter measurements in functional board test

The five independent, identical timing generators provide pacing clocks or delay timing for use within the TSI 8150 or elsewhere in the test system. Each generator allows programmable period (four ranges, 0.5 microsecond to 6.553 seconds), pulse width and delay (four ranges, 0.3 microsecond to 6.553 seconds), and burst count (1 to 65536, or continuous). Timing resolution for the four period, width, and delay ranges is automatically selected from 100 nanoseconds on the lowest range to 100 microseconds on the highest range. Time base accuracy is ±0.01%. Trigger source and destination for the timing generators are programmable. Trigger source can be selected from ten general-purpose internal trigger lines, two dedicated internal trigger lines, two analog trigger inputs, or an immediate-mode GPIB command. Threshold level and slope of the analog inputs are also programmable. Each of the analog inputs can be terminated into 1 megohm or 50 ohms via a front-panel switch. The output from each generator can be assigned to any one of the ten general-purpose trigger lines, as well as to front-panel output connectors for use elsewhere in the system. The front-panel switches allow individual outputs to be connected to 5 volt pull-up resistors for direct TTL compatibility.

The totalizer is a dedicated 24-bit count chain with a range of 0 to 16,777,215. Separate inputs for up and down counting are program-selectable. The up input can also be programmed to be a gate. In this mode, down inputs are ignored until the first gate trigger. A powerful application for this is freezing a data pattern after a breakpoint trigger occurs. Commands allow presetting or clearing the counter at any time. An SRQ can be generated over the GPIB (command-maskable) on detection of counter overflow or underflow.

Available sources for totalizer inputs are the same as the timing generator trigger sources. Minimum pulse width is 50 nanoseconds. Maximum input frequency is 2 MHz.

The TST20 can make time measurements for Period, Frequency, Frequency Ratio, Pulse Width, and Time Between Events, at frequencies to 10 MHz. The function and input source are program-selectable, with the same sources available as for the timing generator trigger sources. The measurement slope (for Width and Time Between Events) is also programmable. The six-digit output of the measurement section is available over the TSI 8150 local controller's data bus.

Accuracy for analog input measurements is ±100 nanoseconds; accuracy for trigger bus measurements is ± 100 nanoseconds (+600 nanoseconds for each rising edge). Measurement range is 100 nanoseconds to 4.194 seconds with 100 nanosecond resolution. Minimum trigger pulse width is 100 nanoseconds.

For more information

For more information on any of these new assemblies for the TSI 8150 Test System Interface, contact your local Tektronix Field Office or representative. U.S. customers can call toll free for information, prices, or to place an order — 1-800-426-2200.

Automated manufacturing test systems for resource-limited companies

Greg Hoag
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This article describes the design and assembly of an actual functional test system combining analog and digital technology to solve a real manufacturing test problem. This system was developed through a team effort between the customer and Tektronix. Then, it was built by Tektronix to the customer's final specifications.

Throughout this discussion, we will show how Tek's unique services can be used to create a more satisfactory solution to automated test problems. The customer for the system described in this article is a project engineer for a major company in the electronic audio and video equipment industry. Since she wishes to remain anonymous, we will refer to her as Mary in this article.

Recognizing the need, searching for the solution

Mary needed to develop a test methodology for a new production video tape player. The circuit boards in the product contained digital, analog, and hybrid circuitry (hybrid as used here means A/D and D/A conversion circuitry). The digital circuitry ran at clock rates of up to 50 MHz; to test it adequately would, at times, require clocking up to 72 bits simultaneously. The analog circuitry ran at frequencies as high as 50 MHz.

Mary's analysis indicated that for her volume, automation would yield a considerable cost savings. Although the company is a major player in the industry, this particular division is of moderate size and cannot afford to maintain a staff of test engineers large enough to design and integrate test systems to meet the constant flow of new products. The test department is also not large enough to provide in-depth expertise in all of the areas necessary to build these systems. She felt they had adequate software expertise, but needed additional support in instrument measurement capabilities, fixturing techniques, electronic interfacing, and mechanical adaptation.

In the search for solutions to her test requirements, Mary looked at the "full-up" test systems from Teradyne as well as several vendors of rack-and-stack IEEE 488 (GPIB) compatible instruments, including Tektronix, Hewlett-Packard (HP), and Fluke. The Teradyne solution was quickly rejected since the initial cost of the system was so great that it could not be offset by the labor and other savings over manual test. Also, programming with the simulation software was expected to take a year or more — more than twice as long as that expected for programming a GPIB-based system. Another drawback was that the standard Teradyne fixturing did not have the bandwidth required for this application.

Of the remaining vendors, Tektronix was chosen over HP and Fluke because of superior instrumentation capabilities and because of superior design and integration support. Mary felt that the most critical test capability in the system was the digital

Figure 1. *This combined analog and digital functional test system has 352 digital channels capable of 50-MHz clocking.*

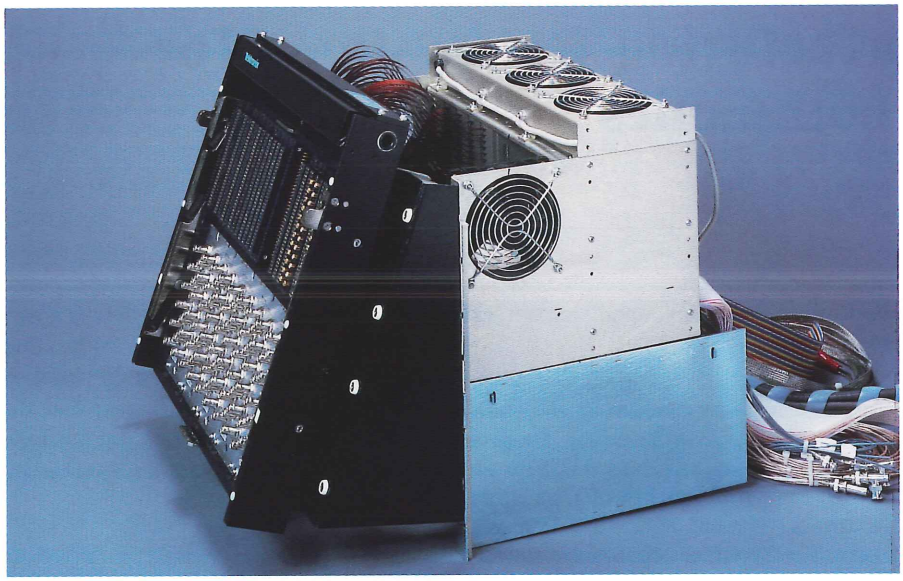


Figure 2. *The custom adapted 92BTARM positions digital probes and analog switches directly behind the quick change test fixture.*

analysis portion. Only the Tektronix DAS 9200 Digital Analysis Subsystem was capable of providing 50 MHz stimulus and acquisition at up to 72-bit words required to test the device at maximum speed. Overall, the system needed 270 digital-acquisition and 72 pattern-generation channels.

Also, Tektronix had the best method of getting these high-speed signals to and from the device-under-test (DUT). The 92BTARM, a quick-change test head adapter, allows the mounting of active digital probes and analog switch cards directly behind the test head. This arrangement allows the shortest possible cable length (thus, highest signal quality) between the instrumentation and the DUT.

A further factor was design and integration support. This included: Technical information on instrument features and test techniques provided by the Tektronix Sales Engineer, designing and building the system hardware, providing guidance in functional test fixturing techniques, and providing system documentation and service. By the time Mary made her decision to go with Tek, she felt that Tek was joining her team — that Tek was an extension of her resources.

The system Tektronix configured for Mary consists of a DAS9229 Digital Analysis Subsystem with a DAS92E9 Expansion mainframe, a 2432 300 MHz

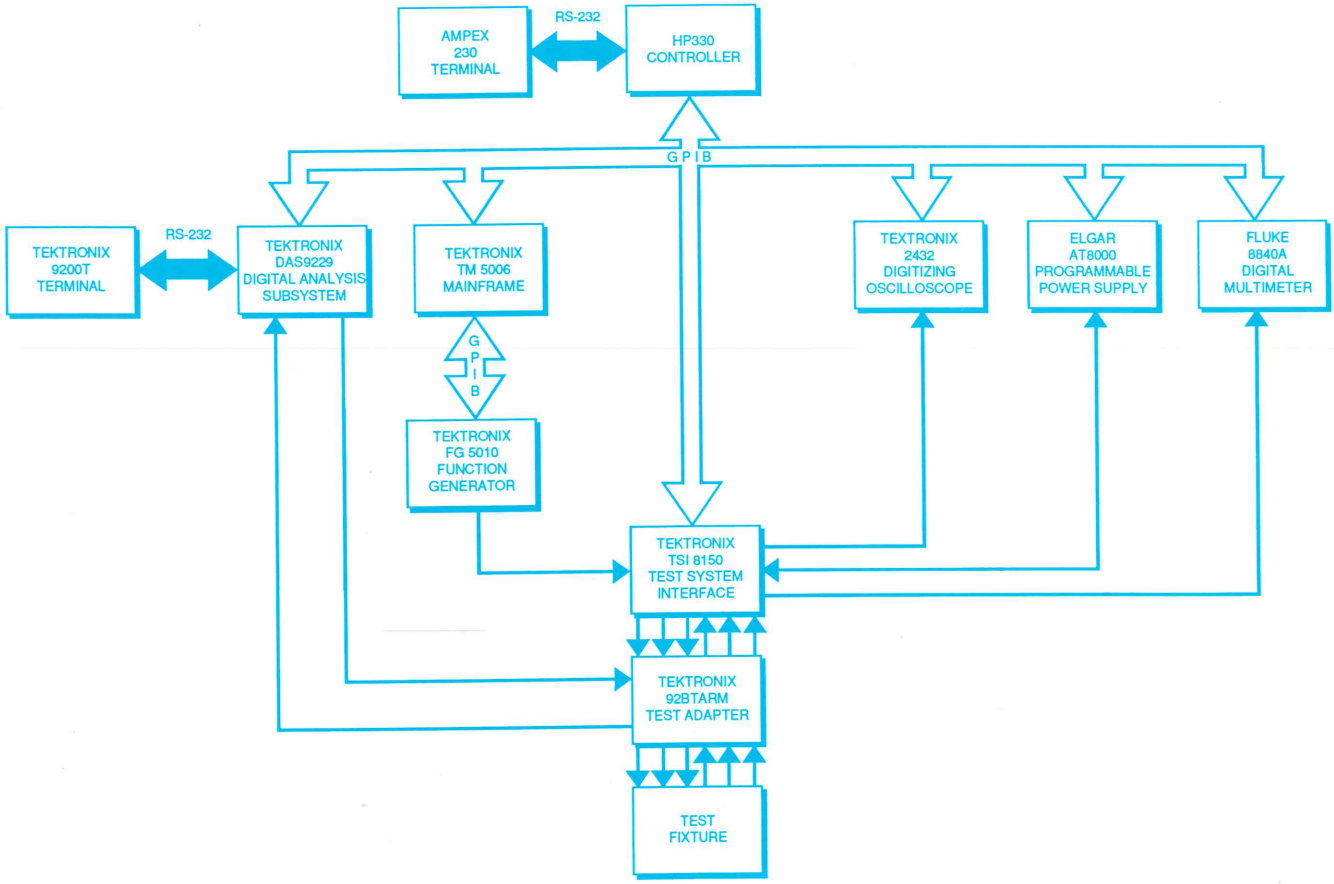


Figure 3. *Block diagram of combined analog and digital functional test system.*

Digitizing Oscilloscope, an FG 5010 Programmable Function Generator, a Fluke 8040A Digital Multimeter, and an Elgar AT8000 Programmable Power Supply system (see Figure 1). This equipment is all controlled over the GPIB by an HP 330 computer using an Ampex 230 terminal. Fixturing and switching is performed via the 92BTARM Board Test Adapter and the TSI 8150 Test System Interface switching subsystem. Key features of the Tektronix integration service that were useful for this situation are summarized below.

The right equipment for the job

The Tek System Designer identified not only the most appropriate Tek equipment for the system, but also identified the Fluke 8840A Digital Multimeter as the best multimeter for this particular application. He also selected the Elgar AT8000 Programmable Power Supply subsystem to supply power to the DUT. Tektronix System Designers, realizing that it is not possible for one company to make all of the equipment to fit every application, commonly specify instrumentation from other vendors for their systems.

Expertise in functional fixturing

Mary's test system needed to test a variety of different boards, each with its own fixture. For this reason Mary maintained control of the fixture design and manufacture. However, Tektronix was able to help here in several ways. First, the Tektronix Test Head Receiver is capable of mounting Virginia Panel interface modules. By bringing all of the signals needed to test the full variety of circuit boards into modules mounted on the system side of the interface, Mary could have fixtures built with mating modules on the test head side of the interface. Individual test heads only need to include the modules necessary to supply the signals required by that test head. This allows the vacuum test heads to be changed by simply lifting a lever, pulling out the vacuum adapter, and swapping test heads.

The second area of assistance was in providing guidance and expertise in functional test fixturing. High-frequency functional board testing which combines analog and digital technologies is still in its infancy. As a result, expertise in integrating these systems is not wide-spread. Tektronix, with its expertise in functional test equipment and wide-bandwidth probing, was able to apply this knowledge to assist Mary with fixture design. Finally, when Mary was ready to have the first fixture built, Tektronix was able to identify a reliable fixture manufacturer with the capability to match her requirements.

Customizing the custom system

Building a custom system does not stop with wiring together programmable instruments. Most customers, if they go to the trouble of designing a custom solution to a problem, prefer not to stop at gluing together off-the-shelf pieces. This was also the case with Mary's system. She desired two simple features. But seemingly simple non-standard features are often not easy to buy. She needed to mount the Ampex 230 terminal in a way that it could be used at the test station. For this, Tek built an adaptor to mount the terminal in the test rack. The keyboard can be set in front of the terminal on a shelf that extends in front of the rack. Also, the test fixture needed to be mounted at an angle so circuit boards would not fall off when the vacuum was not engaged. Tek built a custom bracket to mount the complete Board Test Adapter at the desired angle.

What about software?

For this system, Mary wanted her own test engineers to write the software. Since they chose a computer other than a Tektronix PEP 301 Systems Controller or other MS-DOS compatible controller, she had to choose a programming language supported by the vendor — in this case Hewlett Packard.

For customers using the PEP 301 or other MS-DOS compatible controllers, Tek offers GURU II — a set of GPIB utility programs containing instrument drivers which allow easy configuration of the bus. Tek also offers Microsoft QuickBASIC and QuickC support.

For customers desiring programming cost savings, Tek offers EZ-TEST PC — a test program generation system that allows development of complete test programs from instrument front-panel settings and menu selections with a minimum of programming knowledge or experience. Test programs developed using EZ-TEST PC go beyond test procedures to provide full pass/fail analysis, waveform analysis, user prompts, and data logging. (See the article **Making test procedure generation quick and EZ!** in this issue for more details on EZ-TEST PC.)

For customers looking for even more support, Tek has a staff of test applications engineers who can write the actual test programs. This service is available under a program called Technical Assistance Service (TAS); check the box on the reply card for further information.

The benefits don't stop at delivery

Certainly one of the major benefits of Mary's decision to team up with Tek was the after-sales support she will receive. Often, one of the biggest costs of test systems is maintenance and support of the system. For test departments that build their own system, documentation is generally poor, there is no guarantee that replacement parts will be available, and often only one person is well enough acquainted with the complete system to fix it or write new test procedures for it.

By having Tek build the system, Mary received complete documentation, a system warranty, and the option to have Tek maintain the system after the warranty expires. She also has the security that spare parts will be available long-term since Tek has a policy of supporting most products with spare parts for a period of nine years beyond the termination of regular production. In addition, she has the assurance that Tek is always there, ready to help. Whether the need is advice on use of the current system, help in reconfiguring the system to meet new test requirements, or design and manufacture of new test systems, Tek can help!

Want information?

For information on how Tek can help with your measurement needs, contact your local Tektronix Field Office or representative. We can help whether your problem is small — requiring an off-the-shelf single-instrument solution — or large — requiring a custom-designed multiple-instrument solution. U.S. customers can call the Tektronix National Marketing Center toll free for information or assistance — 1-800-426-2200. For literature describing Tek's System Solutions, check the box on the reply card in this issue.

CLASSES AND SEMINARS

Tektronix offers classes and workshops for the convenience of Tektronix customers with application, operational, or service training needs. Here's the schedule of classes and workshops to be offered in the near future.

Product Service Training Classes

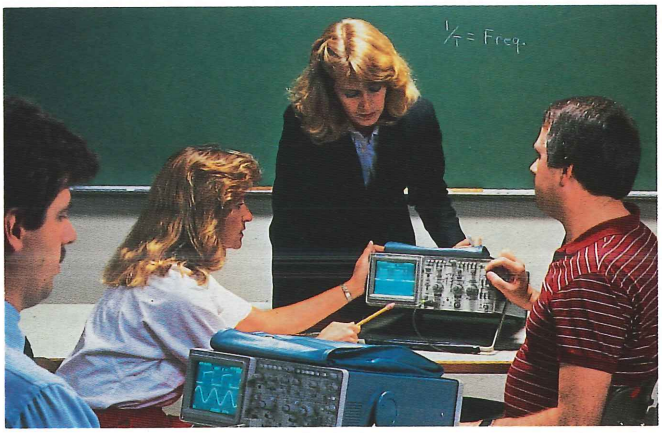
Tektronix Service Training provides new technicians the skills and techniques required for effective maintenance of Tektronix products. In addition, it brings experienced technicians up-to-date on maintenance of new products. Call Tektronix Service Training, 1-800-835-9433, ext. WR1407 to register for the following classes.

CLASS	LOCATION	DATES
465B/475A Portable Oscilloscope	Boston, MA	Feb 13-17
2215/35/36 Portable Oscilloscopes	Boston, MA	Feb 20-24
2465A Portable Oscilloscope	Dallas, TX	Jan 30-Feb 10
7904/7633 Laboratory Storage Oscilloscopes	Atlanta, GA Dallas, TX	Dec 5-16 Apr 24-May 5
TM 500 Calibration Package	Dallas, TX	Apr 10-14
TM 5000 Distortion Ana. (SG/AA)	Beaverton, OR	Dec 12-16
TM 5000 Function Gen. (FG)	Beaverton, OR	Feb 27-Mar 3
TM 5000 Calibration Gen.(CG5001)	Beaverton, OR	Mar 6-10
113XX Programmable Oscilloscopes	Beaverton, OR	Mar 6-10
114XX Programmable Oscilloscopes	Beaverton, OR	Mar 13-17
118XX Digitizing Sampling Oscilloscopes	Beaverton, OR	Mar 20-24

In addition to classroom instruction, Tektronix Service Training has a variety of training packages and video tapes available for self-study. Classes are also available for maintenance of other Tektronix products. Call for further information.

Workshop and class sizes are limited. We recommend that you enroll early. Other classes are planned beyond this schedule. For more information or to register, call the numbers listed above.

We retain the option to cancel or reschedule classes or workshops.



Operation Training Workshops

Call Tektronix IG Customer Training, 1-800-835-9433, ext. 430 to register for the following workshops.

CLASS	LOCATION	DATES
2230 Digital Storage Measurements	Irvine, CA Dallas, TX	Jan 18 Apr 5
2430A Advanced Digital Storage Measurements	Irvine, CA Dallas, TX	Jan 19-20 Apr 6-7
7854 Waveform Processing	Denver, CO Los Angeles, CA Wash.DC	Dec 13-14 Jan 12-13 Mar 14-15
11401/11402 Waveform Measurements	Irvine, CA Dallas, TX	Jan 24 Apr 11
11401/11402 Advanced Waveform Measurements	Irvine, CA Dallas, TX	Jan 24-25 Apr 11-12
11301/11302 Measurement and Analysis	Irvine, CA Dallas, TX	Jan 27 Apr 14
Fundamentals of Digital Oscilloscopes	Irvine, CA Dallas, TX	Jan 17 Apr 4
Instrumentation Control Using a PC Compatible	Irvine, CA Dallas, TX	Jan 26 Apr 13

Most of the above workshops are available in a self-study format. On-site training is also available. For information call 1-800-835-9433, ext 430.

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